Ahmedabad University

PhD ENTRANCE EXAMINATION SYLLABUS

APPLIED CHEMISTRY

1. Concepts of acids and bases, Hard-Soft acid base concept, Non-aqueous solvents.
2. Analytical chemistry- separation, spectroscopic, electro- and thermoanalytical methods.
3. Nuclear chemistry: nuclear reactions, fission and fusion, radio-analytical techniques and activation analysis.
4. Chemical thermodynamics: Laws, state and path functions and their applications; thermodynamic description of various types of processes; Le Chatelier principle; elementary description of phase transitions; phase equilibria and phase rule; thermodynamics of ideal and non-ideal gases, and solutions.
5. Electrochemistry: Nernst equation, redox systems, electrochemical cells; Debye- Huckel theory; electrolytic conductance – Kohlrausch's law and its applications; ionic equilibria; conductometric and potentiometric titrations.
6. 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.
7. Colloids and surfaces: Stability and properties of colloids; isotherms and surface area; heterogeneous catalysis.
8. Polymer chemistry: Molar masses; kinetics of polymerization.
9. Data analysis: Mean and standard deviation; absolute and relative errors; linear regression; covariance and correlation coefficient.
10. IUPAC nomenclature of organic molecules including regio- and stereoisomers.
11. Principles of stereochemistry:
12. Aromaticity: Benzenoid and non-benzenoid compounds – generation and reactions.
13. Common named reactions and rearrangements – applications in organic synthesis.
14. Concepts in organic synthesis: Retrosynthesis, disconnection, synthons, linear and convergent synthesis, umpolung of reactivity and protecting groups.
15. Structure determination of organic compounds by IR, UV-Vis, 1H& 13C NMR and Mass spectroscopic techniques.

Interdisciplinary topics

1. Chemistry in nanoscience and technology.
2. Catalysis and green chemistry.
3. Medicinal chemistry.
4. Supramolecular chemistry.
5. Environmental chemistry.

COMPUTER SCIENCE AND ENGINEERING

THERE ARE THREE SECTIONS:

Section A: Mathematical Fundamentals
Section B: Electronics and Communication Engineering
Section C: Computer Science and Engineering

Notes:

(1) Section A is compulsory with 30% weight.

(2) Section B and Section C which carries 70% weight. It is advisable that a student select from one of these sections which is nearest to the student's area of interest for answering the question.

(3) After selecting one of two options, if a student wishes to answer questions from the other section, s/he may do so.

SECTION A: MATHEMATICAL FUNDAMENTALS

Linear Algebra: Scalars, Vectors and Matrices, Vector space, Matrix operations, Rank of a matrix, linear transformations, Linear Independence and Dependence, System of linear equations, Eigenvalues and Eigenvectors.

Calculus: Limit, continuity, differentiation, integration

Differential Equations: First order equations (linear and nonlinear), higher order linear differential equations, Cauchy's and Euler's equations, methods of solution using variation of parameters, complementary function and particular integral, partial differential equations, variable separable method, initial and boundary value problems.

Probability and Statistics: Introduction to probability, theorems of total and compound probability, Bayes theorem, random variables, probability distributions and density functions, mathematical expectation and moments, binomial Poisson and normal distributions and their properties, correlation and regression, method of least squares.

Discrete Mathematics: Sets, functions, relations, counting, generating functions, recurrence relations and their solutions; algorithmic complexity, growth of functions and asymptotic notations.

SECTION B: ELECTRONICS AND COMMUNICATION ENGINEERING

Signals and Systems

Time and frequency domain analysis of linear circuits: RL, RC and RLC circuits, solution of network equations using Laplace transform. Linear 2-port network parameters, wye-delta transformation.

Continuous-time signals: Fourier series and Fourier transform, sampling theorem and applications.

Discrete-time signals: DTFT, DFT, z-transform, discrete-time processing of continuous-time signals. LTI systems: definition and properties, causality, stability, impulse response, convolution, poles and zeroes, frequency response, group delay, phase delay.

Communication:
Random processes: autocorrelation and power spectral density, properties of white noise, filtering of random signals through LTI systems.
Analog communications: amplitude modulation and demodulation, angle modulation and demodulation, spectra of AM and FM, superheterodyne receivers.

Information theory: entropy, mutual information and channel capacity theorem.

Digital communications: PCM, DPCM, digital modulation schemes (ASK, PSK, FSK, QAM), bandwidth, inter-symbol interference, MAP, ML detection, matched filter receiver, SNR and BER. Fundamentals of error correction, Hamming codes, CRC.

