Syllabus
3 - Year Integrated Ph.D. Entrance Test in Industrial Chemistry

NOTE: Equal weightage shall be given to all units

1. UNIT OPRATIONS

- **DISTILLATION:** Introduction, batch and continuous distillation, Mecabe Thiele Method, reflux ratio, azeotropic, steam, and extractive distillation. Equipment of distillation - plate columns and packed columns
- **ABSORPTION:** Introduction, liquid gas equilibrium, selection criteria for solvent, minimum gas liquid ration, type of packing. Equipment – packed columns, spray columns, bubble columns, packed bubble columns, mechanically agitated contactors.
- **EVAPORATION:** Introduction, equipment for evaporation – short tube evaporator, forced circulation evaporator, falling film evaporators, agitated film evaporators
- **CRYSTALLISATION:** Introduction, Solubility, Super saturation, Nucleation, Crystal growth. Equipment – tank crystalliser, agitated crystalliser, evaporator crystalliser, draft tube crystalliser.
- **FILTRATION:** Introduction, filter media and filter aids, Equipment – plate and frame filter press, etch filter, rotatory drum filter, sparkle filter, candle filter, bag filter, and centrifuge.
- **MIXING AND DRYING:** Theory of mixing, solid – solid, solid – liquid, liquid – liquid mixing equipment. Introduction of drying, free moisture, bound moisture, drying curve, equipment – tray dryer, rotary dryer, flash dryer and spray dryer.

2. TRANSFER OPERATIONS

- **MOMENTUM TRANSFER OPERATIONS:** Introduction of fluid mechanics: Fluid statics, Pascal's law, manometers, velocity gradient and rate of shear. Types of fluids, boundary layer concept, laminar and turbulent flow boundary layer separation.
  Fluid dynamics: Continuity equation, Euler equation, Bernoulli's equation, types of pumps: centrifugal and positive displacement pumps, compressors, fan and blower.
- **HEAT TRANSFER OPERATIONS:** Basic Principle: Fourier's law of conduction, heat conduction through plane walls, hollow cylinder and composite walls, heat transfer coefficient, forced and free convection, heat transfer by radiation: black body
- **HEAT TRANSFER APPLICATIONS:** Heat exchanger: various types, heat exchanger mean temperature difference, heat exchanger effectiveness, number of transfer units and design of heat exchanger. Heat transfer in boiling and condensation.
- **MASS TRANSFER OPERATIONS:** Species transfer, definition of concentrations, velocities and fluxes in multi-species system. Fick's law of diffusion, diffusion of species through stagnant species, Fick's 2nd law of diffusion.

3. CHEMICAL REACTION ENGINEERING

- Introduction, Rate of reaction, Elementary and Non – elementary reactions, molecularity and order of reaction, mechanism of reaction, temperature dependency from thermodynamics, Arrhenius and collision theories.
- **CHEMICAL REACTOR ANALYSIS:** Integral and differential methods for analyzing kinetic data, Interpretation of constant volume batch reactor data for zero, first, second and third order reactions,

Half life period, Auto catalytic reaction, Interpretation of variable volume batch reactor data for zero, first and second order reactions, enzyme catalyzed reactions.

- **INTRODUCTION TO REACTOR DESIGN:** Industrial reactors , Space time and Space velocity. Design of single ideal reactor – Batch, CSTR, PFR using graphical procedure. Multiple reactor system and optimum reactor size, Recycle reactors, Temperature and Pressure effects, Optimum temperature progression in a chemical reaction, Adiabatic and Non adiabatic reaction conditions and conversion.
- **MULTIPLE REACTION SYSTEM AND DESIGN:** Multiple reactions: Independent, Parallel and Series reactions, Instantaneous and over all fractional yield, Choice of reactors for simple and complex reactions and multiple reactor system, Introduction to thermal stability of reactors, Product distribution in multiple reaction system, temperature dependence and vessel size for maximum production.

