The University of Burdwan
Syllabus for B.Sc. Honours
(1+1+1 Pattern)
in
Chemistry
with effect from 2014-2015

Total Marks: 800

Theoretical: 600 Practical: 200

PART I

Theoretical*		**Marks**
Paper I:	Inorganic	50
Paper II:	Organic	50
Paper III:	Physical	50
Practical#		
Paper IV:	Organic	50
	Total:	200

Practical#	**Marks**
Organic qualitative	30
Organic preparation	10
Laboratory note-book + Viva-voce	05+05

PART II

Theoretical*		**Marks**
Paper V:	Inorganic	50
Paper VI:	Organic	50
Paper VII:	Physical	50
Practical[##]		
Paper VIII:	Inorganic	50
	Total:	200

Practical[##]	**Marks**
Inorganic qualitative	30
Inorganic preparation	10
Laboratory note-book + Viva-voce	05+05

PART III

Theoretical*		**Marks**
Paper IX:	Inorganic	100
Paper X:	Organic	100
Paper XI:	Physical	100
Practical[###]		
Paper XII:		100
	Total:	400

Practical[###]	**Marks**
Inorganic experiment	20
Analytical experiment	20
Physical experiment	50
Laboratory note-book + Viva-voce	10

* Examinations of 50 marks papers are of two-hour duration and those of 100 marks papers are four hours duration on same day in each case.

[#] Examination is of six hours duration (10-30 AM to 4-30 PM) on same day.

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[###] Examination is of two six hours duration (10-30 AM to 4-30 PM) spread over two days: First day (six hours) – Inorganic and Analytical; Second day (six hours) – Physical.

Part I

Theoretical

Paper I **Full Marks: 50**

Inorganic

1. **Atomic structure and periodic properties** (**14 lectures**)

Bohr's model, Sommerfeld's extension, de Broglie's wave particle duality; Heisenberg's uncertainty principle and Schrödinger's equation (qualitative); significance of ψ and ψ^2; radial density, angular probability, characteristics of s-/p-/d-orbital, Aufbau principle, Pauli's exclusion/antisymmetry principle (statement and implication), Hund's rules, Slater's rules, quantum defect

Mendeleev-Seaborg's periodic table: basis and possible extension; periodic properties: atomic radius, ionic radius, covalent radius, van der Waals radius, ionization energy, electron affinity, electronegativity and its different scales, orbital/group electronegativity, ionic potential, diagonal relationship, work function; aperiodicity

2. **Bonding and structure** **(14 lectures**)

Different bonds: ionic, covalent, dative, retrodative, hydrogen, metallic, σ-/π-/μ-/δ-, banana (3c-2e); different weak forces, varied hybrid (sp, ds, sp^2, sp^3, d^3s, dsp^2, sp^3d, d^2sp^3, d^3sp^3 etc) orbitals, hypervalence, resonance, bond polarity, dipole moment, Fajan's rules; VB, LCAO, MO (qualitative idea on homo-/heteronuclear di-/tri-/polyatomic molecules such as AX_2 to AX_6), symmetry, energy and overlap, HOMO-LUMO, VB-MO comparison; bond multiplicity, bond strength and related implications

Prediction of structures and shapes of molecules: Helferich rules, VSEPR theory, steric number, Bent's rule; non-rigid molecules, Berry pseudorotation

3. **Acid-base and donor-acceptor** (**8 lectures**)

Different concepts, Pauling's rules, solvent acidity/basicity, Drago-Wayland equation, donor/acceptor number, Gutmann's rules, Hammett acidity function, super acid, solid acid, surface acidity, factors affecting acidity/basicity, HSAB principle, symbiosis, HOMO-LUMO and acid-base interaction; basis, measurement and anisotropicity of hardness/softness, pictorial diagram of frontier orbitals

4. **Redox system** (**6 lectures**)

Complementary/non-complementary redox reactions, standard/formal electrode potentials; influence of pH, complex formation and precipitation reaction on formal potential; Latimer/Forst/Pourbaix diagram, electrochemical series and its implication towards metal extraction principle, basis of redox titration, redox indicator, disproportionation, comproportionation

5. **Coordination chemistry I** (**18 lectures**)

Tassaert's observation, Jorgensen's proposition, Werner's theory; Lewis dot structure, classification and binding modes of ligands: classical, non-classical (π-complexing), σ-/(σ + π)-donor, σ-donor + π-acceptor, bridging (EO/EE) and bridging loop, chelator (*cis/trans*) and chelate effect, congregator, innermetallic, ambidentate, sequestering, flexidentate, innocent, non-innocent, tripod, macrocycle, podand, coronand, crown ether, cryptand, metalloorganic, organometallic, cyclometallated, Schiff-base, metalloligand and duplex behaviour

Synthesis of compounds of different nuclearities; internal parameters: metal and ligand; external parameters: temperature, pressure, solvent, reagent, counter ion, aerobic/anaerobic; stabilization of different oxidation states, choice of starting materials, self assembly

Types of isomerism, statistical numbering system, enumeration of isomers; factors effecting isomer population, interplay of steric and electronic factors, isomorphism and doping, structural equilibria, resolution of optical isomers; IUPAC nomenclature

Paper II **Full Marks: 50**

Organic

1. General introduction (4 lectures)

Nomenclature of organic molecules with special reference to polycyclic, bridge head, aromatic, heteroaromatic and heterocycles compounds, molecular weight (preliminary idea about mass spectroscopy), molecular formula

2. Structure and properties (8 lectures)

Nature of bonding in aliphatic, alicyclic, aromatic and heterocyclic compounds; bond length, bond strength, bond angle and their variations in compounds with sp^3, sp^2 and sp hybridized carbon atoms; orbital pictures of methane, ethane, ethene, ethyne, allene and benzyne; delocalised bonds, resonance, steric inhibition of resonance, hyperconjugation, tautomerism, aromaticity, Huckel's rules, aromatic, nonaromatic and antiaromatic compounds, non-benzenoid aromatic compounds, Huckel's rule

