Tribhuvan University

**Institute of Science and Technology**

**Three Year B.Sc. Chemistry course of study**

(2065)

**Course title:** Basic Chemistry I
**Course No.:** CHEM 311 (major/minor)
**Nature of the course:** Theory

**Full Marks:** 100
**Pass Marks:** 35
**Year:** I

**Course Objectives:**

The outcome of this course will be:

- To stimulate, create and sustain their interest in the study of chemistry.
- To provide a body of chemical knowledge appropriate for higher studies.
- To make aware the importance of scientific method of accurate experimental work.

## Group A: Inorganic Chemistry

**Atomic structure:-** Bohr's theory and refinements, wave mechanical model of the atom, matter waves, de Broglie's equation, Heisenberg's uncertainty principle, Schrödinger's wave equation (time independent), physical significance of wave function, probability density pattern for hydrogen atom, radial and angular wave functions, radial distribution curves, shapes of s, p, d orbital ; charge cloud diagrams and boundary surface diagrams, nodal planes, quantum numbers and their significance, energy level diagram. 10 hrs

**Multi-electron system:-** Pauli exclusion principle, Hund's rule of maximum multiplicity, aufbau principle and its limitations, energy level diagrams, stability of completely filled, half filled and empty orbital. 3 hrs

**Nuclear Chemistry:-** Composition of nucleus (nuclear stability), binding energy, radioactivity, half life determination and nuclear reactions. Group displacement law and radioactivity series. 4 hrs

**Periodic classification of elements and physical properties:-** Periodicity of elements, s, p, d and f blocks, long form of periodic table, discussion of properties like atomic, ionic and covalent radii, ionization potential, screening or shielding effect, electro negativity, different scales of electro negativity measurements (Pauling, Mulliken and Allred and

Rochow), electron affinity (Periodic variation, experimental determination of electron affinity). 7 hrs

**Chemical bonding :-** Ionic bond: packing of ions in crystal, radius ratio, lattice energy, Born equation, Born-Haber cycle, covalent character in ionic compounds, polarizing power and polarizability (Fajan's rule), bond moment and dipole moments, percentage ionic character from dipole moments and electro negativity differences, characteristics of ionic compounds, structure of ionic solids, ionic compounds of type AX (NaCl, CsCl, ZnS), $AX_2$ ( $CaF_2$ $TiO_2$), layer structures, stoichometric and non- stoichometric defects. 8 hrs

**Covalent Bond:-** General characteristics of coordinate-covalent bond, valence bond approach, directional characteristics of covalent bond, resonance energy, hybridization, the extent of orbital participation in molecular bonding, (sp, $sp^2$, $sp^3$, $d^2sp^3$, $dsp^2$, $sd^3$, $dsp^2$, $dsp^3$), multiple bonding, three electron bond, two electron three centered bond, sigma-and pi-bonds, bond length and bond order, bond strength, valence shell electron pair repulsion theory (VSEPR), theory of directed valence, shapes of simple inorganic molecules and ions containing bonds and lone pairs, hydrogen bond (theories of hydrogen bonding, valence bond treatment), metallic bond (Free electron theory and band theory), conductors, insulators and semiconductors, elementary idea of L.C.A.O. and concept of united atoms in molecular orbital theory, bonding, antibonding, and non-bonding orbitals, M.O. configurations of simple diatomic molecules ($H_2$, $He_2$, $N_2$, $O_2$, $F_2$, CO, NO, HCl and related species). 12 hrs

**Acids and Bases:-** Lewis acid-base concept, hard and soft acids and bases (HSAB), application of HSAB principle, relative strengths of acids and bases and the effect of substituents and solvents on them. 4 hrs

**Principles of qualitative and quantitative Analysis:-** Solubility product, common ion effect, their application in group separation, principles of gravimetric and volumetric analysis. 5 hrs

## Group B: Organic Chemistry

**Structure and Properties:** Atomic orbitals, Hybrid orbitals, Polarity of bonds, Melting point, Acids and bases, Dipole-dipole interaction, Hydrogen bonding, Inductive effect, Electromeric effect, Resonance, Mesomeric effect or Conjugative effect, Hyperconjugation effect, Steric effect, IUPAC Nomenclature. hr

**Alkanes:** Energy of activation, Progress of reaction, Energy profile diagram, Exothe and endothermic reaction, Fischer projection formulas, Andiron formulas, Newma

projection formula, Free rotation about the C-C single bond, Conformation of n-butane, Physical properties, Industrial source, Industrial source vs. laboratory preparation, Grignard reagent, Coupling of alkyl halide with organometallic compounds, Reactions: halogenations (substitution reaction), mechanism of halogenations, Orientation of halogenations, Relative relativities of alkanes toward halogenations, Ease of abstraction of hydrogen, Homolytic bond dissociation energies and relative stability of free radicals, Ease of formation of free radicals, Structure of free radicals, Transition state for halogenations, Orientation, Reactivity and selectivity, Rearrangement of free radicals, Combustion, Pyrolysis, Freons and ozone depletion.

**Stereochemistry:** Introduction, Structural isomers and stereoisomer, Stereoisomerism, Optical activity, polarimeter, Specific rotation, Enantiomerism and optical activity, Chirality, chiral centre, Enantiomers, racemic modification, Configuration, absolute configuration (R and S), Sequence rules, Diastereomers, Meso compound, Reaction evolving stereoisomers, Generation of a chiral centre (only one chiral centre). 7 hrs

**Alkyl halide (Nucleophilic substitution):** Homolytic and heterolytic fission, Structure (The functional group), Classification and nomenclature of alkyl halides, Physical properties, Preparation, Nucleophilic aliphatic substitution reactions, Nucleophiles and leaving groups, Rate of reaction (effect of concentration), The $SN^2$ reaction (mechanism and kinetics), The $SN^2$ reaction (stereochemistry, inversion of configuration), The $SN^1$ reaction (mechanism and kinetics), Carbocations (structure and relative stability), $SN^1$ reaction (stereochemistry), Rearrangement of carbocations, $S_N^1$ vs. $S_N^2$ reaction. 8 hrs

**Alcohols and Ethers:** Introduction, Nomenclature, Structure, Physical properties, Industrial source, Fermentation, Fuel from carbohydrate, Ethanol, Preparation, Reactions, Alcohols as acids, bases, Reaction of alcohols with hydrogen halides, Formation of alkyl sulphonates, Oxidation of alcohols, Industrial source of ethers, Preparation of ethers, Williamson synthesis, Reactions of ethers ($PCl_5$ , HX), Role of solvent, Solubility (ionic solutes, protic and aprotic solvents, ionic pair), Phase transfer catalysis. 8 hrs