Embedded Systems and Digital VLSI:
Digital Logic: Data representation and coding; Noise Margins; Basic logic operations, truth-tables and logic gates; Number Systems and Codes: Positional number system; Binary; octal and hexadecimal number systems; Methods of base conversions; Binary; octal and hexadecimal arithmetic; Representation of signed numbers; Fixed-point numbers; Binary coded decimal codes; Gray codes; Error detection and correction codes - parity check codes and Hamming codes; Boolean Algebra & Simplification of Boolean Algebra: Basic postulates and fundamental theorems of Boolean algebra; Standard representation of logic functions; The Map Method; SOP and POS forms; Simplification of Boolean functions using K-map and Quine-McCluskey tabular methods; Digital Combinational-Logic modules: Decoders; encoders; multiplexers; demultiplexers, combinational shifters, and their applications; Parity circuits and comparators; Arithmetic modules- adder; sub-tractor, basic multiplier, ALU. Basic sequencing elements - latches and flip-flops: SR-latch; D-latch; D flip-flop; JK flip-flop; T flip-flop; Definitions of (synchronous) Moore and Mealy Finite State Machines (FSM) – state diagram, state table, state assignment; Analysis and implementation of FSM using D flip-flops, JK flip-flops and T flip-flops; Design examples of FSM; Various Registers - and Counters; Application examples. Verilog Hardware Description Language (HDL): Types of modelling: Gate-level modelling, Data-flow modelling; Behavioural modelling; Structural modelling; Basic constructs and syntax of Verilog language, related to hierarchical and modular modelling; Concept of test-bench and incorporating delays in test-bench; Verilog implementation of combinational circuits/modules. Verilog implementation of sequencing elements (latch and flip-flops) using behavioural modelling; Verilog implementation of sequential-logic circuits and RTL structures.

Computer Organization: Architecture of micro-computer/Central Processing Unit (CPU); Concept of control bus, address bus and data bus. Concept of Instruction Set Architecture. Understanding the building blocks of micro-computer: Data memory, Instruction Memory, Register Set, Address decoding, Arithmetic-logic Unit (ALU), timing pulse generator, Program Counter (PC), Stack Memory and stack pointers, I/O registers, control unit, etc. Design of control unit: Hardwired Control (MUX based and FSM based), Microprogrammed Control (ROM based); Instruction Set Architecture (ISA): Basics of RISC and CISC Architectures; Basics of Harvard and von-Neumann Architectures; Instruction format; Addressing Modes; Instruction Set for an example microprocessor (8085) covering these category of instructions: Data Transfer; Arithmetic; Logical; Branching; Subroutine; Stack; Basic I/O and Interrupt; Assembly language programming. I/O and Memory Organization: Memory hierarchies and organization; Magnetic disk, ROM, SRAM, DRAM, Cache, associative memories, cache replacement policies; I/O interfaces; Memory and I/O addressing; Basics of Pipelining: Arithmetic Pipeline; Instruction Pipeline; Pipeline Hazards; Basic Flynn's taxonomy; Basics of parallel processing and vector processing; Fundamentals of Embedded System Design: Microcontroller (AVR / ATmega32) architecture (including: timers, interrupts, communication modules: I2C, SPI, UART, etc), programming (Assembly and EmbeddedC), Interfacing of basic sensors and actuators;

Digital VLSI: Trends in VLSI/Semiconductor industry, Moore's scaling; Fundamentals of semiconductor devices: PN, MS, BJT; Devices inherent in the MOSFET: Drain-Body and Source-Body PN junctions, Metal-semiconductor contacts, MOS Capacitor; IV characteristics of P-channel and N-channel planar MOSFETs; Non-ideal effects; Basic steps of CMOS fabrication process/technology; Static CMOS inverter and VTC characteristics; Resistive Load NMOS inverter and Pseudo NMOS inverter and VTC characteristics; Design and transistor sizing of standard gates (NAND, NOR, EXOR, tri-state INV) and compound gates; RC modelling and Elmore delay analysis of gates (pattern dependent delay analysis); Sutherland's logical effort method of delay estimation and sizing of cascaded paths/gates; Static and dynamic Power of gates; Euler Diagram/Paths for layout of gates, stick diagrams, Lambda rules (DRC) and layouts of gates; Pass-transistor tree based logic gates (and similar other logic styles – CPL, transmission gates, DPL, etc); Pseudo-NMOS logic; CVLS logic; Dynamic logic (domino, NP domino, Zipper);

SECTION C: COMPUTER SCIENCE AND ENGINEERING

Programming and Data Structures

Programming in C. Recursion. Arrays, stacks, queues, linked lists, trees, binary search trees, binary heaps, graphs.