Inductive and field effects; dipole moment, H-bonding and its effect on physical and chemical properties of organic molecules

3. Introduction to organic reactions (7 lectures)

Homolysis and heterolysis of bonds; types of reactions: ionic, radical and pericyclic; Bronsted-Lowry concept, Lewis concept, strengths of acids and bases; effect of solvent on acidity and basicity; relationship between structure and acidity and basicity, acid-base reactions

Thermodynamics and kinetics of organic reactions, energy profiles for one-step and two- step reactions, catalyzed reactions, Hammond postulate, principle of microscopic reversibility, kinetically and thermodynamically controlled reactions; methods of determination of organic reactions: study of intermediates, kinetic and stereochemical studies, non-kinetic and kinetic studies with isotopes (primary and secondary kinetic isotope effects), crossover experiments

4. Reactive intermediates (8 lectures)

Formation, structure, stability and reactions of classical and non-classical carbocations, carbanions, free radicals, arynes, ylides, carbenes and nitrenes

5. Stereochemistry (20 lectures)

Concept of constitution, stereochemical representation: Fischer, Newman, Sawhorse, Flying-wedge and their interconversions, molecular symmetry: plane, centre, simple and alternating axes; symmetry operations, chirality and chiral centre, configuration, configurational nomenclature: D/L, R/S, erythro/threo; optical activity and optical isomerism, optical rotation: specific and molecular; optical purity, enantiomeric excess; resolution of optical isomers; chiral axis in allenes, biphenyls and spiranes and their R/S descriptors

Geometrical isomerism (diastereomerism) of molecules with C=C, C=N (oximes) and simple cyclic molecules; *cis/trans* and *E/Z* nomenclature

Conformation of alkanes and cycloalkanes: dihedral angle and angle of torsion, gauche, eclipsed and staggered arrangements; synperiplanar, synclinal, anticlinal, antiperiplanar conformations; conformation-energy diagram of ethane, propane and *n*-butane, relative stability of conformers on the basis of steric effect, dipole-dipole interaction, H-bonding; conformational analysis of cyclohexane and its mono- and di-substituted derivatives with chair, boat and twist boat forms and their symmetry properties and optical activity; strains in molecules: angle, bond, torsional and steric; steric and stereoelectronic factors

6. Aliphatic nucleophilic substitution reactions (8 lectures)

Free radical and nucleophilic substitutions at sp^3 carbon: S_N1, S_N2, S_Ni S_N1', S_N2', S_Ni' reactions; NGP

Factors affecting rates of S_N1 and S_N2 reactions, phase transfer catalyst and its use in organic reaction, use of crown ether in substitution reaction; functional group transformations using S_N2 reactions

7. Elimination reactions (5 lectures)

E1, E2 and E1CB mechanisms, reactivity, Saytzeff/Hofmann orientation and stereoselectivity; elimination vs substitution; syn-eliminations: pyrolysis of ester, xynthate, tert-N-oxide

Paper III **Full Marks: 50**

Physical

1. Kinetic theory and the gaseous state (18 lectures)

Idea of distribution functions, properties of gamma functions, Maxwell's speed and energy distributions in one-, two- and three- dimensions, distribution curves, different types of speeds and their significance, principle of equipartition of energy and its application to calculate the classical limit of molar heat capacity of gases

Collision of gas molecules, collision diameter, collision number and mean free path, frequency of binary collision in same and different molecules, wall collision and rate of effusion

Andrew's and Amagat's plots, compressibility factor, van der Waals equation and its features, critical constants and critical state, law of corresponding states, virial equation; significance of second virial coefficient, Boyle temperature, Dieterici equation and its features

2. Thermodynamics I (14 lectures)

Basic formalism, concept of thermal equilibrium and zeroth law of thermodynamics, state and path functions, partial derivatives and cyclic rule, concept of heat and work, reversible and irreversible processes, graphical representation of work done

First law, U and H as state functions, concept of C_P and C_V and their relations, Joule's experiment and its consequence, isothermal and adiabatic processes

Thermochemistry: Kirchoff's equation, heat changes during physicochemical processes at constant P/V, bond dissociation energies, Born-Haber's cycle

3. Thermodynamics II (18 lectures)

Second law of thermodynamics and its need, Kelvin, Planck and Clausius statements and their equivalence, Carnot cycle and refrigerator, Carnot's theorem, thermodynamic scale of temperature

Physical concept of entropy, Clausius inequality, entropy change of system and surroundings for various processes and transformations, entropy change during isothermal mixing of ideal gases, entropy and unavailable work, auxiliary state functions (G and A) and their variations with T, P and V, criteria of spontaneity and equilibrium

Thermodynamic relations, Maxwell relations, thermodynamic equation of state, Gibbs-Helmholtz equation and its consequence, Joule-Thomson (J-T) experiment inversion temperature, J-T coefficient for a van der Waals gas, general heat capacity relations

4. Chemical kinetics I (10 lectures)

Introduction, reaction rate and extent of reaction, order and molecularity; kinetics of zero, first, second, fractional and pseudo-first order reactions; determination of order of reaction, opposing, consecutive and parallel reactions (first order), concept of steady state and rate determining step, chain reaction: elementary idea, illustrations with H_2-Br_2 and H_2-O_2 reactions

Temperature dependence of reaction rate, Arrhenius equation

Practical

Paper IV **Full Marks: 50**

Organic

Qualitative analysis (30 marks)

Recording of physical characteristics
(colour, texture, odour and melting point)
Preliminary tests
(ignition test, soda lime test, litmus test, unsaturation test, Beilstein test)

Lassaigne's test
(detection of special elements N, S, halogens)
Solubility classification
(H_2O, 5% HCl, 5% NaOH, 5% $NaHCO_3$, conc. H_2SO_4, conclusion)
To be recorded in a tabular form)
Functional group detection
[Nitrogen containing: aromatic -NH_2 and -NO_2, -$CONH_2$, -CONHAr;
non-nitrogenous: phenolic -OH, -COOH, -CO- (aldehydic or ketonic), -CO_2R]
Literature survey
(selection of suitable derivative)
Derivative preparation
(procedure and recording of melting point)
Conclusion

