Syllabus: Ph.D. Entrance Exam 2020

RESEARCH METHODOLOGY

Design of research experiments; definitions of various types of clinical trials; randomization; hypothesis testing; types of variables; type-1 and type-2 error in null hypothesis, probability and confidence interval, standard deviation and standard error; t-test, P-Value, ANOVA, manual and computer based methods of calculation of statistical significance; method and sources of literature survey; basics of bioinformatics, ethics of scientific experiments and publications; Plagiarism; Intellectual property rights; Good laboratory practice; Data archiving and management; Human and animal ethical committee: mandate, structure, & guidelines; Biosafety aspects for human and ecosystem in scientific experiments;

LIFE SCIENCES

Microscopic Techniques, Plasma Membrane Structure, Membrane Transporters; Cytoskeleton:Structure and Dynamics; Microtubules and Mitosis;Intracellular protein transport; Cell organelles, Cell Signaling pathways; Cell – Cell Adhesion and Communication; Cell Cycle; Mitosis, Meiosis, Role of Cyclins and Cyclin Dependent Kinases; Apoptosis and senescence; hallmarks of cancer cells. Genome organization in prokaryotes and eukaryotes, -Nuclear and Mitochondrial DNA, DNA Replication and repair, Transcription, RNA Processing, Translation, Gene Expression Regulation, gene silencing,coding and non-coding DNA, Mitochondrial inheritance, molecular cytogenetics, gene mapping, Mendalian genetics and determinants of inheritance, Animal models for human diseases, human genome project. Physiology and biochemistry of prokaryotes, soil microbiology, agriculturally important microorganisms, basics of rDNA technology. General and applied aspects of microbiology; Medical microbiology, antimicrobial resistance; Microbial evolution, taxonomy, and diversity; Microbial ecology; Bioremediation, bacterial metabolism, ultrastructure of bacteria, tools and techniques of a microbiology lab. Basics of innate and adaptive immunity, MHC structure, function and regulation, Concept of memory B and T cell generation, immunosuppression and immunomodulation, history of vaccination. Components of the Nervous System,Brain parts and endocrine regulation, Neuron and Glial Cells - DifferentTypes, Structure, Function. Synapse: Nerve Impulse, Neurotransmitters, Organization of Nervous System- CNS

PHYSICS

1. **Mathematical Methods of Physics**
   Dimensional analysis; Vector algebra and vector calculus; Linear algebra, matrices Fourier series, Fourier and Laplace transforms; Elementary ideas about tensors
2. **Classical Mechanics**
   Newton's laws; Two-body collisions, scattering in laboratory and centre-of-mass frames; Rigid body dynamics, moment of inertia tensor, non-inertial frames and pseudoforces;, Lagrangian and Hamiltonian formalisms and equations of motion; Theory of relativity
3. **Electromagnetic Theory**
   Electrostatics: Gauss' Law and its applications; Laplace and Poisson equations, boundary value problems; Magnetostatics: Biot-Savart law, Ampere's theorem, electromagnetic induction; Maxwell's equations in free space and linear isotropic media; Scalar and vector potentials; Electromagnetic waves in free space, dielectrics, and conductors; various Optical phenomena; Dynamics of charged particles in static and

uniform electromagnetic fields

4. Quantum Mechanics

Wave-particle duality; Schrodinger equations; particle-in-a-box, harmonic oscillator; Tunneling through a barrier; Motion in a central potential; Orbital angular momentum, Angular momentum algebra, spin; Addition of angular momenta; Hydrogen atom, spin-orbit coupling, Time- independent perturbation theory and applications; Time dependent perturbation theory and Fermi's Golden Rule; Selection rules; Semi-classical theory of radiation

5. Statistical Physics

Classical and quantum statistics, ideal Fermi and Bose gases; Principle of detailed balance; Blackbody radiation and Planck's distribution law; Bose-Einstein condensation

6. Electronics

Semiconductor device physics, diodes, junctions, transistors, field effect devices, homo and heterojunction devices, device structure, device characteristics, frequency dependence and applications; Optoelectronic devices, High-frequency devices, Operational amplifiers and their applications; Digital techniques and applications, A/D and D/A converters

7. Atomic & Molecular Physics

Quantum states of an electron in an atom; Electron spin; Stern-Gerlach experiment; Spectrum of Hydrogen, helium and alkali atoms; Relativistic corrections for energy levels of hydrogen; Hyperfine structure and isotopic shift; width of spectral lines; LS & JJ coupling; Zeeman, Paschen Back & Stark effect; X-ray spectroscopy; Electron spin resonance, Nuclear magnetic resonance; Physics of Lasers

8. Condensed Matter Physics

Bravais lattices; Reciprocal lattice, diffraction and the structure factor; Bonding of solids; Elastic properties, phonons, lattice specific heat; Free electron theory and electronic specific heat; Relaxation phenomena; Drude model of electrical and thermal conductivity; Hall effect and thermoelectric power; Types of magnetism ; Electron motion in a periodic potential, band theory solids; Superconductivity, type – I and type - II superconductors, Josephson junctions, BCS theory

9. Nuclear and Particle Physics

Basic nuclear properties: size, shape, charge distribution, spin and parity; Binding energy, semi-empirical mass formula; Liquid drop model; Fission and fusion; Nature of the nuclear force, form of nucleon-nucleon potential; Elementary ideas of alpha, beta and gamma decays and their selection rules; Nuclear reactions, reaction mechanisms, compound nuclei and direct reactions; Elementary particles