Algorithms

Searching, sorting, hashing. Asymptotic worst case time and space complexity. Algorithm design techniques: greedy, dynamic programming and divide-and-conquer. Graph search, minimum spanning trees, and shortest paths.

Theory of Computation

Regular expressions and finite automata. Context-free grammars and push-down automata. Regular and context-free languages, pumping lemma. Turing machines and undecidability.

Operating System

Memory hierarchy: cache, main memory and secondary storage; I/O interface (interrupt and DMA mode). Processes, threads, inter-process communication, concurrency and synchronization. Deadlock. CPU scheduling. Memory management and virtual memory. File systems.

Computer Networks

Concept of layering. LAN, Ethernet. Flow and error control techniques, switching. IPv4 and IPv6, routers, interdomain and intradomain routing algorithms. TCP/UDP and sockets, congestion control. Application layer protocols, e.g., DNS, SMTP, POP, FTP, HTTP. Basics of wireless networks, Wi-Fi. Network security: authentication, basics of public key and private key cryptography, digital signatures and certificates, firewalls.

Databases

ER-model. Relational model: relational algebra, tuple calculus, SQL. Integrity constraints, normal forms. File organization, indexing (e.g., B and B+ trees). Transactions and concurrency control

MECHANICAL ENGINEERING

Notes:

(1) Section A is Compulsory.

(2) From Sections B-E, students may attempt as many questions from each sections. However, it is more likely that student would attempt all questions from one section which is nearest to student's area of interest.

SECTION A: ENGINEERING MATHEMATICS

Linear Algebra: Matrix, linear equations, eigenvalues and eigenvectors.
Calculus: Functions of single variable, limit, continuity and differentiability, Taylor series (in one and two variables, mean value theorems, indeterminate forms; evaluation of definite and improper integrals; double and triple integrals; partial derivatives, total derivative,), maxima and minima, applications of Gauss, Stokes and Green's theorems, Fourier series; gradient, divergence and curl, vector identities, directional derivatives, line, surface and volume integrals.
Differential equations: First order equations (linear and nonlinear); higher order linear differential equations with constant coefficients; Euler-Cauchy equation; initial and boundary value problems; Laplace transforms; solutions of heat, wave and Laplace's equations.
Complex variables: Analytic functions; Cauchy-Riemann equations; Cauchy's integral theorem and integral formula; Taylor and Laurent series.
Probability and Statistics: Definitions of probability, sampling theorems, conditional probability; mean, median, mode and standard deviation; random variables, binomial, Poisson and normal distributions.
Numerical Methods: Numerical solutions of linear and non-linear algebraic equations; integration by trapezoidal and Simpson's rules; single and multi-step methods for differential equations.

SECTION B: APPLIED MECHANICS AND DESIGN

Engineering Mechanics: Free-body diagrams and equilibrium; trusses and frames; virtual work; kinematics and dynamics of rigid bodies in plane motion; friction and its applications including rolling friction, belt-pulley, brakes, clutches, screw jack, wedge, vehicles, etc.; Lagrange's equation, impulse and momentum (linear and angular) and energy formulations;
Mechanics of Materials: Stress and strain, elastic constants, Poisson's ratio; Mohr's circle for plane stress and plane strain; thin cylinders; shear force and bending moment diagrams; bending and shear stresses; concept of shear centre; deflection of beams; torsion of circular shafts; Euler's theory of columns; energy methods; thermal stresses; strain gauges and rosettes; testing of materials with universal testing machine; testing of hardness and impact strength.
Theory of Machines: Mechanism and its inversions, Displacement, velocity and acceleration analysis of planar mechanisms; dynamic analysis of linkages; cams; gears and gear trains; flywheels and governors; balancing of reciprocating and rotating masses; gyroscope.
Vibrations: Free and forced vibration of single degree of freedom systems, effect of damping; vibration isolation; resonance; critical speeds of shafts. Machine Design: Design for static and dynamic loading; failure theories; fatigue strength and the S-N diagram; principles of the design of machine elements such as bolted, riveted and welded joints; shafts, gears, rolling and sliding contact bearings, brakes and clutches, springs.