Organic preparation (10 marks)

(A) Condensation: preparation of phthalimide
(B) Nitration: nitration of nitrobenzene, acetanilide
(C) Oxidation: oxidation of benzyl chloride/benzyl alcohol, benzoin
(D) Acetylation: acetylation of aniline using glacial acetic acid
(E) Hydrolysis: hydrolysis of amide/imide, esters
(F) Bromination: bromination of acetanilide using KBr, $KBrO_3$ and glacial acetic acid
LNB (5 marks)
Viva-voce (5 marks)

PART II

Theoretical

Paper V **Full Marks: 50**

Inorganic

1. Coordination chemistry II (**24 lectures**)

VB/CF theory: postulates, applications, limitations; crystal field strength, CFSE, CFAE, d-orbital splittings in ML_2-ML_8 systems, factors affecting 10 Dq, variation of ionic radii, lattice/solvation energy, interpretation of stereochemical preference, spinel/inverted spinel, weak/strong field, low/high spin, pairing energy, Jahn-Teller theorem/distortion

Russel-Saunder's coupling scheme, ground state spectroscopic terms for d^n/f^n ions, CF terms, Orgel/Tanabe-Sugano diagram and application to some simple cases, Laporte/spin selection rule, d-d/charge transfer transition, MLCT/LMCT/IVCT/LLCT/MMCT transition, transition moment integral, mechanism of intensity stealing in transition metal complexes, spectrochemical series, Nephalauetic effect, prediction of bonding and structure

Different types of magnetic molecules, magnetic susceptibility, orbital/spin magnetic moment, orbital contribution to spin moment, Pascal's constants, Curie equation, Curie/Neel temperature, Lande interval rule, spin-orbit coupling, subnormal/anomalous magnetic moment, multiplet width, super-exchange, spin crossover and bistability, interpretation of magnetic properties of d^n ions, prediction of valence and stereochemistry

2. Chemistry of elements **(36 lectures)**

(a) Normal and inert gas elements (12 lectures)

(b) Transition metals (20 lectures)

(c) Lanthanoids (Ln**'s) and actinoids (An's) (4 lectures)**

Chemistry of the above elements is to be studied in the light of the principle enumerated in **Paper I** in **Part I** syllabus and in item **1** highlighted above. These studies will cover a comprehensive **comparative accounts** of physical and chemical behaviours of elements and their compounds (in different valency states), geometric/electronic structure, stereochemistry and bonding, spectra and magnetism, thermal stability, reactivity in aqueous and non-aqueous solutions, preparation/synthesis of homoleptic/heteroleptic compounds, ores and uses of elements and their compounds. Periodicity, aperiodicity, diagonal relationship, d-orbital participation leading to pecularity are also to be stressed**.**

Elements *(for* ***2a****,* ***2b*** *and* ***2c)*****:** allotropic/isotopic/nuclear form, electronic configuration, position in periodic table, span of oxidation states with trend, periodic/aperiodic variation in atomic/ionic properties, atomicity, structure, boding, state of aggregation, reactivity, inertness, peculiarity, uses

Compounds *(for* ***2a)*****:** A comparative view of synthesis, structure, bonding (hybridization and VSEPR) and reactivity of hydrides, carbides, nitrides, oxides/hydroxides/oxoacids, halides, sulphides, silicates, homopoly/heteropoly cation/anion, interelement compounds, basic/acidic properties, uses

Compounds *(for* ***2b)*****:** Synthesis, structure, stereochemistry, bonding, colour, magnetism and use of different coordination complexes of varied nuclearities containing ammine, amide, nitride, polyamine, pyridine, polypyridine, hydride, halide, pseudohalide, amino acid, mono-/di-/polycarboxylate, biguanide, diars, dmgH, oxinH, acacH, dmso, Schiff base, olefin, CO, NO, N_2, O_2, cpH, benzene etc as blocking ligands and/or bridging units emphasizing on historically important compounds of different colours, complexes named after the discoverers and the ones used in laboratory as reagents and in industry for different purposes

Preliminary (*for* ***2c)*****:** Naming, electronic configuration, probable oxidation states, Ln/An contraction and consequences

Paper VI **Full Marks: 50**

Organic

1. Stereochemistry (4 lectures)

Stereogenecity, chirotopicity, achirotopicity, prochirality, topicity of ligands and faces (Pro-*R*, Pro-*S* and *Re/Si* designations), chemoselective, regioselective, steroselective: diasteroselective, enantioselective reactions with examples. Asymmetric synthesis: Cram's rule

2. Electrophilic and radical addition to C-C multiple bonds (4 lectures)

Halogenation, hydrohalogenation, hydration, hydrogenation, epoxidation, hydroxylation, ozonolysis, 1,3-dipolar additions; electrophiilic addition to conjugated dienes and allenes; radical addition addition of HBr; reduction of alkynes and bezenoid aromatics

Diels-Alder reaction, addition of carbenes

3. Nucleophilic addition to carbonyl group (10 lectures)

Reactions with water, alcohols, amines, thiols, HCN, bisulfite, Wittig reaction, Meerwein-Pondorf-Varley reduction, reduction with lithium aluminum hydride and sodium borohydride, Wolff-Kishner reduction, Clemmensen reduction, Bouveault-Blanc reduction, addition of organometallics, addition of diazomethane, Cannizzaro reaction, aldol condensation including directed aldol reaction, Claisen condensation, Knoevenagel reaction, Stobbe reaction, Reformatsky reaction, Mannich reaction, Darzen's glycidic ester synthesis, Perkin reaction, benzoin condensation, Dieckman reaction, acyloin condensation, nucleophilic addition (Michael addition) to α,β-unsaturated carbonyl system