**Alkenes:** Geometrical isomerism, Physical properties, Industrial source, Preparation, Dehydrohalogenation of alkyl halide, Kinetics of dehydrohalogenation, $E_2$ reaction (mechanism, orientation and reactivity), $E_1$ reaction (mechanism, orientation and reactivity), Dehydration of alcohols, Reaction of alkenes, Reaction at the carbon-carbon double bond, (hydrogenation, addition of hydrogen halides, addition of hydrogen bromide and peroxide effect, addition of sulphuric acid, addition of water, electrophilic addition (mechanism, orientation and reactivity), Addition of halogens, and mechanism, Halohydrin formation, Oxymercuration-demercuration, Hydroboration-oxidation, (orientation and mechanism of hydroboration), Free radical addition (mechanism and orientation),

Hydroxylation, Ozonolysis, Analysis of alkenes, Application of alkenes to prepare polymers (Polypropelene and polyethylene)

hrs

**Alkynes:** Structure of acetylene, Physical properties, Industrial source of acetylene, Preparation of alkynes; Reactions of alkynes, Reduction to alkenes, Electrophilic addition to alkynes, Hydration of alkynes, Acidity of alkynes, Reactions of metal acetylides, Formation of carbon-carbon bonds.

4 hrs

## Group C: Physical Chemistry

**Gaseous state:** Introduction: Gaseous state, SI units for pressure, volume and temperature, Ideal gas equation and universal gas constant, dimension and value of R in different units, kinetic theory of gases, derivation of kinetic gas equation, root mean square velocity, average velocity, most probable velocity, average kinetic energy of gas molecules, molecular interpretation of temperature, deduction of gas laws from kinetic gas equation (Boyle's, Charles's, Avogadros and Dalton's laws).

Maxwell distribution of speeds, different types of speeds of gaseous molecules and their derivation from Maxwell's equation. Collision properties: Collision diameter, collision frequency, mean free path. Deviation of real gas from ideal behaviour, causes of deviations, derivation of van der Walls equation, explanation of behaviour of real gas from van der Walls equation, other equations of state, viral equation, Boyle's temperature and van der Walls constants, critical phenomenon, relation between van der Walls constant and critical constants.

Liquefaction of gases: Faraday method, principle of Linde refrigerator, Claude's principle of liquefaction of air, adiabatic demagnetization.

12 hrs.

**Liquid State:** Qualitative treatment of liquids, vapour pressure, vapour pressure and boiling point, surface tension and its determination by drop weight, capillary rise methods, Viscosity and fluidity, effect of temperature on viscosity, determination of viscosity by Ostwald's viscometer, applications of surface tension and viscosity measurements.

3 hrs.

**Solid state:** Crystalline and amorphous solids, crystal structure, unit cells and crystal systems, Bravais lattices, cubic crystals (simple, body centered and face centered cubic), classification of solids on the basis of dominant type of bond (ionic, covalent, metallic and molecular crystals) with examples and their properties.

4 hrs.

**Chemical Equilibrium:** Reversible reaction, the law of mass action, characteristics of equilibrium constant, uses of equilibrium constant, relation between $K_p$ and $K_c$ applications

of law of mass action to homogeneous equilibrium, effect of temperature, pressure and components on chemical equilibrium, numerical problems on chemical equilibrium, Le Chatelier's principle and its applications. 3 hrs.

**Ionic Equilibrium**: Strong and weak electrolytes, Ostwald's dilution law and limitations, auto ionization of water, relative strength of acids and bases. pH and pH scale, hydrolysis and hydrolysis of salts: qualitative and quantitative treatments, common ion effects in ionic equilibrium, buffer solution buffer capacity and buffer range, numerical problems in pH and buffer, pH change in acid base titration (weak and strong), theory of acid base indicator: Ostwald's theory, quinonoid theory, selection of acid base indicators in titrations, solubility and solubility product principle, application of solubility product principle, numerical problems on solubility and solubility product. 8 hrs.

**Colligative properties**: Dilute solution, Raoult's law and determination of vapor pressure lowering, laws of elevation of boiling point and depression of freezing point, determination of osmotic pressure, determination of molecular weight from osmotic pressure, van't Hoff factor, abnormalities in solution due to association and dissociation, numerical problems. 6 hrs.

**Colloidal solution**: Colloidal state of matter, lyophilic and lyophobic colloids, preparation, purification, and properties of colloids (kinetic, optical and electrical properties), Soap and detergents. 4 hrs.

**Thermodynamics and thermo-chemistry**: Some thermodynamic terms, first law of thermodynamics, sign convention for heat and work including IUPAC recommendation, isothermal but not reversible expansion of an ideal gas, isothermal reversible expansion of an ideal gas, experimental determination of $\Delta E$ using bomb calorimeter, enthalpy, experimental determination of $\Delta H$, enthalpy of physical changes (enthalpy of fusion, vaporization, sublimation), enthalpy of chemical changes (enthalpy of formation, combustion, solution, dilution and neutralization), Hess's law of constant heat summation, enthalpy change from bond energy, molar heat capacity, relation between $C_p$ and $C_v$, variation of heat of reaction with temperature (Kirchoff's equation), calorific value of fuel, calorific value of food. 10 hrs.

**Course Title:** Basic Practical Chemistry I
**Course No.:** CHEM 312 (major/minor)
**Nature of the Course:** Practical

**Full Marks:** 50
**Pass Marks:** 20
**Year:** I

**Course Objectives:**
The outcome of this course will be:

- To make students aware of the importance to scientific method of accurate experimental work.
- To develop in students abilities to perform experiments having due regard for safety.
- To develop in students skills of observation and their ability to record and interpret those observations

**Experiments on Inorganic Chemistry**

**Volumetric analysis:-** Volumetric analysis involving acidimetry and alkalimetry (combination of strong and weak acids and bases); Determination of total alkalinity and phenolphthalein alkalinity in a given sample of water, permanganate titration (estimation of iron in Mohr's salt, determination of calcium in calcium carbonate), silver nitrate titration: Determination of chloride content in a given sample of water, iodometric titration (potassium dichromate and copper sulphate); Determination of residual chlorine in a given sample of water. 18 hrs

**Inorganic Preparation:-** Sodium cobaltinitrite, Sodium thiosulphate, Potassium dichromate, Ammonium Ferric Sulphate, Potash alum, Tetrammine Copper Sulphate, Prussian blue, Potassium Tris oxalate Aluminate. 30 hrs

**Experiments on Organic Chemistry**

1. Thermometer calibration.
2. Purification of crude organic compounds.
3. Re-crystallization (Acids, Acetanilide, Amides, Benzoates, etc.).
4. Determination of melting point and mixed melting point.
5. Purification of liquid compounds by distillation.
6. Determination of boiling points (Anilines, Nitrobenzene, Nitroaniline, etc.).
7. Molecular weight determination by Rast method.
8. Isolation of steam volatile compounds.
9. Classification of organic compounds by solubility (water, ether, 5% HCl, 5% Sodium hydroxide, 5% Sodium bicarbonate, conc. $H_2SO_4$).