4. CATALYSIS AND CORROSION

- **CATALYSIS:** Principles of catalysis, catalysis sites, yield, selectivity and introduction to industrial catalysis. Relationship between reactivity and the structure and composition of surfaces in the Atomic scales, static technique: LEED, AES, and transport technique.
- **CORROSION:** Introduction, dry or chemical corrosion, wet or electrochemical corrosion, mechanism Of corrosion, galvanic corrosion, concentration cell corrosion, passivity, pitting corrosion, intergranular corrosion, waterline corrosion, stress corrosion, galvanic series, Factors influencing corrosion, corrosion control (protection against corrosion)

5. PETROCHEMICALS & LUBRICANTS

- **PETROCHEMICALS:** Constituents of Petroleum, processing or refining, petrochemicals, feedstocks, Petrochemicals from methane, ethylene, propylene, butylenes and cyclic ring. Manufacture of petrochemicals by chemical conversion.
- **LUBRICANTS:** Introduction, surface energy, absorption, laws of friction, theories of wear, mechanism of lubrication, classification of Lubricants, lubricating emulsions, properties of lubricants. Flash point, smoke point, turbidity point.

6. ENVIRONMENTAL CHEMISTRY & AGROCHEMICALS

- **ENVIRONMENTAL CHEMISTRY:** Environment, Environmental segments- lithosphere, hydrosphere, biosphere, atmosphere. Radiation balance of the earth. Lapse rate & temperature inversion. Air pollution: Introduction, classification, air pollutants & their effects, control of air pollution. Water pollution- Introduction, water pollutants: oxygen demanding wastes, pathogens, nutrients, salts, thermal pollution, heavy metals, pesticides, volatile organic compounds; characterization of wastewater, methods & equipments used in wastewater treatment. Physical, chemical and biological water quality parameters; their assessment. Water pollution; water pollutants; toxicity aspects; international and national standards; control. Water treatment processes: aeration, solid purification nanofiltration, chemical treatments, reverse osmosis, desalination.
  Soil & land pollution. Trace elements- pollution & control.
  Industrial pollution: Sugar, drug, paper and pulp sectors, thermal power plants. Disposal of waste and its management. Chemical solutions to environmental problems, principles of decomposition, biodegradability, better industrial processes.
- **AGROCHEMICALS:** Classification of pesticides, structure, synthesis, mode of action and application of the following: Nicotine, Pyrethroids, diclone, captan, BHC, heptachlor, dieldrin, Melation , Parathion.
  Dithiocarbamates: Nabum, Ziram, structure and mode of formulation.
  Dry formulation of pesticides by dusts, granules, table powders and seed disinfectant.
  Liduid formulation of pesticides by Emulsions , suspensions, aerosols and sprays.

7. MATERIAL SCIENCE

- **CEMENT:** Introduction, composition and properties of cement, manufacture of Portland cement, setting and hardening of cement.
- **GLASS:** Introduction, types of glass, properties of glass, manufacture.
- **LIME:** Types of lime, production of lime, properties , structure, preparation and occurrence of lime
- **CERAMICS:** Introduction, types of ceramic materials, properties of ceramics, ceramic products and their applications.

8. PIGMENTS, DYES AND PAINTS

- **PIGMENTS:** General characteristics of pigments, types of pigments, blue pigments, red pigments, black pigments, green pigments and yellow pigments, general properties and methods of preparation of white pigments.
- **DYES:** Introduction, general characteristics, colour and constitution, classification of dyes according to their mode of application and based on chemical constitution. Some commercial dyes viz., azo dyes , acid, acid mordent, direct milling and stilbene azo dyes, basic dyes - Anthraquinone dyes, Indigo dyes, Reactive dyes, disperse dyes.
- **PAINTS AND VARNISHES:** General characteristics of paint varnishes and lacquers , their function, manufacture and classification. General account of enamel and emulsion paints, water based paints.
- **TESTING OF FORMULATIONS/PAINTS:** Viscosity, brush ability, color measurement, color matching, opacity, drying time, adhesion, film thickness, water resistance, durability and weatherometers.