4. Molecular rearrangement (5 lectures)

Wagner-Meerwein, Pinacol-Pinacolone, Dakin, Bayer-Villiger, Beckmann, Favorasky, Hoffmann, Lossen, Schmidt, Curtius, benzil-benzillic acid, dienone-phenol, Wolf, Claisen, Fries, Photo Fries, Orton, Demjanov, benzidine-semidine

5. Reagents in organic synthesis (6 lectures)

Grignard, alkyl lithium, LDA, $LiAlH_4$, B_2H_6, Me_3SiCl, R_2CuLi, Wilkinson catalyst, $NaBH_4$, DIBAL-H, 1,3-dithiane, OsO_4, $KMnO_4$

6. Named reactions (6 lectures)

Birch, von Richter, Houben-Hoesch, Arndt-Eistert homologation, Hell-Volhard-Zelinsky, Hunsdiecker, Oppenauer, Sandmeyer, Stephen, Williamson ether synthesis

7. Alicyclic compounds (6 lectures)

Structure of simple alicyclic compounds upto six-membered ring; strain theory in classical and modern theoretical approach, ease of ring formation; physical properties with respect to dipole moment and acid strengths (cyclohexane system only)

Synthesis and reactions in cyclohexane systems: E2 elimination, rearrangement, S_N1 and S_N2 including NGP, oxidation of cyclohexanols

8. Synthesis, physical properties and reactions

(6 lectures)

(i) Aliphatic and aromatic nitrogen compounds: amines, nitro compounds, nitroalkanes, alkyl nitriles, aromatic diazonium compounds, diazomethane; (ii) nitrophenols, aminophenols, nitroanilines, amino carboxylic acids

9. Aromatic electrophilic substitution (8 lectures)

Mechanism, orientation and reactivity; nitration, nitrosation, sulfonation, halogenation, Friedel-Crafts, Haworth synthesis, Gatterman-Koch, Gatterman, Hoesch, Vilsmeier-Haack, Reimer-Tiemann, Kolbe-Schmidt, chloromethylation, Manasse, Kolbe

10. Aromatic nucleophilic substitution (5 lectures)

Addition-elimination mechanism, ArS_N1 mechanism, elimination-addition (benzyne) mechanism; orientation and reactivity

Paper VII **Full Marks: 50**

Physical

1. Thermodynamics and equilibrium (16 lectures)

Additivity rule, partial molar quantities, chemical potential and its variation with T and P, Gibbs-Duhem equation, fugacity of gases and fugacity coefficient

Thermodynamic condition of equilibrium, degree of advancement and Le Chatelier's principle, Van't Hoff isotherm, isobar and isochore

Activity and activity coefficients of electrolyte/ion in solution, Debye-Hückel limiting law (without derivation), solubility equilibrium and influence of common and indifferent ions

Ostwald's dilution law, pH, buffer solution and buffer capacity, Henderson equation, hydrolysis and hydrolysis constant of salts, indicators: acid-base and its function, Hammett acidity function

2. Phase equilibrium and colligative properties (18 lectures)

Definition of phase, component and degree of freedom, phase rule and its derivation, phase diagram, phase equilibria for one-component system: water and carbon dioxide, first order phase transition and Clapeyron equation, Clausius-Clapeyron equation: derivation and applications

Liquid-vapour equilibrium for two-component systems, Duhem-Margules equation, Henry's law, Konowaloff's rule, deviation from ideal behavior, azeotropic solution, liquid-liquid phase diagrams for phenol-water, triethylamine-water and nicotine-water systems, solid-liquid phase diagram, eutectic mixture, Nernst distribution law, solvent extraction

ΔG, ΔS, ΔH and ΔV of mixing for binary solutions, vapour pressure of solution, ideal solutions, colligative properties, Raoult's law; ebullioscopy, cryoscopy and osmosis (thermodynamic treatment only): inter relationships and abnormal behavior in solution, van't Hoff *i*-factor

3. Chemical kinetics II (8 lectures)

Collision theory of bimolecular reactions, unimolecular reactions, Lindemann theory, transition state theory, free energy and entropy of activation, pressure-dependence of rate constant, primary kinetic salt effect

Homogeneous catalysis with reference to acid base and enzyme catalyses

4. Properties of fluids (10 lectures)

General features of fluid flow (streamline and turbulent flows) Reynolds number, nature of viscous drag for streamline motion, Newton's equation, viscosity coefficient, kinetic theory of gas viscosity, viscosity of gases vs liquids, Poiseuille's equation and its derivation, temperature dependence of viscosity, intrinsic viscosity, principle of determination of viscosity coefficients of liquids by Ostwald viscometer and falling sphere methods

Nature of the liquid state, vapour pressure, surface tension, surface energy, excess pressure, capillary rise and measurement of surface tension, work of adhesion and cohesion, condition of wetting, vapour pressure over a curved surface, temperature-dependence of surface tension, principle of determination of surface tension, concept of liquid crystals and superfluids

5. Macromolecules **(8 lectures)**

Introduction, types of polymers, classification of solvents; degree, extent and kinetics of polymerization; number and weight average molecular weights and their relation, determination of molecular weights by osmometry and viscometry

Practical

Paper VIII **Full Marks: 50**

Inorganic
Qualitative (30 marks)

Detection and analysis of mixtures containing not more than four radicals with at least one acidic radical selected from the following: basic radicals – silver, lead, mercury, bismuth, copper, cadmium, arsenic, antimony, tin, iron, aluminium, chromium, zinc, manganese, cobalt, nickel, calcium, strontium, barium, magnesium, sodium, potassium, ammonium; acidic radicals – oxide, hydroxide, acetate, carbonate, chloride, bromide, iodide, sulphide, sulphite, sulphate, thiosulphate, chromate, phosphate, nitrate, nitrite, borate, silicate, fluoride, arsenite and arsenate (oxide, hydroxide, acetate and carbonate not to be counted among four radicals). **Semi-micro method** of analysis to be followed in qualitative analysis. Centrifuge machine, thioacetamide instead of H_2S and spot tests for specific radicals are to be used.

