JSPM UNIVERSITY
न हि ज्ञानेन सदृशं

JSPM UNIVERSITY PUNE



SYLLABUS

RPET 2023

Research Program Entrance Test

Subject Concerned Syllabus

Chemistry

Physical Chemistry

1) **Chemical Kinetics** : order, molecularity, differential and integral rate laws, first- second- and third-order reactions, zero order reactions, reactions of half integral order, complexities in reaction kinetics reversible reactions, consecutive reactions, steady state approximation- elucidating reaction mechanisms, parallel (or side) reactions, autocatalysis, Arrhenius equation, unimolecular reactions, Collision theory, theory of absolute reaction rates, Eyring equation, enthalpy, entropy and free energy of activation, potential energy surface accompanying simple reactions, dependence of rate constants of ionic reactions on pressure or dielectric constant, primary and secondary salt effects, Enzyme catalysis, Michaelis-Menten mechanism, K_M and r_{max} from the Lineweaver-Burk and Eadie-Hoftsee methods, fast reactions, relaxation and flow techniques, oscillatory reactions.
2) **Thermodynamics** : Carnot cycle, first and second laws of thermodynamics, dependence of enthalpy, entropy and free energy on pressure or temperature, absolute entropy, third law of thermodynamics, Partial molar quantities, statistical thermodynamics, Maxwell-Boltzmann/ Fermi -Dirac/Bose-Einstein statistics, partition function, Thermodynamic parameters from partition functions, residual entropy, nonequilibriumthermodynamics, entropy production, Onsager's Reciprocal relationships.
3) **Surface-, Electro- chemistry and Materials Chemistry** : Adsorption, Freundlich and Langmuir adsorption isotherms, multilayer adsorption and BET theory, surface area determination , Temkin isotherm, adsorption in solution, surface excess,Gibbs adsorption equation, 2D gas law, phase rule and its applications, Electrochemical cells, half-cell reactions, Nernst equation, overvoltage, liquid junction potential, strong and weak electrolytes, Debye Huckel theory, principles underlying polymer chemistry, chain and branched polymers, determination of molecular weight (number and mass average) of polymers, introductory nanoscience, synthesis and characterization of nanomaterials.
4) **Elementary Quantum Chemistry and Chemical Bonding:** Bohr theory, quantization, uncertainty principle and wave particle duality, postulates of quantum mechanics, Schrodinger equation, Exactly solvable systems Particle in

1D, 2D and 3D box, degeneracy, quantum mechanical harmonic oscillator, Hydrogen atoms , radial function and spherical harmonics, shapes and representation of hydrogenic atomic orbitals, many electron atoms, SCF theory, Slater rules and periodicity, R-S coupling, Valence bond and Molecular orbital theory , H_2 molecule, equivalence of VBT and MOT, Homonuclear and Hetronuclear diatomic molecules, correlation diagrams, hybrid orbitals (sp, sp^2 and sp^3 hybridization), variational method, Huckel molecular orbital theory, approximations therein, mobile bond order, charge densities and free valence index , delocalization energy, aromaticity, Applications of Huckel theory.

5) **Nuclear and Radiation Chemistry**: nuclear dimensions, stability of nucleus, isotopes, isotones and isobars, nuclear forces, nuclear models(shell, liquid drop and Fermi gas models) , artificial radioactivity and nuclear reactions (spallation, fission, fusion etc.), alpha, beta and gamma decay, measurements of radiation, GM-, proportional- and scintillation- counters, isotopic dilution analysis, applications of radioisotopes, neutron activation analysis, hot atom chemistry, recoil energy, Szilard Chalmers reaction, radiation chemistry- dose and dose rate, Fricke and ceric sulfate dosimeters, biological effects of radiation, specific ionization, E_{max}, radiation absorption coefficient and interrelation therein,

   radiolysis of water

6) **Molecular Spectroscopy General principles**: FTIR, spectral line widths and spectral line intensities, selection rules in microwave and infrared spectroscopy , classification of molecules, determination of bond distances in diatomic and linear triatomic molecules, intensity profile in microwave spectra, infrared spectra, Morse potential, overtonesand combination and hot bands, polyatomic molecules, skeletal and normal vibrations, effect of isotopic substitution on microwave and infrared spectra, Classical and quantum theory of Raman effect, polarizability ellipsoid, Raman activity, Stokes and antistokes lines, vibrational Raman spectra, Combining IR and Raman data to elucidate structure/shape of molecules, effect of nuclear spin, Electronic spectra, Potential Energy curve, Born Oppenheimer Approximation, sequence and progression, Franck Condon principle, predissocation, dissociation energies from IR and electronic spectra, Fortrat parabolae, Solvent effects , bathochromic and hypsochromic shifts, oscillator strength, LASER, magnetic resonance spectroscopy, principles underlying NMR and ESRspectroscopy.