9. FOOD SCIENCE

- **FOOD MICROBIOLOGY:** Microorganisms important in food microbiology; common food borne bacteria, common genera of food borne moulds, common genera of food borne yeasts, intrinsic and extrinsic parameters of foods that affect microbial growth, low-temperature food Preservation and characteristics of psychotropic microorganisms, high-temperature food preservation and characteristics of thermophilic microorganisms, preservation of foods by drying, indicators of food safety and quality, principles of quality control.
- **FOOD TOXICANTS:** Toxic trace elements in food- Arsenic, Mercury, Lead, Cadmium; Veterinary medicines and feed additives - Antibiotics, Anthelmintics, Analysis; Polychlorinated biphenyls; Harmful Substances from Thermal Processes-Polycyclic Aromatic Hydrocarbons (PAHs), Furan, Acrylamide; Nitrate, Nitrite, Nitrosamines; Polychlorinated Dibenzodioxins (PCDD) and Dibenzofurans (PCDF); Food-borne illness – bacterial and fungal, Toxic compounds of microbial origin, mycotoxins.
- **MILK AND DAIRY PRODUCTS:** Physico-chemical properties of milk, composition of milk- Proteins, casein fractions, micelle formation, gel formation, proteins, carbohydrates, lipids, organic acids, minerals, vitamins, enzymes, plasmin, lactoperoxidase, Processing of milk- purification, creaming, heat treatment, homogenization, types of milk.
- **VEGETABLES AND THEIR PRODUCTS:** Composition- nitrogen compounds, carbohydrates, lipids, organic acids, phenolic compounds, aroma substances; storage; vegetable products-dehydrated vegetables, canned vegetables, frozen vegetables, pickled vegetables, vegetable Juices, vegetable pastes, vegetable powders.

10. POLYMER CHEMISTRY

- **INDUSTRIAL POLYMERS :** Polyethylene, polypropylene; polystyrene, polyvinyl chloride, polyvinylacetate, polyvinylalcohol, acrylic polymers-PMMA, polyacrylonitrile, polyacrylamide, fluoropolymers-PTFE, polyamides- nylons.

- **POLYESTERS:** Polyethylene terephthalate, polycarbonates, polydienes- natural rubber, polyisoprenes, rubbers derived from butadiene, cellulose and related polymers- regenerated cellulose, cellulose nitrate, cellulose acetate, cellulose ethers, phenol-formaldehyde polymers, aminopolymers- urea formaldehyde resin.
- **POLYMER PROCESSING:** classification of polymer processing, extrusion and extuders, calendering, film blowing, injection moulding, blow moulding, vacuum forming, rotational, transfer and compression moulding, fibre spinning, polymer additives.
- **CHEMICAL REACTIONS OF POLYMERS:** Addition reactions- halogenation, hydrogenation, electrophillic addition of aldehydes; polar additions- michael condensation, hydroboration, diel's alder condensation; Rearrangement reactions- isomerization reactions; Substitution reactions: Friedel-craft alkylation reactions, nitration and sulfonation reactions of polymers with aromatic rings, cross linking reactions of polymers, formation of graft and block copolymers

11. MEDICINAL CHEMISTRY

- **DRUG DESIGN:** Biological targets and concept of lock and key, agonsits and antagonists, Natural products as guiding of principles for drug discovery, with classic examples like quinine, Oil of winter green etc. SAR, Modified natural products as improved drugs with examples like etoposide, vincristine,(anti cancer) and new generation penicillin, concept of pharmacophore, Drug design inspired by natural products and biochemical pathways. Example of suphanilamide/PABA. Wholly synthetic drugs history and development with examples like salvarsan, cisplatin, and ibuprofen.
  The commercial synthetic procedures, classification, mechanism of action, uses and structure activity relationship for selected drugs as included under

- **ANTIBIOTICS:** Penicillin, Tetracyclines, Macrolides, Streptomycin, Chloramphenicol and Quinolones.
- **SULPHA DRUGS:** Sulphanilamide, Sulphathiazole, Sulphadiazine and Sulphaacetamide
- **ANTIMALARIALS:** Chloroquine phosphate, Primaquine and Mefloquine
- **ANTIFUNGAL AGENTS:** Ketoconazole, Griseofulvin
- **ANTIHELMINTICS:** Albendazole, Mebendezole
- **ANTI- TUBERCULAR:** Isoniazid, Rifampicin, Pyrazinamide, and Ethambutol
- **ANTI-NEOPLASTICS :** Melphalan, Chlorambucil, Cisplatin

12. GREEN CHEMISTRY

Introduction, Definitions of Green Chemistry. Brief introduction of twelve principles of Green Chemistry, with examples, special emphasis on atom economy, reducing toxicity, green solvents, Green Chemistry and catalysis and alternative sources of energy, Green energy and sustainability
The following Real world Cases in Green Chemistry should be discussed:
Surfactants for carbon dioxide - – Replacing smog producing and ozone depleting solvents with CO2 for precision cleaning and dry cleaning of garments.
Designing of environmentally safe marine antifoulant .
Rightfit pigment: Synthetic azo pigments to replace toxic organic and inorganic pigments.
An efficient, green synthesis of a compostable and widely applicable plastic made from corn.