SECTION C: FLUID MECHANICS

Fluid Mechanics: Fluid properties; fluid statics, forces on submerged bodies, stability of floating bodies; control-volume analysis of mass, momentum and energy; fluid acceleration; differential equations of continuity and momentum; Bernoulli's equation; dimensional analysis; viscous flow of incompressible fluids, boundary layer, elementary turbulent flow, flow through pipes, head losses in pipes, bends and fittings; basics of compressible fluid flow.
Heat-Transfer: Modes of heat transfer; one dimensional heat conduction, resistance concept and electrical analogy, heat transfer through fins; unsteady heat conduction, lumped parameter system, Heisler's charts; thermal boundary layer, dimensionless parameters in free and forced convective heat transfer, heat transfer correlations for flow over flat plates and through pipes, effect of turbulence; heat exchanger performance, LMTD and NTU methods; radiative heat transfer, Stefan- Boltzmann law, Wien's displacement law, black and grey surfaces, view factors, radiation network analysis.

SECTION D: THERMAL SCIENCES

Thermodynamics: Thermodynamic systems and processes; properties of pure substances, behavior of ideal and real gases; zeroth and first laws of thermodynamics, calculation of work and heat in various processes; second law of thermodynamics; thermodynamic property charts and tables, availability and irreversibility; thermodynamic relations. Applications: Power Engineering: Air and gas compressors; vapour and gas power cycles, concepts of regeneration and reheat. I.C. Engines: Air-standard Otto, Diesel and dual cycles.
Refrigeration and air-conditioning: Vapour and gas refrigeration and heat pump cycles; properties of moist air, psychrometric chart, basic psychrometric processes. Turbomachinery: Impulse and reaction principles, velocity diagrams, Pelton-wheel, Francis and Kaplan turbines; steam and gas turbines.

SECTION E: MATERIALS, MANUFACTURING AND INDUSTRIAL ENGINEERING

Engineering Materials: Structure and properties of engineering materials, phase diagrams, heat treatment, stress-strain diagrams for engineering materials.
Casting, Forming and Joining Processes: Different types of castings, design of patterns, moulds and cores; solidification and cooling; riser and gating design. Plastic deformation and yield criteria; fundamentals of hot and cold working processes; load estimation for bulk (forging, rolling, extrusion, drawing) and sheet (shearing, deep drawing, bending) metal forming processes; principles of powder metallurgy. Principles of welding, brazing, soldering and adhesive bonding.
Machining and Machine Tool Operations: Mechanics of machining; basic machine tools; single and multi-point cutting tools, tool geometry and materials, tool life and wear; economics of machining; principles of non-traditional machining processes; principles of work holding, jigs and fixtures; abrasive machining processes; NC/CNC machines and CNC programming.
Metrology and Inspection: Limits, fits and tolerances; linear and angular measurements; comparators; interferometry; form and finish measurement; alignment and testing methods; tolerance analysis in manufacturing and assembly; concepts of coordinate-measuring machine (CMM).
Computer Integrated Manufacturing: Basic concepts of CAD/CAM and their integration tools; additive manufacturing.
Production Planning and Control: Forecasting models, aggregate production planning, scheduling, materials requirement planning; lean manufacturing.
Inventory Control: Deterministic models; safety stock inventory control systems.
Operations Research: Linear programming, simplex method, transportation, assignment, network flow models, simple queuing models, PERT and CPM.

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CHEMICAL ENGINEERING

Chemical Reaction Engineering
Design of mixed flow and plug flow reactors, single and multiple reactions, non-ideal flow and models for non-ideal reactors, kinetics of heterogeneous reactions, effectiveness factor.

Fluid Mechanics
Laminar and turbulent flow in pipes and closed channels, flow past immersed bodies, agitation and mixing, Bernoulli equation for potential flow and flow with friction, pump work in Bernoulli Flow, pumps, compressors

Heat Transfer
Heat transfer by Conduction (steady and unsteady state), Extended fins, natural and forced convection inside and outside pipes, radiation, boiling, condensation, evaporation, heat exchangers

Mass Transfer
Diffusion, Interphase mass transfer, Mass transfer coefficient, vapor-liquid equilibria in Distillation, absorption, Liquid-liquid extraction, leaching, drying and adsorption

Thermodynamics
First law, second law, entropy, carnot cycle, rankine cycle, Equations of state, phase equilibria, Maxwell's relations, Gibbs- Duhem equation, vapor-liquid equilibria for binary and multicomponent systems

Mechanical Operations
Filtration, classification, crushing and grinding equipment like ball mills, crushers, cyclone seperators

Process Control
Open and closed loop systems, Response of first and second order systems, Laplace transforms, P, PI, PID control, Process measurements like temperature, pressure, flow and level measurements

Process Design Economics
Cost estimation and its methods, Depreciation and methods to estimate depreciation, feasibility analysis, Net worth, Return on Investment, NPV