7) **Solid state Chemistry** :crystalline and amorphous solids, crystal structure types, unitcell, Miller indices, Bragg equation, Bravis lattices, defects in crystals, Frenkel and Schottky defects, Band theory of solids, molecular solids, phosphorescence and fluorescence.

8) **Symmetry and Group theory** :definition of group, multiplication tables, symmetry elements and symmetry operations, point groups, determination of point group, representations, reducible and irreducible representations, character tables, Use of character tables, SALC, Applications to chemical bonding and spectroscopy.

Inorganic Chemistry

1. **Structure and Bonding** : Atomic orbitals, electronic configuration of atoms (L-S coupling) and the periodic properties of elements, ionic radii, ionization potential, electron affinity, electronegativity, concept of hybridization. Molecular orbitals and electronic configuration of homonuclear and heteronuclear diatomic molecules. Shapes of polyatomic molecules. VSEPR theory. Symmetry elements and point groups for simple molecules. Bond lengths, bond angles, bond order and bond energies. Resonance. Types of chemical bond (weak and strong). Intermolecular forces. Types of solids, lattice energy.
2. **Acids and Bases** : Bronsted and Lewis acids and bases. pH and pKa, acid-base conceptin non-aqueous media, SHAB concept, Buffer solutions.
3. **Redox Reactions** : Oxidation numbers, Redox potentials, Electrochemical series, Redox indicators.
4. **Introductory Energetics and Dynamics of Chemical Reactions** : Law of conservation of energy. Energy and enthalpy of reactions. Entropy, free energy, relationship between free energy change and equilibrium. Rates of chemical reactions (first-and second- order reactions). Arrhenius equation and Concept of transition state. Mechanisms, including S_N1 and S_N2 reactions, electron transfer reactions, catalysis Colligative properties of solutions.
5. **Aspects of s, p, d, f Block Elements** : General characteristics of each block. Chemical principles involved in extraction and purification of common metals. Coordination chemistry, Structural aspects, isomerism, octahedral and tetrahedral crystal-field spliting of d-orbitals. CFSE, magnetism and colour of transition metal ions. Sandwich compounds metal carbonyls and metal clusters. Rare gas compounds, non- stoichiometric oxides. Radioactivity and transmutation of elements.
6. **Chemistry of Non-transition Elements** : General discussion on the properties of the non-transition elements, special features of individual elements, synthesis, properties and structure of their halides and oxides, polymorphism of carbon, phosphorus and sulphur. Synthesis, properties and structure of boranes, carboranes, borazines, silicates, carbides, silicones, phosphazenes,

sulphur, oxyacids of nitrogen, phophorus, sulphur and halogens. Interhalogens, pseudohalides and noble gas compounds.

7. **Chemistry of Transition Elements** : Coordination chemistry of transition metalions. Stability constants of complexes and their determination, stabilization of unusual oxidation states. Stereochemistry of coordination compounds. Ligand field theory, spliting of d-orbitals in low symmetry environments. Jahn-Teller effect, interpretation of electronic spectra including charge transfer spectra, spectrochemical series, nephelauxetic series. Dia-para-ferro and antiferromagentism, quenching of orbital angular moments, spin orbit coupling. Inorganic reaction mechanisms, substitution reactions, trans-effect and electron transfer reactions, photochemical reactions of chromium and ruthenium complexes. Fluxional molecules. Iso and heteropolyacids, metal clusters. Spin crossover in coordination compounds.
8. **Chemistry of Lanthanides and Acitindes** : Spectral and magnetic properties, use of lanthanide compounds as shift reagents.
9. **Organometallic Chemistry of Transition Elements** : Synthesis, structure and bonding,organometallic reagents in organic synthesis and in homogeneous catalytic reactions (hydrogenation, hydroformylationn, isomerisation and polymerisation), pi- metal complexes, activation of small molecules by coordination.
10. **Topics in Analytical Chemistry:** Adsorption, partition, exclusion, electrochromatography. Solvent extraction and ion exchange methods. Application of atomic and molecular absorption and emmision spectroscopy in quantitative analysis. Light scattering techniques including nephelometry and Raman spectroscopy. Electroanalytical techniques, voltametry, cyclic voltametry, polarography, amperometry, coulometry and conductometry. Ion-selective electrodes. Anodic stripping voltametry, TGA, DTA, DSC and on-line analysers.
11. **Bioiorganic Chemistry** : Molecular mechanism of ion transport across membranes, ionophores. Photosynthesis-PS-I, PS-II, nitrogen fixation, oxygen uptake proteins, cytochromes and ferrodoxions.