13. ADVANCED ORGANIC SYNTHESIS

- **ORGANIC SYNTHESIS DESIGN:** (i)Organic reactive intermediates: Generation, stability and reactivity of carbocations, carbanions, free radicals, carbenes, benzynes and nitrenes.
  (ii)Functional groups inter-conversion
  (iii)Connection and Disconnection approach
  (iv)Protection-deprotection of functional groups such as –OH, -CHO, -C=O, -COOH and $–NH_2$
- **MOLECULAR REARRANGEMENTS:** Beckmann, Benzidine, Benzilic Acid, Claisen, Di-p-Methane, Favorskii, Fries, Hofmann, Pinacol, Stevens, Wagner–Meerwein and Wolff Rearrangement

- **NAME REACTIONS:** Aldol Reaction, Baeyer–Villiger Oxidation, Heck Reaction, McMurry Reaction, Mitsunobu Reaction, Paterno–B¨uchi Reaction, Prins Reaction, Sharpless Epoxidation, Simmons–Smith Reaction, Stille Coupling Reaction, Stork Enamine Reaction, Suzuki Reaction, Wittig Reaction
- **TOTAL SYNTHESIS OF BIOLOGICALLY IMPORTANT MOLECULES:** Longifolene, Fredericmycine A, Eremophilone, Taxol, vitexin, oestrone and cortisone.
- **MANUFACTURE OF INDUSTRIAL ORGANIC CHEMICALS:** Aniline, Acetone, Phenol, Glycerol, formaldehyde and formic acid

14. CHEMISTRY OF NATURAL PRODUCTS

- **TERPENOIDS AND CAROTENOIDS:**
  Classification, nomenclature, occurrence, isolation, general methods of structure determination, isoprene rule.
  Structure determination and synthesis of the following representative molecules: Menthol, α-Terpeneol, Santonin, Abietic acid and ß-amyrin. Biosynthesis of Terpenoids
- **ALKALOIDS:**
  Definition, nomenclature and physiological action , occurrence, isolation, general methods of structure elucidation, classification based on nitrogen heterocyclic ring and role of alkaloids in plants.
- **PLANT PIGMENTS:**
  Occurrence , nomenclature and general methods of structure determination. Isolation and synthesis of Apigenin, Quercetin, Myrcetin, Diadzein, Cyanidin and Hirsutidin.
- **BIOPOLYMERS:**
  Classification, structure and properties of amino acids, primary structure of peptides – N-terminal amino acid determination, carboxyl terminal amino acid determination, partial hydrolysis of peptides, cyclic peptides, biologically active peptides, isoelectric points of proteins. classification and properties of proteins, colour reaction of proteins, sequencing of proteins, conformation and structure of proteins-primary, secondary, tertiary and quaternary structure, coagulation and denaturation of proteins

15. SPECTROSCOPIC TECHNIQUES

- **UV VISIBLE SPECTROSCOPY:** Theory, Principle, Instrumentation, Characteristic absorption of different compounds. Interpretation of spectra. Applications of UV- VISIBLE spectroscopy. Absorption of electromagnetic radiation by organic molecules , allowed and forbidden transitions, absorption laws and molar absorptivity, electronic systems and transition energies. UV spectra of aromatic and heterocyclic compounds.
- **INFRARED SPECTROSCOPY:** Introduction, absorption in the infrared region, theory, principle, Instrumentation, Vibration modes, calculation of vibration frequencies, factors affecting vibrational frequencies, characteristic vibrational frequencies of alkanes, alkenes, alkynes, aromatic compound, alcohols and phenols. Applications of Infrared spectroscopy, interpretation of infrared spectra of organic compounds.
- **NMR:** Introduction, theory of NMR spectroscopy, vector model, multiplicity, instrumentation, chemical shift, H -1 NMR spectroscopy, interpretation of NMR spectra of some representative compounds, spin-spin splitting, environmental effect on NMR spectra. Applications
- **ATOMIC ABSORBPTION SPECTROSCOPY:** Theory, Principle, Instrumentation (single and double beam photometers), spectral interferences