10. Identification of functional groups.
11. Introduction to micro scale organic experiments.

51 hrs

**Experiments on Physical Chemistry**

1. Determination of surface tension of liquid using Stalagmometer.
2. Determinaton of viscosity using Ostwald viscometer.
3. Preparation of standard buffer solution using sodium acetate and acetic acid and determine the pH of unknown solution using universal indicator.
4. Preparation of standard buffer solution using ammonium hydroxide and ammonium chloride and determine the pH of unknown solution using universal indicator.
5. Determination of heat of neutralization of strong acid and strong base.
6. Detrmination of heat of solution of potassium acetate.
7. Determination of heat of hydration of sodium sulphate.
8. Determination of molecular weight of organic compound by Rast method.

51 hrs

**Course title:** Basic Chemistry II
**Course No.:** CHEM 321 (major \ minor)
**Nature of the course:** Theory

**Full Marks:** 100
**Pass Marks:** 35
**Year:** II

**Course Objectives:**
The outcome of this course will be:

- To explain their knowledge in terms of the relevant principles, concepts, theories, definition, patterns and generalization.
- To explain everyday applications and uses of chemistry.
- To present chemical ideas in a clear and logical forms.

## Group A: Inorganic Chemistry

**Refining and purification of metals:-** Applications of the following processes in the refining, separation and extraction of metal; Ion Exchange chromatography, Solvent extraction, oxidative refining, parting process, zone refining, Mond's process.

5 hrs

**Comparative study of s- and p- block elements and their important compounds:-** General group trends, electron configuration, atomic radii, ionization potential, electron affinity, electronegativity, inert pair effect.
General Properties of the elements
The occurrence and isolation of the elements, factors influencing the choice of extraction process.
Comparative study of s and p block elements and their important compounds.

**Alkali metals:-** Solubility in $NH_3$, Hydration energy and mobility of ions, R-Li, Chlor-alkali industry and its application. Crown and Crypt ethers.

**Alkaline earth metals:-** Be-Anomalous behavior, $CaH_2$, Grignard's reagent, chlorophyll, Biological properties of Ca and Mg.

**Gr III:-** Principle of extraction of Al, Alums, $BF_3$, Borax, $2e^-$ 3 centred bond, Halides of Al, Aluminum alkyls, cement Inert pair effect (Gr III, IV, V)

**Gr IV:-** Structure and allotropy of the element, Difference between C, Si and other remaining elements.

Carbon clusters:- Fullerene (Preparation, Structure and applications)
Carbides, Carbonyls, Silicon carbide, Silicates, Freons, Internal π bonding using d orbital (structure of $(CH_3)_3N$ and $(Si\ H_3)_3N$).

**Gr V:-** Nitrogen cycle, liquid ammonia as solvent, Phosphate fertilizers, Halides, Role of phosphate esters in biological process.

**Gr VI:-** Acid rain, $P\pi - d\pi$ bonding, difference between oxygen and other elements, Thionyl chloride, tetra sulfur tetra nitride

**Gr VII:-** Prechloric acid, Isolation of Fluorine, Electropositive character of iodine

**Gr 0:-** Isolation of Noble gases, clathrate compounds, 20 hrs

**Chemistry of d-block elements and their compounds:-** General trends in electronic configurations, ionic and covalent atomic radii, electronegativity, electron affinity, ionization potential, colour and magnetic properties, variable valancy, complex formation with reference to 3d-block elements. General introduction of first transition (3d) second transition (4d) and third transition series Comparision of the elements of 3d series with 4d and 5d transition series in terms of (i) electronic configuration (ii) reactivity of element (iii) stability of oxidation state (iv) highest oxidation state and (v) stability of complexes. Concept of co- ordination complexes, Werner's theory of co-ordination compounds, comparative study of chemistry of elements of 3d- series (excluding Sc, Ti, V) chemistry of representative compounds of 3d- block elements. ($TiO_2$, $TiCl_4$, Zeigler-Natta catalyst, Vanadates, $V_2O_5$, $CrO_2Cl_2$, $K_2CrO_7$, Ferrocene, Nickel Carbonyl), bioinorganic chemistry of Iron, Chromium and Copper.

14 hrs

**Preparation, properties, bonding and structure of the following:-** Oxides and oxyacids of phosphorous (structure and application only) hydrazine, hydroxylamine, hydrazoic acid, hydrogen peroxide, ozone, sodium thiosulphate, peracids of sulphur, potassium permanganate, potassium dichromate.

12 hrs

## Group B: Organic Chemistry

**Cyclic Aliphatic Compounds:-** Nomenclature, Industrial source, Preparation, Reactions, Reactivity of cyclopropane and cyclobutane by comparing with alkanes, Stability of Cycloalkanes–Baeyer's Strain Theory, Sachse and Mohr prediction and Pitzer's strain theory, Factors affecting stability of conformations, Conformational structure of cyclobutane, cyclopentane and cyclohexane, Equatorial and axial bonds.

6 hrs

**Aromaticity:-** Concepts of Aromaticity, Structure of Benzene, Resonance structure and orbital picture of benzene, Stability of benzene (resonance energy), Huckel's rule and its application to benzenoid (benzene and naphthalene) and non benzenoid (cyclopropenyl cation, cyclopentadienyl anion and tropylium ion), General mechanism of electrophilic substitution, mechanism of nitration, sulphonation, halogenations, Friedel Craft 's alkylation and acylation, Theory of reactivity and orientation, Effect of substituent groups, Ring activating and deactivating groups with examples, Effect of halogen on electrohilic aromatic substitution.

10 hrs

**Aldehydes and ketones:-** Nomenclature of aliphatic and aromatic carbonyl compounds, Structure of carbonyl group, Synthesis of aldehydes and ketones, Physical properties (Keto-enol tautomerism, Reactivity of carbonyl group in aldehydes and ketones), Nucleophilic addition reactions, Oxidation, Reduction, Base and acid catalyzed halogenation reactions, Addition of Grignard's reagent, planning a Grignard's synthesis, Limitation of Grignard's synthesis, Base and acid catalyzed halogenation of ketones, Aldol condensation, dehydration of aldol products, use of aldol condensation in synthesis, Cross aldol condensation, Wittig reaction, Claisen condensation.Analysis of aldehydes and ketones with 2,4-DNP test, Tollen's test, Fehling's test, Schiff Test, and Haloform test with equations, spectroscopy.