Reporting of the systematic analysis of the samples for qualitative analysis should be under the following headings:

(i) Physical characteristics and solubility of the sample;
(ii) Preliminary tests for basic and acid radicals: **only the positive tests to be mentioned;**
(iii) Systematic analysis of the sample: (a) the group present to be clearly analyzed, (b) the confirmatory tests to be reported;
(iv) Preliminary tests for acid radicals: **only the positive tests for acid radicals present**, including spot tests, tests for acid radicals in presence of other interfering radicals to be reported;
(v) Naming of radicals;
(vi) Probable composition with proper justification to be noted as a conclusion.

Preparations (10 marks)

Simple salt: $NiCO_3$, vitriols like $CuSO_4.5H_2O$ and $ZnSO_4.7H_2O$
Double salt: Mohr's salt and potash alum
Complex salt: $[Ni(en)_3]Cl_2.2H_2O$, $[Cr(acac)_3]$ and $[Cu(oxin)_2]$

PART III

Theoretical

Paper IX Full Marks: 100

Inorganic
Group A

1. **Inorganic solids** **(10 lectures)**

Close-packed structures, different polyhedra, Lave's principle, radius ratio rule and its limitations; cubic, tetrahedral and octahedral holes; ionic/covalent/molecular/H-bonded solids, structures of ionic solids: MX (NaCl, CsCl and ZnS), MX_2 (CaF_2, SiO_2, TiO_2)/M_2X (Na_2O), MX_3 (AlF_3) types; imperfectness in structures and crystal defects, Born-Haber cycle, lattice energy, metallic structure, band theory

2. **Reaction mechanism** **(10 lectures)**

Fundamentals, energy profile of reactions, measurement of reaction rates, rate laws and mechanism and factors affecting them, activation parameters, substitution reactions in octahedral cobalt(III) and square planar platinum(II) complexes, cis/trans effect and applications, spectator ligand, nucleophilicity parameter, mechanistic switchover along group and across period

3. **Metal ions in living systems** **(10 lectures)**

Essential elements, biological metal ions/ligands and their classifications according to HSAB principle; cooperativity; physiological buffer and its action, functions of biological metal ions; biological ligands such as porphyrin/adenosine triphosphate; haemoglobin: a structural unit and function in living system, oxygen transport/uptake, active/passive transport, picket-fence model, Na^+ ion - K^+ ion pump; metals and chelating agents as drugs; toxicity of metal ions: Al, Cr, Cu, As, Cd, Hg and Pb

4. **Organometallic compounds** **(10 lectures)**

Definition, nomenclature, classification; 18-electron rule – application/exception, EAN; preparation, properties, structure, bonding, reactivities and applications of alkyls and aryls of Li, Al, Hg, Sn, Ti; a brief account of metal-ethylenic complexes and homogeneous hydrogenation, some simple fluxional molecules; coordinative unsaturation: oxidative addition, reductive elimination and insertion reactions

5. **Synthesis, structure, bonding (using IR results) and reaction** (**10 lectures**)

i) *Carbonyl complexes*: synthesis of mono-, di- and polynuclear aggregates; substitution, reduction, oxidation, reaction on metal bound CO as functional group; ν(CO) stretching frequency as diagnostic tool in the identification of ligational motifs (bridging/terminal/metalloligand), structure, bonding, π-acidity of CO; effect of coligands on ν(CO), basicity of bound CO, probing reactivity of bound CO

ii) *Nitrosyl complexes*: synthesis of mixed ligand compounds of different nuclearities; reaction on metal bound NO as functional group; ν(NO) as marker in proposing different oxidation state (NO^+, NO, NO^-) of free and bound NO, linear and bent NO and reactivity: electrophilicity and nucleophilicity

iii*) Cyclopentadienyl, benzene, acetylacetonate, cyanide, N_2 and O_2 complexes*: organometallic view, hapticity, quasi-aromaticity, super-aromaticity, electrophilic/nucleophilic reactions; ν(C=C), ν(C=O), ν(C≡N), ν(N=N) and ν(O=O) as marker of hapticity and reactivity

6. **Nano and supramolecular chemistry** **(10 lectures)**

Definition, molecule to supramolecule, molecular aggregate to crystalline aggregate; synthetic methods: choice of building units, reaction condition, design of structures: nano and mega carbon tubes, meso structures, nanoclusters and nanowires; applications

Group B

7. Nuclear and radioanalytical chemistry (**20 lectures**)

Preamble, various radioactive disintegration modes, nature of radiations, theory of radioactive disintegration, different types of radioactive equilibria, half life/average life period; different natural/artificial radioactive series, group displacement law, units/measurements of radioactivity

Different nuclides/radionuclides, separation of isotopes, applications of isotopes in medicine, industry, chemical reaction pathways and dating techniques, effect of radiation on water, typical radiometric estimation and radiometric titration

Mass defect and binding energy, different parameters governing stability of atomic nucleus, concept of nuclear force, different types nuclear reactions, nuclear fusion/fission, source of solar energy, principle of atom/hydrogen bomb

8. Statistical methods in analytical chemistry **(14 lectures)**

Significant figures, precision and accuracy, errors – systematic and random, mean, variance, standard deviation, different forms of standard deviations, sample and universal standard deviations

Qualitative idea about different frequency distribution, normal distribution, mathematical expression for normal distribution, calculation of area under normal distribution curve by numerical integration, relation between probability and area

Propagation of errors, general and specific cases, functions involving multiplication, division, exponential and logarithmic calculations

The t-distribution and application, confidence limit, significance testing, least-squares analysis, sensitivity and detection limit

9. Analytical methods **(10 lectures)**

a) **Volumetric analysis**

Acid-base reaction: polyprotic acids, mixture of monoprotic acids, reactions in non-aqueous solvents – levelling effect, titration in basic solvents and in glacial acetic acid