Organic Chemistry

1. IUPAC Nomenclature of Simple Organic and Inorganic Compounds.
2. **Concept of Chirality** : Recognition of symmetry elements and chiral structures, R-S nomenclature, diastereoisomerism in acyclic and cyclic-systems, E-Z isomerism. Conformational analysis of simple cyclic (chair and boat cyclohexanes) and acyclic systems, Interconverison of Fischer, Newman and Sawhorse projections.
3. **Common Organic Reactions and Mechanisms** : Reactive intermediates. Formation and stability of carbonium ions, carbenes, nitrenes, radicals and arynes. Nucleophilic, electrophilic, radical substitution, addition and elimination reactions. Familiar name reactions : Aldol, Perkin, Stobbe, Dieckmann condensations ; Hofmann, Schmidt, Lossen, Curtius, Beckmann and Fries rearrangements, Reimer-Tiemann, Reformatsky and Grignard reactions. Diels-Alder reaction, Claisen rearrangement, Friedel-Crafts reaction, Witting reaction. Routine functional group transformations and inter- convertions of simple functionalities. Hydroboration, Oppenauer oxidation, Clemmensen, Wolf-Kishner, Meerwein-Ponndorf Verley and Birch reductions.
4. Elementary principles and applications of electronic, vibrational, NMR, EPR, Mossbauerand mass spectral techniques to simple structural problems.
5. **Bioiorganic Chemistry** : Molecular mechanism of ion transport across membranes, ionophores.Photosynthesis-PS-I, PS-II, nitrogen fixation, oxygen uptake proteins, cytochromes and ferrodoxions.
6. **Aromaticity** : Huckel's rule and concept of aromaticity : annulenes and heteroannulenes,fullerenes. (C_{60})
7. **Stereochemistry and Conformational Analysis** : Newer methods of assymetric synthesis (including enzymatic and catalytic nexus), enantio-and diastereo selective synthesis. Effects of conformation on reactivity in acylic compounds and cyclohexanes.
8. **Selective Organic Name Reactions** : Favorskii reaction, Strok enamine reaction, Michael addition, Mannich reaction, Sharpless asymmetric expoxidation, ene reaction, Barton reaction, Hofmann Loffler-Freytag reaction, Shapiro reaction, Baeyer-Villiger reaction, Chichibabin reaction.
9. **Mechanisms of Organic Reactions** : Labelling and kinetic isotope effects, Hamett equation,(sigma-rho) relationship, non-classical carbonium ions, neighbouring group participation.
10. **Pericyclic Reactions** : Selection rules and stereochemistry of electrocyclic reactions, cycloaddition and sigmatrophic shifts, Sommelet-Hauser, Cope and

Claisen rearrangements.

11. **Heterocycles:** Synthesis and reactivity of furan, thiophene, pyrrole, pyridine, quinoline,isoquinoline and indole. Skraup synthesis, Fischer indole synthesis.
12. **Reagents in Organic Synthesis** : Use of following reagents in organic synthesis and fuctinal group transformations-Complex metal hydride. Gilman's reagent, lithium, dimethylcuprate, lithim, disopropylamide (LDA) dicyclohexylcarbodimide, 1, 3-dithiane (reactivity umpolung). Trimethy, silyl iodide, tri-n-butyltin hydride, Woodward and Prevost hydroxylation, osmium tetraoxide, DDQ, selenium dioxide, phase transfer catalysts, crown ethers and Merrifield resin. Peterson's synthesis, Wilkinson' catalyst, Baker's yeast.
13. **Chemistry of Natural Products** : Familiarity with methods of structure elucidation and biosynthesis of alkaloids, terpenoids, steroids, carbohydrates and proteins, Conformations of proteins and nucleic acids.
14. **Bioorganic Chemistry** : Elementary structure and function of biopolymers such as proteins and nucleic acids, Genetic code, Mechanism of enzyme action.
15. **Photochemistry** : Principles of energy transfer, cis-trans isomerization, Paterno-Buchi reaction,Norrish Type I and II reactions, photoreduction of ketones, di-pi-methane rearrangement, photochemistry of arenes.
16. **Spectroscopy:** Combined applications of mass, UV-VIS, IR and NMR spectroscopy for structural elucidation of compounds.