12 hrs

**Carboxylic acids:-** Structure and Nomenclature, Industrial source, Methods of preparation by carbonation of Grignard regents, Hydrolysis of nitrile, amides and esters, Preparation of aromatic acids by oxidation of side chain, hydrolysis of benzotrichlorides and Kolbe reaction, Physical properties, hydrogen bonding, dimmeric association, acidity strengths (relative differences in the acidities of aromatic and aliphatic acids), Effect of substituent in acidity, spectroscopy. Chemical properties: (reaction involving H, OH and COOH groups), Salt formation, Anhydride formation, Acid chloride formation, Amide formation, introduction to polyamide and ester formation with mechanism), Reduction to alcohols, Carbanion in organic synthesis, Active methylene compounds such as Malonic acid synthesis of carboxylic acid, Acetoacetic ester synthesis of ketones, decarboxylation of β-keto acid and malonic acid, Synthetic application of acetoacetic esters (Preparation of monocarboxylic acid and dicarboxylic acids) and malonic acid esters (Preparation of monocarboxylic acid and dicarboxylic acid and α,β-unsaturated carboxylic acids), Reaction active methylene compounds with urea.

17 hrs

**Amines :-** Structure, Nomenclature, Classification, Industrial source, Preparation, Physical properties, Industrial source preparation, reduction of nitro compounds, amminolysis of halides, reductive amination, Hoffmann rearrangement, structure and basicity, effect of substituents on basicity of aromatic amines, ring substitution in aromatic amines, reactions of amines with nitrous acid, reactions of hydrazines, reactions of diazonium salt (Azo

coupling, Sandmeyer reaction), reactions of hydrazo compounds (benzedine rearrangement), reactions of diazomethane, synthesis of phenol, diazonium salt (replacement by –H), synthesis using diazonium salts, synthesis of azo-compounds, cyanides, isocyanides, amides and polyamides, spectroscopy.

8 hrs

**Phenols:-** Structure, nomenclature, physical properties, salts of phenols, industrial source, preparation, reactions, acidity of phenols, Fries rearrangement, ring substitution, Kolbe's reaction, Riemer- Tiemann reaction, formation of aryl ethers. Gattermann synthesis, chelation, phenols as antioxidant and physical properties, spectroscopy of phenol and alcohol.

4 hrs

**Introduction to Organic polymers:** Definition polymer, Preparation of Bakelite and uses.

1 hr

**(Total 58-60 Hrs)**

## Group C: Physical Chemistry

**Chemical Kineties:** Concept of rate of a chemical reaction, measurement of reaction rate, reaction rate and stoichiometry, rate of reaction and concentration of reactant, order and molecularity of a reaction, rate determining step, rate equations ( differential and integrate) for zero, first and second order reaction, pseudo first order reaction, half life of a reaction, effect of temperature on the reaction rate, concept of activation energy, theories of reaction rates: collision theory and transition state theory (qualitative treatment only), kinetic study of some reaction mechanism (decomposition of ozone, reaction between $O_2$ and HBr, $I_2$ and propanone in acidic medium). 10 hrs.

**Catalysis:** Types of catalysis: poisons, promoters and inhibitors, Criteria of catalysis, activation energy and catalysis, theories of catalysis: intermediate compound formation and adsorption theories, general acid base catalysis, enzyme catalysis. 4 hrs.

**Photochemistry:** Thermo-chemical and photochemical reactions, Grothus Draper law, Stark Einstein law of photochemical equivalence, primary and secondary processes in photochemical reaction, quantum yield, and reason for high and low quantum yields.
Absorption of light, Lambert- Beer's law and its application.
Some photochemical processes: Fluorescence, phosphorescence, chemiluminescence, and photosensitization. 4 hrs.

**Electrolytic conductance:** Metallic and electrolytic conductances, electrical resistance and conductance, specific conductance, conductivity cell and cell constant, conductivity water equivalent and molar conductivities, determination of equivalent and molar conductivities relation between molar conductivity and equivalent conductivities, variation o

conductances with dilution for strong and weak electrolytes, some applications of conductance measurements: Determination of (i) solubility products of sparingly soluble salts, (ii) degree of ionization and ionization constant of weak acids, (iii) ionic product of water. Conductometric titration involving neutralization and precipitation reactions, advantages of conductometric titration, Kohlraush law of independent migration, ionic conductance and ionic mobility, Hittorf's rule, transference number, determination of transference number by moving boundary and Hittorf's methods.

8 hrs.

**Electrochemical cells:** Electrolytic and Galvanic cells, electrode reaction and single electrode potential, electrochemical series, hydrogen electrode and measurement of standard electrode potential, primary and secondary reference electrodes, representation of electrochemical cell, Nernst's equation and derivation of emf of a cell, calculation of equilibrium constant of a cell reaction from standard emf of a cell, applications of em measurements: Determination of pH using hydrogen, quinhydrone, glass and antimony electrodes, pH meter. Potentiometric titrations. Commercial cells: Primary Cells (dry cell and botton cells), and secondary cells (Lead cells, Nickel cadmium cells), Fuel cells.

9 hrs.

**Thermodynamics:** Adiabatic expansion of an ideal gas (TV-relation, PV-relation and P relation), comparison between isothermal and adiabatic expansion, work done in reversib adiabatic expansion, Joule's Thomson effect, inversion temperature.

Spontaneous and non-spontaneous changes, Second law of thermodynamics differe statements of the law, Carnot's cycle, thermodynamic efficiency, entropy and mathematical derivation from Carnot's cycle, physical significances of entropy: entro and unavailable energy, entropy and probability, entropy and randomness.

Entropy changes of a system, surrounding and universe, entropy change in isothermal adiabatic processes, relation between enthalpy change and entropy change, entropy cha during expansion of an ideal gas, Free energy and work function and their significan criteria of spontaneity and equilibrium in terms of entropy and free energy.

15 hrs

**Course title:** Basic Practical Chemistry II
**Course No.:** CHEM 322 (major \ minor)
**Nature of the course:** Practical

**Full Marks:** 50
**Pass Marks:** 20
**Year:** II

**Course Objectives:**
The outcome of this course will be:

- To handle and manipulate chemical apparatus and materials safely.
- To record accurately and clearly the result of experiments.
- To apply appropriate chemical principle and make generalizations and predictions from chemical facts, observations and experiment data.