Redox reaction: Redox titrations: feasibility, indicator, different types like chromometry, permangonometry, iodometry and iodimetry

Complexometric reaction: different multidentate ligands as complexometric titrants, applications of EDTA, metal ion indicator, typical examples of EDTA titration, masking/demasking agent

Precipitation reaction: a few typical examples like Vohlard titration, use of adsorption indicators

b) ***Electroanalytical analysis*** **(5 lectures)**

Classification of electroanalytical methods; basic principle of pH-metric, potentiometric and conductometric titrations; techniques used for determination of equivalence point/pKa value; basic principle of high frequency titration, electrogravimetry

c) ***Spectrophotometric analysis*** **(4 lectures)**

Principle and terminology, Lambert-Beer's law and its limitations, colorimetric determination of single analyte, spectrophotometric determination of multicomponent analytes, atomic absorption/emission spectrometry: principles and instrumentations, estimation of sodium and potassium in water samples

10. Methodologies in separational chemistry **(7 lectures)**

Basic principle of solvent extraction, distribution ratio, extraction equilibria and effect of pH, Craig, counter-current extraction: basic principle, simple applications; TLC/column chromatography: R_f-value and its significance, elution, migration rate, column efficiency, column resolution, band broadening; ion-exchange separation: basic principle, exchange capacity; elementary idea on GC and HPLC

Paper X **Full Marks: 100**

Organic

Group A

1. Dyes **(3 lectures)**

Phenolphthalein, methyl orange, malachite green, alizarin

2. Medicinal chemistry **(5 lectures)**

Preliminary concept on pharmacodynamics and pharmacokinetics; syntheses and uses of paracetamol (antipyretic), aspirin and phenacetin (analgesics), sulphanilamide and sulphaguanidine (sulpha-drugs), chloroquine (antimalarial)

3. Heterocyclic compounds **(16 lectures)**

Syntheses, properties and uses of furan, pyrrole, thiophene, pyridine, quinoline, isoquinoline and indole

4. Amino acids and proteins **(14 lectures)**

Essential and non-essential amino acids, isoelectric point, ninhydrin reaction, synthesis of glycine, alanine and tryptophan; classification of proteins, geometry of peptide linkage, elementary idea about primary and secondary structures of proteins; C-terminal, N-terminal and their determination; peptide synthesis, Merrifield synthesis

5. Carbohydrate chemistry **(11 lectures)**

Chemistry of monosaccharides and disaccharides including structures and configurations: D-glucose, fructose, galactose, arabinose and sucrose; stepping-up and stepping-down of monosaccharides, conversion of aldose to ketose and vice versa; mutarotation, epimerization, anomeric effect, elementary idea about starch and cellulose

6. Alkaloids and terpenenoids **(11 lectures)**

General studies of terpenenoids and alkaloids; biosynthesis of terpenes; determination of structures of citral, nerol, α-terpineol, piperin, ephedrine and coniine

Group B

7. Methodology in organic synthesis **(15 lectures)**

Disconnection approach, synthon, synthetic equivalents, umpolung, one-group disconnection of alcohols, olefins and ketones; synthesis involving enolates and enamines with special reference to diethyl malonate and ethyl acetoacetate; two-group disconnections for dioxygenated molecules (1,2-; 1,3-; 1,4-; 1,5- and 1,6-systems), Robinson annelation; reconnection; synthesis through protection of functional groups

8. Pericyclic reactions **(16 lectures)**

FMO approach, definition, classification, electrocyclic reactions (including Woodward-Hofmann selection rules): [4+2] cycloaddition with special reference to Diels-Alder reaction, alder ene reaction, [2+2] cycloaddition; sigmatropic reactions: [1,j] and [i,j] shifts, [1,3] and[1,5] H-shifts, [3,3] sigmatropic shifts with reference to Cope and Claisen rearrangements

9. Spectroscopy **(20 lectures)**

UV: Electronic transitions with reference to σ-σ*, n-σ*, π-π*, n-π* transitions; absorption maximum and absorption intensity, effect of solvent; Woodward rule with reference to conjugated system like dienes, trienes and α,β-unsaturated carbonyls including cyclic systems

IR: Hooke's law, stretching and bending vibrations, characteristic and diagnostic stretching frequencies, factors affecting stretching frequencies (H-bonding, electronic factor, ring size), finger-print region, diagnostic bending frequencies for benzene and its *o*-, *m*- and *p*-isomers

^{1}H NMR: Principle, nuclear spin, NMR-active nuclei, chemically equivalent and nonequivalent protons; chemical shift, upfield and downfield shifts; shielding/deshielding of protons in systems involving C-C, C=O, C=C, benzene, cyclohexane; spin-spin splitting with reference to CH_3CH_2Br, CH_3CH_2OH, Br_2CHCH_2Br; characteristic ^{1}H NMR signals for simple molecules

Application of the above spectroscopic methods in structure elucidation of simple organic molecules

10. Nucleic acids **(4 lectures)**

Heterocyclic bases, nucleosides, modified nucleosides, nucleotides; idea about DNA and RNA

11. Green chemistry **(5 lectures)**

Principles, starting materials, reagents, solvents, catalysts, utilities

Paper XI **Full Marks: 100**

Physical

Group A

1. Electrochemistry (25 lectures)

Conductance and its measurement, cell constant, specific and equivalent conductances, their variations with dilution for strong and weak electrolytes, molar conductance, Kohlrausch's law, Walden's rule, ion conductance and ionic mobility, application of conductance measurement (determination of solubility product and ionic product of water), conductometric titrations, transport number, ion atmosphere, asymmetry and electrophoretic effects, Wien effect and Debye-Falkenhagen effect, Debye-Hückel theory with derivation

Electrochemical cells, half cells/electrodes with types and examples, cell reactions and thermodynamics of cell reactions, Nernst equation, standard cells, calomel, Ag/AgCl, quinhydrone and glass electrodes: features and applications, potentiometric titrations (acid base and redox), concentration cells, liquid junction potential and its minimisation