10. Physics of Nanomaterials:

Introduction – Nanoscale; Nanomaterials: Methods for synthesis of nanomaterials, Properties of nanomaterials – Electrical, Magnetic, Optical, Mechanical, Characterization techniques – X ray Diffraction (XRD), Electron Microscopies, Nanostructures; Carbon nanotubes Characteristics and applications

CHEMISTRY

1. Chemical periodicity
2. Structure and bonding in homo-and heteronuclear molecules, including shapes of molecules (VSEPR Theory).
3. Concepts of acids and bases, Hard-Soft acid base concept, Non-aqueous solvents.
4. Main group elements and their compounds: Allotropy, synthesis, structure and bonding, industrial importance of the compounds.
5. Transition elements and coordination compounds: structure, bonding theories, spectral

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and magnetic properties, reaction mechanisms.

6. Inner transition elements: spectral and magnetic properties, redox chemistry, analytical applications.
7. Organometallic compounds: synthesis, bonding and structure, and reactivity. Organometallics in homogeneous catalysis.
8. Analytical chemistry -separation, spectroscopic, electro-and thermoanalytical methods.
9. Bioinorganic chemistry: photosystems, porphyrins, metalloenzymes, oxygen transport, electron-transfer reactions; nitrogen fixation, metal complexes in medicine.
10. Characterisation of inorganic compounds by IR, Raman, NMR, EPR, Mössbauer, UV-vis, NQR, MS, electron spectroscopy and microscopic techniques.
11. Nuclear chemistry: nuclear reactions, fission and fusion, radio-analytical techniques and activation analysis.
12. Basic principles of quantum mechanics: Postulates; operator algebra; exactly-solvable systems:particle-in-a-box, harmonic oscillator and the hydrogen atom, including shapes of atomic orbitals; orbital and spin angular momenta; tunneling.
13. Chemical bonding in diatomics; elementary concepts of MO and VB theories; Huckel theory for conjugated π-electron systems.
14. Molecular spectroscopy: Rotational and vibrational spectra of diatomic molecules; electronic spectra; IR and Raman activities –selection rules; basic principles of magnetic resonance.
15. Chemical thermodynamics: Laws, state and path functions and their applications; thermodynamic description of various types of processes; Maxwell's relations; spontaneity and equilibria; temperature and pressure dependence of thermodynamic quantities; LeChatelier principle; elementary description of phase transitions; phase equilibria and phase rule; thermodynamics of ideal and non-ideal gases, and solutions.
16. Statistical thermodynamics: Boltzmann distribution; kinetic theory of gases; partition functions and their relation to thermodynamic quantities –calculations for model systems.
17. Electrochemistry: Nernst equation, redox systems, electrochemical cells; Debye-Huckel theory; electrolytic conductance –Kohlrausch's law and its applications; ionic equilibria; conductometric and potentiometric titrations.
18. Chemical kinetics: Empirical rate laws and temperature dependence; complex reactions; steady state approximation; determination of reaction mechanisms; collision and transition state theories of rate constants; unimolecular reactions; enzyme kinetics; salt effects; homogeneous catalysis; photochemical reactions.
19. Colloids and surfaces: Stability and properties of colloids; isotherms and surface area; heterogeneous catalysis.
20. Solid state: Crystal structures; Bragg's law and applications; band structure of solids.
21. Polymer chemistry: Molar masses; kinetics of polymerization.
22. IUPAC nomenclature of organic molecules including regio-and stereoisomers.
23. Principles of stereochemistry: Configurational and conformational isomerism in acyclic and cyclic compounds; stereogenicity, stereoselectivity, enantioselectivity, diastereoselectivity and asymmetric induction.
24. Aromaticity: Benzenoid and non-benzenoid compounds–generation and reactions.
25. Organic reactive intermediates: Generation, stability and reactivity of carbocations, carbanions, free radicals, carbenes, benzynes and nitrenes.
26. Organic reaction mechanisms involving addition, elimination and substitution reactions with electrophilic, nucleophilic or radical species. Determination of reaction pathways.
27. Common named reactions and rearrangements –applications in organic synthesis.
28. Organic transformations and reagents: Functional group interconversion including oxidations and reductions; common catalysts and reagents (organic, inorganic,

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organometallic and enzymatic). Chemo, regio and stereo-selective transformations.

29. Concepts in organic synthesis: Retrosynthesis, disconnection, synthons, linear and convergent synthesis, umpolung of reactivity and protecting groups.
30. Asymmetric synthesis: Chiral auxiliaries, methods of asymmetric induction –substrate, reagent and catalyst controlled reactions; determination of enantiomeric and diastereomeric excess; enantio-discrimination. Resolution –optical and kinetic.
31. Pericyclic reactions –electrocyclisation, cycloaddition, sigmatropic rearrangements and other related concerted reactions. Principles and applications of photochemical reactions in organic chemistry.
32. Synthesis and reactivity of common heterocyclic compounds containing one or two heteroatoms (O, N, S).
33. Chemistry of natural products: Carbohydrates, proteins and peptides, fatty acids, nucleic acids, terpenes, steroids and alkaloids. Biogenesis of terpenoids and alkaloids.
34. Structure determination of organic compounds by IR, UV-Vis, ^{1}H& ^{13}C NMR and Mass spectroscopic techniques.

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