## Experiments on Inorganic Chemistry

**Gravimetric Analysis:-** Quantitative estimation of barium and sulphate ions as barium sulphate, iron as ferric oxide (Mohr salt). 18 hrs

**Qualitative Analysis of simple Inorganic salt mixture containing 2 cations and 2 anions:-** $Hg^{+}$, $Pb^{++}$, $Ag^{+}$, $Cu^{++}$, $Hg^{++}$, $As^{+++}$, $Sb^{+++}$, $Sn^{++}$, $Bi^{+++}$, $Cd^{++}$, $Al^{+++}$, $Zn^{++}$, $Mn^{++}$, $Fe^{+++}$, $Co^{++}$, $Ni^{++}$, $Cr^{+++}$, $Ca^{++}$, $Ba^{++}$, $Sr^{++}$, $Mg^{++}$, $K^{+}$, $NH_4^{+}$, $NO_3^{-}$, $Cl^{-}$, $Br^{-}$, $I^{-}$, $SO_4^{--}$, $CO_3^{--}$, $PO_4^{---}$ 25 hrs

**Spot test analysis.** 8 hrs

## Experiments on Organic Chemistry

**Preparative Organic Chemistry:-** Single step preparation involving the following types :- Methylation of Phenol using dimethyl sulphate, Esterification of acids, Acetylation of phenols, Benzoylation of amines, Nitration of nitrobenzene, Reduction of nitro compounds, Oxidation of Toluene or benzadehyde, Preparation of osazone and Preparation of methyl orange. These experiments should involve basic organic experiment techniques such as hot filtration, distillation under reduced pressure, filtration under partial vacuum, etc. (Above reactions will be useful in identification of organic compounds and preparation of their derivatives). 51 hrs.

## Experiments on Physical Chemistry

1. Determination of the order and rate constant for the acid catalyzed oxidation of ethyl alcohol with potassium dichromate.
2. Study the kinetics of hydrolysis of methyl acetate

3. Study the kinetics of reaction between potassium persulphate and iodine by iodine clock method.
4. Conductometric titration between strong acid and strong base, weak acid strong base.
5. Determination of pH using quinhydrone electrode.
6. Calibration of pH meter and measurement of pH using glass electrode.
7. Determination of pH using antimony electrode.
8. Potentiometric titration of acetic acid with sodium hydroxide and determination dissociation constant.

48 hrs

Course title: General Chemistry I
Course No.: CHEM 331 (major)
Nature of the course: Theory

Full Marks: 100
Pass Marks: 35
Year: III

**Course Objectives:**
The outcome of this course will be:

- To explain everyday applications and use of chemistry.
- To promote in studies the acquisition of knowledge and understanding of chemica patterns and principles.
- To present chemical ideas in a clear and logical form.
- To evaluate the environmental and technological implications of chemistry.

## Group A: Inorganic chemistry

**Hydrogen:-** Isotopes of hydrogen, general study of hydrides and their classification. 4 hrs

**Nobles gases and their compounds:-** Preparation, properties and structure of xenon fluorides and oxo-compounds (Valence bond treatment, VSEPR treatment, molecular orbital treatment for $XeF_2$) 5 hrs

**Detailed study of preparation, properties, bonding and structure of the followings:-** Boric acid, borates, boron nitride, borazines, boron hydrides, metal borohydrides, silicates, silicones, silanes, and siloxanes, interhalogen compounds, pseudohalogens, pseudohalides. 12 hrs

**Chemical fertilizers:-** Nitrogen fixation and synthetic fertilizers. 6 hrs

**Reactions in nonaqueous solvents:-** Reactions of $NH_3$, reactions of $SO_2$. 6 hrs.

**Environmental pollution:-** An elementary study of environmental pollution in air and water.

**Air pollution system:-** Sources, Emission, Anthropogenic emissions, (gases and particulate matter), Acid rain, Smog, depletion of ozone layer.

**Water pollution:-** Dissolved oxygen, total alkalinity, Biochemical oxygen demand and Chemical oxygen demand, Eutrophication, Classification of water pollutants, Control of water pollution. 10 hrs

**Inorganic polymers:-** Homo polymers and copolymers, boron nitrides, borazine Organosilicon compounds and Silicones, Phosphonitrilic compounds, Polythiazyls $(SN)_x$ 7 hrs

## Group B: Organic chemistry

**Organic reactions and methods for determining mechanism:-** Types of mechanism types of reaction, thermodynamic and kinetic requirements for reaction, the Baldwin's rules of ring closure, kinetic and thermodynamic control, the Hammond postulate, microscopic reversibility, methods of determining mechanism, identification of products, determination of the presence of an intermediate, the study of catalysis, isotope labeling, stereochemical evidence, rate expression for first and second order reaction, isotope effect. 8 hrs

**Reactive Intermediates:-** Stability, structure, generation and fate of carbocation, carbanion, free radical, carbene, nitrene and benzyne, nonclassical carbonium ion, neighboring group participation by $\pi$ and $\sigma$ bonds, Aromaticity and anti-Aromaticity. 12 hrs

**Spectroscopy and Structure:-** Determination of structure (spectroscopic methods), the mass spectrum, the electromagnetic spectrum, the infrared spectrum, the ultraviol spectrum, the nuclear magnetic resonance (NMR)spectroscopy, $^1$H-NMR spectrum, number of signals, equivalent and non equivalent protons, chemical shift, peak area and proton coupling, spin-spin coupling, coupling constant, $^{13}$C-NMR spectroscopy, $^{13}$C-NMR chemical shift, $^1$H-NMR and $^{13}$C-NMR of hydrocarbons, alcohols, aldehydes, ketones carboxylic acid, amines, phenol, ether and aromatic compounds (simple molecules only). 16 hrs

**Heterocyclic systems:-** Structure of pyrrole, furan and thiophene, source of pyrrole, furan and thiophene, electrophilic substitutions in pyrrole, furan and thiophene (reactivity and orientation), saturated five member hetero cycles, structure of pyridine, source of pyridine compounds, reactions of pyridine, electrophilic substitution in pyridine, nucleophilic substitution in pyridine, basicity of pyridine, reduction of pyridine. 6 hrs

**Name reactions:-** Introductory study of glossary of at least 40 name reactions, their simple mechanism and the utilities of the synthetic reagents involved therein under the following heading of reaction types – oxidation, reduction, condensation, substitution, rearrangement, addition and elimination (names are given in the Appendix I). 15 hrs

## Group C: Physical Chemistry

**(Total nearly 55-60 Hrs)**

**Electrochemistry**

**Electrolytic Conductance:** Failure of Arrhenius theory in case of strong electrolytes; Debye-Huckel theory of interionic attraction. (elementary treatment only), activity and

activity coefficients, ionic strength, Debye-Huckel limiting law (elementary treatment only).