2. Properties of solids, interfaces and dielectrics (27 lectures)

Unit cell, Bravais lattice, crystal system, packing in cubic crystals, Miller indices, Bragg's equation and its applications, crystal structures of NaCl and KCl

Special feature of interfaces, physical and chemical adsorptions, Langmuir and Freundlich adsorption isotherms, surface excess and Gibbs adsorption isotherms, heterogeneous catalysis (single reactant)

Electrical double layers, zeta potential, overvoltage, Stern double layer (qualitative idea), Tyndall effect, electrokinetic phenomena (qualitative idea), colloids and electrolytes, micelle and reverse micelle, critical micelle constant (CMC)

Electrical properties of molecules, polarizability, induced and orientation polarization, Debye and Clausius-Mossotti equations (without derivation) and their applications

Origin and types of intermolecular forces, different types of potential and their diagrams

3. Symmetry and group (8 lectures)

Introduction, symmetry elements and operations with illustrations, symmetry elements and physical properties, group and symmetry group, group multiplication table, point group, determination of molecular point groups

Group B

4. Quantum chemistry (25 lectures)

Black body radiation, Planck's radiation law, photoelectric effect, Wilson-Sommerfeld quantization rule, application to Bohr atom, harmonic oscillator, rigid rotator and particle in 1-d box, de Broglie relation and energy quantization in Bohr atom and box, Heisenberg uncertainty principle, Bohr's correspondence principle and its applications to Bohr atom and particle in 1-d box

Elementary concept of operators, eigenfunctions and eigenvalues, linear operators, commutation of operators, expectation value, hermitian operator, properties, Schrödinger's time independent equation, acceptability of wave function, probability interpretation of wave function

Particle in a box, setting up of Schrödinger's equation of 1-d box, its solution and application, degeneracy, comparison with free particle eigenfunctions and eigenvalues, normalization, orthogonality and probability distribution of ψ, expectation values of x, x^2, p_x, p_x^2 and their significance in relation to the uncertainty principle, extension of the problem to two- and three-dimensions and the problem of degeneracy

Stationary Schrödinger equation for the H-atom in polar coordinates, separation of radial and angular parts, solution of Φ part and emergence of magnetic quantum number, hydrogenic wave functions up to n = 2 (only expressions), real wave functions, concept of orbitals and shapes of s and p orbitals

5. Photochemistry and spectroscopy (25 lectures)

Primary photophysical processes, potential energy diagram, Franck-Condon principle and vibrational structure of electronic spectra, bond dissociation, decay of excited state by radiative and nonradiative paths, fluorescence and phosphorescence, Jablonsky diagram, laws of photochemistry, quantum yield, photochemical equilibrium, photosensitized reactions, kinetics of HI decomposition

Alkali metal spectra, multiplicity of spectral lines, idea of spin quantum number, physical idea of spin orbit coupling

Rotational spectroscopy of diatomic molecules, rigid rotator model, characteristic features (spacing and intensity), applications

Vibrational spectroscopy of diatomic molecules, Simple Harmonic Oscillator (SHO) model; vibration rotation spectra, applications

Raman effect, characteristic feature and condition of Raman activity with illustrations, rotational and vibrational Raman spectra, rule of mutual exclusion with examples

NMR spectra, nuclear spin, Larmour precision, chemical shift, spin-spin interaction

6. Statistical thermodynamics and the third law (10 lectures)

Thermodynamic probability, entropy and probability, Boltzmann distribution formula (with derivation), application to barometric distribution, partition function and thermodynamic properties (U, H & P), Einstein's theory of heat capacity of solids and its limitations

Nernst heat theorem and its implications, approach to zero Kelvin, Planck's formulation of third law and absolute entropies

Practical*

Paper XII Full Marks: 100

Inorganic experiments (20 marks)

(A) Volumetric estimation using (i) redox and (ii) complexometric titration:

(i) Redox titration using chromometry, permanganometry and iodometry for one of the metal ions such as iron, copper, manganese and calcium in a binary mixture such as estimation of (a) Fe(III) in a mixture with Ca(II), (b) Fe(III) in a mixture with Cu(II) or Mn(II), (c) Cu(II) in a mixture with Fe(III) or Mn(II) and (d) Mn(II) in a mixture with Cu(II) or Fe(III)

(ii) Complexometric titration using EDTA for one of the metal ions like calcium, magnesium and iron in a binary mixture: (a) estimation of Ca(II) or Mg(II) in a mixture and (b) Fe(III) in a mixture with Ca(II) using sulphosalicylic acid indicator

Analytical experiments (20 marks)

(A) Titrimetric analysis of (i) ascorbic acid with iodine, and (ii) aniline and phenol using $KBrO_3$-KBr mixture

(B) Colorimetric analysis of (i) Mn(II) in permanganate solution and (ii) Cr(III) in dichromate solution

Physical chemistry experiments (50 Marks)**

(A) Surface tension of a liquid/solution by drop-number method

(B) Viscosity coefficient of a liquid/solution by Ostwald viscometer

(C) Equilibrium constant of the reaction $KI + I_2 = KI_3$ by partition method

(D) Solubility/solubility product of Mg-carbonate in presence/absence of common ions and/or neutral electrolytes

(E) Conductometric titrations of an acid or a base (acid may be monobasic/dibasic, and similarly for the base)

(F) Potentiometric titrations of an acid or a base (acid may be monobasic/dibasic, and similarly for the base)

(G) Kinetics of decomposition of H_2O_2 by potassium iodide

(H) Kinetics of saponification of ester by conductometric method

(I) Conductometric verification of Ostwald dilution law

(J) Colorimetric determination of pK_{in} of methyl red

*Digital analytical balance (accuracy up to third/fourth decimal) must be used for experiments on inorganic, analytical and physical chemistry.