Analytical Chemistry

1. **Fundamentals of Analytical Chemistry, Sampling and Data Treatment:** Analytical process; units and concentration terms; sampling of solids, liquids and gases; sample preparation and preservation; errors and their classification; accuracy, precision, significant figures, mean, standard deviation and confidence limits; propagation of errors; rejection of data; Student t-test, F-test, correlation and linear regression; calibration curves, standard addition and internal standard methods; detection and quantitation limits.
2. **Chemical Equilibria and Classical Methods of Analysis:** Acid-base, redox, precipitation and complex-formation equilibria; buffers and pH calculations; solubility and solubility product; gravimetric analysis; principles, indicators, titration curves and applications of acid-base, redox, precipitation, complexometric and non-aqueous titrations.

3. **Separation, Extraction and Preconcentration Techniques:** Solvent extraction and distribution equilibria, multiple extraction, masking and stripping; ion-exchange methods; solid-phase extraction and solid-phase microextraction; co-precipitation; digestion, dry ashing and fusion; principles of sample clean-up and preconcentration.
4. **Chromatographic Methods:** Principles of chromatographic separation; adsorption and partition chromatography; paper chromatography and TLC; column efficiency, plate theory, rate theory, resolution and selectivity; gas chromatography and HPLC instrumentation, columns, stationary and mobile phases, injection systems and detectors; ion-exchange, size-exclusion and supercritical-fluid chromatography; qualitative and quantitative analysis; introduction to GC-MS and LC-MS.
5. **Electroanalytical Methods:** Electrode potentials and reference electrodes; potentiometry, pH measurement and ion-selective electrodes; conductometry; coulometry and amperometry; polarography; voltammetry including cyclic voltammetry, hydrodynamic voltammetry and anodic, cathodic and adsorptive stripping voltammetry; instrumentation, current-potential relationships and analytical applications.
6. **Molecular Spectroscopic Methods:** Beer-Lambert law, instrumentation and quantitative applications of UV-Visible spectrophotometry; derivative and multicomponent spectrophotometry; fluorescence and phosphorescence; IR and FTIR spectroscopy; Raman spectroscopy; basic principles and analytical applications of NMR and ESR/EPR spectroscopy; spectral interpretation and structure elucidation.
7. **Atomic and Elemental Analysis:** Atomic absorption and atomic emission spectroscopy; flame and graphite-furnace atomization; sources, monochromators and detectors; spectral and chemical interferences; calibration and standard-addition methods; ICP-OES and ICP-MS, sample introduction, plasma generation, mass analysers, interferences and trace-element analysis; introduction to X-ray fluorescence.
8. **Mass Spectrometry and Hyphenated Techniques:** Principles of mass spectrometry; ionization methods, mass analysers and detectors; molecular ion, fragmentation and isotope patterns; qualitative and quantitative applications; GC-MS, LC-MS and ICP-MS; selected-ion monitoring and basic spectral library matching.

9. **Thermal Methods of Analysis:** Principles, instrumentation and applications of thermogravimetric analysis (TGA), differential thermal analysis (DTA) and differential scanning calorimetry (DSC); factors affecting thermal curves; simultaneous thermal analysis and evolved-gas analysis; applications to inorganic, organic, polymeric and pharmaceutical materials.
10. **Structural and Surface Characterization:** Principles and analytical applications of X-ray diffraction; particle-size and surface-area measurements; basic principles and applications of optical microscopy, SEM and TEM; surface and materials characterization relevant to chemical analysis.
11. **Quality Assurance, Method Development and Validation:** Analytical method development; validation parameters including specificity/selectivity, linearity and range, accuracy, precision, repeatability, intermediate precision, robustness, detection limit and quantitation limit; calibration and system suitability; quality control samples, blanks, replicates and certified reference materials; basic concepts of GLP, laboratory safety and documentation; interpretation and reporting of analytical results.
12. **Applications of Analytical Chemistry:** Selection and application of appropriate analytical methods for pharmaceutical, environmental, food, water, industrial and materials samples; trace analysis, impurity profiling and elemental analysis; comparison of methods on the basis of sensitivity, selectivity, accuracy, precision and fitness for purpose.