**Electrochemical Cells:** Reversible and irreversible cells, types of reversible electrodes, thermodynamic quantities of cell reaction from emf ( $\Delta G, \Delta H, \Delta S$ and K), chemical cells with and without transference, concentration cells with and without transference, liquid junction potential, Application of emf measurement: Determination activities and activity coefficients, formal and standard electrode potential, solubility products. Electrolysis and polarization, overvoltage and hydrogen overvoltage.

20 hrs

**Phase Equilibrium:** Statement and meaning of the terms- phase, component and degree of freedom, Gibbs phase rule, phase equilibria of one component system- water and sulphur, phase equilibria of two component system- simple eutectic Pb-Ag system, desilverization of lead, system involving compound formation with congruent melting point (Mg –Zn) and incongruent melting point( $CuSO_4.H_2O$ system).

**Liquid Mixture:** Ideal and non-ideal liquid mixture, distillation of binary liquids, ratio of distillate to residue, fractional distillation, azetropes.

**Partial miscible mixture:** Phenol-water system, tri-methylamine water system, nicotine water system. Lower and upper consolute temperatures, Henry's law, Nernst distribution law and applications, distribution of solute between two phases, solvent extraction.

15 hrs.

**Surface Chemistry:** Physical and chemical adsorption, types of adsorptions, adsorption isotherms- Freundlich isotherm, Langmuir adsorption isotherm, BET equation and its use in surface area determination.

8 hrs.

**Colloids:** Helmholtz and diffuse layers in colloids, zeta potential, electrophoresis, electro-osmosis, precipitation of sol, gold number, Hardy Schutz law, association of colloids, cleansing action of soap and detergents, emulsion and gels, solution of macromolecules, determination of molecular weight of macromolecules by (a) osmotic pressure (b) viscosity and (c) sedimentation method.

7 hrs.

**Course Title:** General Practical Chemistry I
**Course No.:** CHEM 332 (major)
**Nature of the Course:** Practical

**Full Mark:** 50
**Pass Mark:** 20
**Year:** III

**Course Objectives:**
The outcome of this course will be:

- To handle and manipulate chemical apparatus and material safely.
- To make accurate observation and measurements, being aware of possible sources of error.
- To plan and organize simple experimental investigations to test hypotheses.
- To perform numerical calculations in which guidance on the methods of solution is provided.

## Experiments on Inorganic Chemistry

**Qualitative analysis of salt mixture containing not more than 6 ionic species (excluding salts insoluble in acids) out of the following:-** $Pb^{++}$, $Hg^{++}$, $Ag^{+}$, $Hg^{+}$, $Bi^{+++}$, $Cu^{++}$, $Cd^{++}$, $As^{+++}$, $Sb^{+++}$, $Sn^{++}$, $Fe^{++}$, $Fe^{+++}$, $Cr^{+++}$, $Al^{+++}$, $Co^{++}$, $Ni^{++}$, $Mn^{++}$, $Zn^{++}$, $Ba^{++}$, $Ca^{++}$, $Sr^{++}$, $Mg^{++}$, $K^{+}$, $NH_4^{+}$, $CO_3^{--}$, $S^{--}$, $SO_3^{--}$, $S_2O_3^{--}$, $NO_2^{-}$, $CH_3COO^{-}$, $F^{-}$, $Cl^{-}$, $Br^{-}$, $I^{-}$, $NO_3^{-}$, $SO_4^{--}$, $C_2O_4^{--}$, $PO_4^{---}$, $BO_3^{---}$

33 hrs

**Complexometric titration:-** Determination of $Zn^{++}$, $Mg^{++}$, $Ca^{++}$ and total hardness of water using EDTA.
Determination of Ca Hardness of water.
Determination of total iron in ground water.

18 hrs

## Experiments on Organic Chemistry

**Qualitative analysis of organic compounds:-** Systematic qualitative analysis of simple mono functional organic compounds and preparation of their at least one derivative (aldehyde, ketone, carboxylic acid, carbohydrate, phenol, hydrocarbon, amine, nitro, amide and ammonium salt).

**51 hrs**

## Experiments on Physical Chemistry

1. Determination of critical solution temperature of phenol-water system and the composition of the solution at CST.
2. Determination of partition coefficient of iodine in chloroform and water.
3. Verification of Ostwald dilution law and determination of dissociation constant.

4. Determination of the equivalent conductivity of strong electrolyte at infinite dilution by conductance measurement.
5. Verify Nernst equation.

**Course title:** General Chemistry II
**Course No.:** CHEM 333 (major)
**Nature of the Course:** Theory

**Full Marks:** 100
**Pass Marks:** 35
**Year:** III

**Course Objectives:**
The main outcome of this course will be:

- To develop student's ability to communicate in appropriate ways.
- To encourage student's to apply their chemical knowledge and understanding to familiar and unfamiliar higher studies in chemistry.
- To pursue higher studies in chemistry.
- To explain the social, economic, environmental and technological implications of chemistry.

## Group A: Inorganic Chemistry

**Coordination Compounds:-** Isomerism in coordination compounds, IUPAC nomenclature of coordination compounds, factors influencing the formation of complexes (thermodynamic and kinetic stability).

7hrs

**Bonding and application of coordination compounds:-** Valence bond theory, inner and outer orbital complexes, crystal field theory, characterization of complexes by spectroscopic, Optical and magnetic methods, chelates and polynuclear complexes, stereochemistry of complexes with coordination number 4 and 6, substitution reactions & trans effect, application of complexes in analytical and biological fields.

20hrs

**Lanthanides and Actinides:-** Electronic structure, oxidation, states, colour and spectra magnetic properties, lanthanide contraction.

5hrs

**Elementary study of carbonyls and nitrosyls:** - General method of preparation, bonding, application of 18 electron rule, structure of carbonyls.

6 hrs

**Organometallic Compounds:-** Non transition metals: General survey of types, synthetic methods, metals alkyls of group I, II and III elements. Transition metals :- transition metal to carbon σ bonds, alkene complexes, haptonomenclature, alkyne complexes, allyl complexes, metallocenes (preparation properties, structure and elementary approach of bonding with reference to ferrocene).

9 hrs

**Bio-inorganic chemistry:-** Introduction, Roles of metals in Biological system, Essential and Trace elements in Biological system metals and its complex as Therapeutic agents. Study of Fe in Biological system (Oxygen carrier and electron transfer). 5 hrs

## Group B: Organic Chemistry

**Principle of Organic Synthesis:-** Protecting groups, retrosynthetic analysis, retron and synthon, multistep synthesis (3-4 steps only, for example, but not limited to, preparation of nitroanilines, 2-brmo-4-nitrobenzoic acid, p-amino acetophenone, synthesis of furan, pyrrole, thiophene and their derivatives, amino acids). 10 hrs.