****Marks distribution:**

(i) Theory and/or working equation with explanation of terms
(ii) Presentation (data in tabular form, recording of temperature and mentioning proper units everywhere)
(iii) Correct calculations and/or graphs with proper choice of axes and their labelling, proper placing of points, drawing smooth curves with captions
(iv) Correctness of results and interpretation

Tentative List of Recommended Books

Paper I

R. L. Dutta and G. S. De, Inorganic Chemistry, Pt – I, 7th Edn, 2013, The New Book Stall, 2013.
R. L. Dutta, Inorganic Chemistry, Pt –II, 5th Edn, 2013, The New Book Stall, 2006.
R. Sarkar, General and Inorganic Chemistry, Pt- I, II, 2nd Edn, Books & Allied (P) Ltd, 2009.
A. K. Das, Fundamental Concepts of Inorganic Chemistry, (Vol. 1-3), 2nd Edn, CBS Publisher, 2012.
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G. Wulfsberg, Inorganic Chemistry, Viva Books Private Ltd., New Delhi, 2001.
D. F. Shriver, P. W. Atkins and C. H. Langford, Inorganic Chemistry, Oxford University Press, New York, 1990.
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N. N. Greenwood and A. Earnshaw, Chemistry of the Elements, 2nd Edn, Elsevier, India, 2005.
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A. G. Sharpe, Inorganic Chemistry, 3rd Edn, Pearson Education, New delhi, 2004.
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S. Sengupta, Basic Stereochemistry of Organic Molecules, 2009.
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W. Kemp, Organic Spectroscopy, 3rd Edn., McMillan, Hong Kong, 1991.
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T. H. Lowry and K.C. Richardson, Mechanism and Theory in Organic Chemistry, 3rd Edn., Harper and Row, New York, 1998.
T. W. G. Solomons, Organic Chemistry.
G. M. Loudon, Organic Chemistry.
J. Clayden, N. Greeves, S. Warren and P. Wothers, Organic Chemistry, Oxford University Press, Oxford, 2001.

I. Fleming, Frontier Orbitals and Organic Chemical Reactions, John Wiley, 1980.
W. Caruthers, Modern Methods of Organic Synthesis, 3rd Edn., Low Price Edition, Cambridge University Press, 1996.
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P. Sykes, A Guide to Mechanism in Organic Chemistry, 6th Edn, Pearson.
R. T. Morrison and R. N. Boyd, Organic Chemistry.
R. O. C. Norman and J. M. Coxon, Principle of organic synthesis.
I. L. Finar, Organic Chemistry, Vol I, 6th Edn., Addison Wesley Longmann, London, 1998.
I. L. Finar, Organic Chemistry, Vol II, 5th Edn., ELBS, London, 1995.

Paper III

G. W. Castellan, Physical Chemistry, Narosa Publishing House, Calcutta, 1995.
Ira N. Levine, Physical Chemistry, PHI Learning Pvt. Ltd.
R. A. Alberty and R. J. Silbey, Physical Chemistry, John Wiley and Sons, Inc., New York, 1995.
G. K. Vemulapally, Physical Chemistry, Prentice-Hall of India Pvt. Ltd., New Delhi, 2006.
S. Glasstone, Text Book of Physical Chemistry, Macmillan and Company Ltd., London, 1951.
D. A. McQuarrie and J. D. Simon, Physical Chemistry: A Molecular Approach, Viva Books Private Limited.
H. Chatterjee, Physical Chemistry (Vol. I-III), Platinum
V. Kireev, Physical Chemistry, Mir Publishers, Moscow.
E. N. Yeremin, Fundamentals of Chemical Thermodynamics, Mir Publishers, Moscow.
P. C. Rakshit (Revised by S.C. Rakshit), Physical Chemistry, Sarat Book Distributers, Kolkata.
P. W. Atkins & Julio De Paula, Physical Chemistry, Oxford University Press, Oxford
S. N. Mukherjee, Introduction to Physical Chemistry, Art Union, Calcutta.
K.L. Kapoor, A Text Book of Physical Chemistry (Vol. 1 – 5), Macmillan India Limited, New Delhi.
S. Pahari, Physical Chemistry (Vol. 1 & 2), New Central Book Agency (P) Ltd.
Berry, Rice & Ross, Physical Chemistry, Oxford University Press.
K.L. Chugh & S. L. Agnish, A Text Book of Physical Chemistry (Vol 1 – 3), Kalyani Publishers.
K. J. Laidler, Chemical Kinetics, Pearson, New Delhi, 2014.
W. J. Moore, Physical Chemistry, Longman Green and Co. Ltd., 1953.
Pahari and Pahari, Problems on Physical Chemistry, New Central Book Agency (P) Ltd.
A. Ghoshal, Numerical Problems on Physical Chemistry, Books and Allied (P) Ltd.
T. Engle and P. Reid, Physical Chemistry, 3rd Edn, Pearson, 2014.

Paper IV (Practical)

G. Svehla, Vogels Qualitative Inorganic Analysis, 7th Edn, Dorling Kindersley (RS) 2006.

A. K. Nad, B. Mahapatra & A. Ghosal, An Advanced Course in Practical Chemistry, New Central, 2007.
Vogel's Text Book of Practical Organic Chemistry (5th Edn).
Mann and Saunders, Practical Organic Chemistry.
S. C. Das, Advanced Practical Chemistry

Paper V

R. L. Dutta and G. S. De, Inorganic Chemistry, Pt – I, 7th Edn, 2013, The New Book Stall, 2013.
R. L. Dutta, Inorganic Chemistry, Pt –II, 5th Edn, 2013, The New Book Stall, 2006.
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Paper VIII (Practical)

J. Mendham, R.C. Denney, J.D. Barnes, M. Thomas and B. Sivasankar, Vogel's Text Book on Quantitative Chemical Analysis, 6/e, Pearson
G. Shevla & B. Sivasankar, Vogel's Qualitative Inorganic Analysis, 7/e, Pearson
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Paper X

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