Transport Phenomena
Velocity distribution in circular tube, flat plate, falling film for laminar flow, velocity distribution in a pipe and channel for turbulent flow, expression for pressure drop across a packed bed, temperature distribution across a heated wire, temperature distribution due to free and forced convection, concentration distribution across a catalyst particle for homogeneous reaction, heterogeneous reaction

APPLIED PHYSICS

Introduction to Solid State Physics

Crystalline solids, unit cells and direct lattice, two and three dimensional Bravais lattices, closed packed structures. Interaction of X-rays with matter, absorption of X-rays. The reciprocal lattice and its applications to diffraction techniques. The Laue, powder and rotating crystal methods, crystal structure factor and intensity of diffraction maxima, defects, line defects and planer (stacking) faults. The role of dislocations in plastic deformation and crystal growth. The observation of imperfections in crystals, X-ray and electron microscopic techniques. Electrons in a periodic lattice: Bloch theorem, band theory, classification of solids, effective mass. Phase diagrams.

Physics of Semiconductor Devices

Energy Band and Charge Carriers: Energy bands in semiconductors, Types of semiconductors, Charge carriers, Intrinsic and extrinsic materials. Carrier concentration: Fermi Level, Electron and hole concentration equilibrium, Temperature dependence of carrier concentration, Compensation and charge neutrality. Conductivity and mobility, Effect of temperature, Doping and high electric field. Optical Photoconductive Junctions: p-n junction and contact potential, Fermi levels, Space charge, Reverse and Forward bias, Zener and Avalanche breakdown. Capacitance of p-n junction, Schottky barriers; Schottky barrier height, C-V characteristics, current flow across Schottky barrier: thermionic emission, Rectifying contact and Ohmic contact. LED: Radiative transition, Emission spectra, and LED materials, Solar cell and photodetectors, power conversion efficiency, Fill factor, Equivalent circuit, Voc, Isc and Load resistance, Spectral response.

Fundamental of Nanomaterials

Introduction to Nanomaterials, Definition of Nano, Atomic Structure and atomic size, significance of nano material over micro/macro, size dependent properties. Importance of surface at Nanoscale, Significance of Particle shape and Size in Nanomaterials, Surface to Volume Ratio, Particle orientation. Atomic structure: Electron orbits, The Bohr atom; Quantum Structure: 2D (Quantum well), 1D (Quantum Wires), 0D (Quantum Dots); Quantum mechanics: Schrodinger equation (steady state form), Particle in a box. The Hydrogen molecule; Molecular Spectra: Rotational, Vibration Levels and Electronic, Raman Spectrum; Size dependent physical, chemical, optical and magnetic properties.

Electromagnetic Theory

Displacement current, Maxwell's equations; Boundary conditions on the fields at interfaces, Vector and scalar potentials, Electromagnetic energy and momentum; Conservation laws, Inhomogeneous wave equation and Green's function solution. Electromagnetic wave equation, Solution and propagation of monochromatic waves in nonconducting media, Polarization and energy density, Reflection and transmission at oblique incidence, Waves in conducting media, Wave guides, TE, TM and TEM waves in rectangular wave guide.

Electronics

Differential amplifier - circuit configurations, dual input, balanced output differential amplifier, DC analysis , AC analysis, inverting and non-inverting inputs CMRR , constant current bias level translator. Block diagram of a typical Op-Amp-analysis. Open loop configuration inverting and non-inverting amplifiers. Op-amp with negative feedback. Op-amp input offset voltage - input bias current - input offset current, total output offset voltage, CMRR frequency response. DC and AC amplifier summing scaling and averaging amplifiers instrumentation amplifier, integrator and differentiator, Voltage regulators - fixed regulators - adjustable voltage regulators switching regulators.

Mathematical Physics

Definitions and types of matrices, Solution of linear algebraic equations, Eigen values and Eigen vectors; Functions of matrices, Linear Differential equation of first order, Linear differential equations with constant coefficient, Differential Equations and Special Functions, Beta and Gamma functions, Second ordered linear differential equations with variable coefficients, complex analysis.

Quantum Mechanics

Empirical basis, de-Broglie hypothesis of matter waves, Heisenberg's uncertainty relation, Schrödingers wave equation, Physical interpretation and conditions on wave function; Eigenvalues and Eigen-functions, Particle in a square-well potential, Tunneling through a barrier, Harmonic oscillator, Schrödinger equation for spherically symmetric potentials, Angular momentum operator, electron spin, Zeeman effect.