**Introduction of Green Chemistry:-**Definition of green chemistry, Need of green chemistry, Basic principle of green chemistry, Green catalyst (Phase transfer catalyst). 1 hr

**Carbohydrates:-** Introduction, definition and classification, (+)–glucose as an aldohexose, (-)–fructose as a 2-keto hexose, stereo isomers of (+)–glucose, oxidation (effect of alkali, osazone formation (epimers), lengthening and shortening the carbon chain of aldoses, conversion of an aldose into its epimer, conversion of aldose into ketose and vice versa, configuration of (+)–glucose (the Fischer proof), configuration of aldoses, optical families D and L, tartaric acid, families of aldoses (absolute configuration), open and cyclic structure of glucose, configuration about C-1, methylation, determining ring size, conformation. 15 hrs.

**Lipids:-** Lipids, occurrence and composition of fats, hydrolysis of fats, fats as a source of pure acids and alcohols, detergents, unsaturated fats, phosphoglycerides, cell membrane, steroids. 6 hrs.

**Proteins and Nucleic Acid:-** Protein, structure of amino acids, amino acids as dipolar ions, isoelectric point, configuration of natural amino acids, preparation of amino acids, reactions of amino acids, Dopa mine and its uses in medicine peptides (geometry of peptide linkage), determination of structure of peptides, synthesis of peptides, proteins (classification and functions), structure of protein, peptide chain, side chain (isoelectric point, electrophoresis), conjugated proteins, secondary structure of protein, nucleoproteins and nucleic acids, the genetic code. 15 hrs.

**Bio-organic Chemistry:-** Biological oxidation and reduction, (ethanol and acetaldehyde), biological oxidation and reduction (deuterium labeling experiments), stereochemistry of biological oxidation and reduction, organic chemistry of vision, biosynthesis of fatty acids, mechanism of enzyme action (chymotrypsin). 10 hrs.

(Nearly 50-60 hrs)

## Group C : Physical Chemistry

**Chemical Energetics:** Entropy, entropy change is isolated system, dependence of entropy on temperature, volume and pressure, entropy change in ideal gas, entropy of mixing, entropy change in physical and chemical transformation, third law of thermodynamics, third law and its significance, free energy, free energy change for reaction. Gibbs Helmholtz equation, properties and significance of $\Delta G$, reaction isotherms. Clapeyron equation, Clausius-Clapeyron equation, thermodynamics of equilibrium constant, Kp and Kc for gaseous system, properties of equilibrium constant, thermodynamic criteria of equilibria.

18 hrs

**Chemical Kinetics:** Consecutive reactions, parallel reaction, opposing reaction, effect of temperature on reaction velocity, energy of activation, theories of reaction rates: Collision theory of a bimolecular and unimolecular reactions, transition state theory, chain reaction, kinetics of the following photochemical reactions: (a) hydrogen and chlorine (b)hydrogen and bromine

18 hrs.

**Solid state chemistry:** Interplanar distance in cubic system, Brags law and its application, Crystal structure of NaCl and KCl, Frenkel and Schottky defets, color centers and formation of F-centre.

5 hrs.

**Spectroscopy**

**Introduction:** Electromagnetic radiation, origin of molecular spectra, classification of molecular spectra.

**Rotational Spectrum:** Microwave spectrum, energy levels of rigid rotor, selection rules, application of rotation spectra, qualitative description of non-rigid rotor.

**Vibrational Spectrum:** Infrared spectrum, energy levels of simple harmonic oscillator, selection rules, pure vibrational spectrum, effect of anharmonic motion, idea of vibrational frequency of different functional groups.

**Raman Spectrum:** Concept of polarizibility, pure rotational and pure vibrational Raman spectra of diatomic molecules, selection rules.

**Electronic Spectrum:** Introduction, Frank condon principles, application of electronic spectroscopy. 9 hrs.

**Course Title:** General Practical Chemistry II
**Course No.:** CHEM 334 (major)
**Nature of the Course:** Practical

**Full Marks:** 50
**Pass Marks:** 20
**Year:** III

**Course objectives:**

The main outcome of this course will be:

- To follow instructions for practical work.
- To make accurate observation and measurements being aware of possible sources of error.
- To record accurately and clearly the results of experiments.
- To explain practical techniques, procedures and safe laboratory working practices.

**Experiments on Inorganic Chemistry**

**Quantitative Estimation:-** Precipitaton titration of silver nitrate in acidic media (Volhard Method ), Redox titration involving potassium dichromate (Mohr's salt, determination of iron in hematite)

12 hrs

**Gravimetric Analysis:-** Nickel as complex with dimethyl glyoxime, copper as cuprous thiocyanate, aluminum as oxinate, lead as lead chromate, magnesium as magnesium ammonium phosphate and pyrophosphate.

27 hrs

**Paper Chromatography:-** Qualitative analysis of some inorganic anions and cations by paper chromatography (two each)

6 hrs

**Ion – Exchange chromatography:** – Separation of metal ions from mixture.

a) Preparation of potassium trioxalatoferrate (III) trihydrate and measurements of its Conductivity,
b) Estimate the amount of iron present in the above complex.

6 hrs

**Experiments on Organic Chemistry**

Spectral analysis (spectra of simple organic compounds will be provided and students are required to interpret the given spectra and find out the structures of organic compounds). Two sets of multistep synthesis (2-3 steps synthesis), Quantitative analysis of any two: (OH- group, nitrogen, sulphur, glucose, carbonyl group), Isolation of the following natural products (any two): lactose, caffeine, camphor, essential oil, Purification by thin layer chromatography/column chromatography. Benzoin condensation (a green synthesis using thiamine hydrochloride).

51 hrs.

**Experiments on Physical Chemistry**

1. Determination of activation energy for acid catalyzed hydrolysis of methyl acetate.
2. Determination of rate constant of hydrolysis of ethyl acetate by sodium hydroxide.
3. Study of kinetics of acid catalyzed iodination of propanone.
4. Verification of Freundlich and Langmuir adsorption isotherms.
5. Verification of Lambert Beer law and determination of concentration of a solution.

**Text Books: For all theoretical courses i.e. CHEM 311, 321, 331 and 333**


1. J. D. Lee, Concise Inorganic Chemistry, 5th Edition, John Wiley and sons.Inc, 2007.
2. F. A. Cotton, G. Wilkinson & C. Gaus, Basic Inorganic Chemistry, 3rd Edition, John Wiley & Sons (Asia), Pvt., Ltd., 2007.
3. R. T. Morrison & R. N. Boyd, Organic Chemistry, 6th Edition, Prentice- Hall of India Pvt., Ltd., 2008.
4. I. L. Finar, Organic Chemistry, Vol. I and Vol. II, Prentice Hall, London, 1955 (available recent edition).
5. Streitweiser & Heathcock, Introductory Organic Chemistry, Wiley and Sons, New York, 1981
6. J. March, Advanced Organic Chemistry, 4th Edition, Wiley Eastern Ltd., India, 2005.
7. N. D. Cheronis and J.B. Entrikin, Identification of Organic Compounds, A Student's Text using Semi -micro Techniques, John Wiley& Sons, Inc (Latest edition).
8. R. L. Shriner, R.C Fusion and D.Y Cartin, The Systematic Identification of Organic Compounds, A Hand Manual, John Wiley and Sons, Inc. New York (Latest).
9. S. H. Maron & C. Prutton, Principles of Physical Chemistry, 4th Edition, Oxford & IBH Pub.Co., 1992
10. M. K. Sthapit and R. R. Pradhananga, A text book of Physical Chemistry, Taleju Prakashan, Nepal 2007.
11. D. F. Shriver and P W. Atkins, Inorganic Chemistry, Oxford University Press.


**Reference Books: For all theoretical courses i.e. CHEM 311, 321, 331 and 333**


1. A. Sharpe, Inorganic Chemistry, 2nd Edition, ELBS & Longman, Singapore, 1986 (recent edition)
2. R. D. Madan, Satya Prakash, Modern Inorganic Chemistry, S. Chand & Compan Ltd., 1994.
3. K. N. Upadhyaya, A Text Book of Inorganic Chemistry, 2nd Edition, Vikas Publishing House Pvt., Ltd., 1995
4. G. Marc Loudon, Organic Chemistry, Oxford University, 4th edition

5. Lawry and Richardson, Mechanism and Theory in Organic Chemistry, Haper and Row, New York, 1981
6. C. Norman, Principles of Organic Synthesis, 2nd Edition, Chapman and Hill. London 1978, (recent edition)
7. Warren, Organic Synthesis, The Disconnection Approach, Wiley, New York, 1982 (available recent edition)
8. House, Modern Synthesis Reactions, 2nd Edition, W. A. Benjamin. New York, 1972
9. K. L. Kapoor, Text book of Physical Chemistry, Macmillan India Ltd., Vol. I to Vol.V, 3rd edition, 2001
10. Alberty, Physical Chemistry, 6th Edition, Wiley Eastern Ltd., New Delhi, 1992
11. S. Glasstone & D. Lewis, Elements of Physical Chemistry, Mcmillan & Co., Ltd.
12. S. Negi & S. C. Anand, A Text Book of Physical Chemistry, Wiley Eastern Ltd., 1991
13. R. M. Silverstein, G. L.Bassler & T. C. Morril, Spectrometric Identification of Organic Compounds, Wiley, New York, 1981, (Preferably available recent edition)
14. C. Agrawal, Modern Inorganic Chemistry, Wiley Eastern, New Delhi, 1981, (available recent edition)
15. T.W. Graham Solomons, Organic Chemistry, (latest edition), John Wiley and Sons, New York.
16. R. A.Bansal, A Text Book of Organic Chemistry, 2nd Edition, Wiley Eastern Ltd., New Delhi, 1993 (available recent edition)
17. S. Bahl, G. D. Tuli & A. Bhal, Essential of Physical Chemistry, 24th Edition, S. Chand & Co. 2000.
18. M. L. Sharma and P. N. Chaudhary, A Textbook of B. Sc. Chemistry (Vol. I & II), second edition, Ekta Books Nepal, 2007.
19. A. K. Bhagi and G. R. Chatwal, Bioinorganic and Supramolecular Chemistry, Himalaya Publishing House, Mumbai.
20. A. K. Bhagi and G. R. Chatwal, Environmental Chemistry, Himalaya Publishing House, Mumbai.
21. James, E. Huheey, Ellen A. Keiter, Richard L. Keiter, Inorganic Chemistry Principles of Structure and Reactivity, Addison Wesley Publishing House.

**Text Books: For all practical courses i.e. CHEM 312, 322, 332 and 334**

1. A. I. Vogel, A Text Book of Quantitative Inorganic Analysis, Including Elementary Instrumental Analysis, ELBS & Longman, 1969, (Preferably available recent edition).

D.K. Vishnoi - Practical organic chemistry;

2. A. I. Vogel, A Text Book of Qualitative Inorganic Analysis, ELBS & Longman, 1969, (recent edition).
3. R. L. Shriner, R. C. Fusion & D. Y. Cartin, The Systematic Identification of Organic Compounds, A Laboratory Manual, John Wiley and Sons, Inc. New York, 1986. (Preferably available recent edition).
4. B. P. Levitt, ed. Findlay's Practical Physical Chemistry, Longman, London, 1973.
5. Moti Kaji Sthapit and R. R. Pradhananga, Experimental Physical Chemistry, Taleju Prakasan, Kathmandu (1998).
6. K. N. Ghimire, M. R. Pokhrel & K. P. Bohara, University Experimental Inorganic Chemistry, Quest Publication, Kirtipur, Kathmandu, 2008.
7. N. M. Khadka, S.D Gautam and P. N. Yadav, A Core Experimental Chemistry for B.Sc. Kaea Book Centre, Kathmandu.
8. K. N. Ghimire & K. P. Bohara, University Experimental Physical Chemistry, Quest Publication, Kirtipur, Kathmandu, 2008.

**Reference Books: For all practical courses i.e. CHEM 312, 322, 332 and 334**

1. Gurdeep Raj, Advanced Practical Inorganic, 10th Edition, Goel Publishing House, Meerut, 1994.
2. A. I. Vogel, A Text Book of Practical Organic Chemistry, Including Qualitative Organic Analysis, Longmans, 1958, (Preferably available recent edition)
3. A.I. Vogel, A Text Book of Practical Organic Chemistry, Including Qualitative Organic Analysis, Longmans, (Latest Edition).
4. F. G. Mann and B. C. Saunders, Practical Organic Chemistry, Orient Longman, 1986, (recent edition).
5. D. P. Shoemaker & C. W. Garland, Experiments in Physical Chemistry, McGraw Hill, Kogakusha Ltd. Tokya, 1967.
6. B. D. Khosla, A. Gulati & V. C.Garg, Senior Practical Physical Chemistry, 5th Edition, R. Chand & Co., New Delhi, 1987.
7. J. N. Gurtu and K. Gurtupoor, Advanced Experimental Chemistry (Vol I-III), S. Chand & Co. New Delhi.
8. S. C. Rastogi and S. K. Agrawal, Advanced Inorganic Analysis.
9. S. K. Agrawal and Keemti Lal, Advanced Inorganic Chemistry, Pragati Prakasan, Meerut.
10. A. K. De, Environmental Chemistry, New age International Ltd Publishers, New Delhi.