Modern Pharmaceutical Analysis(PCS102)

1. UV- Ultraviolet/Visible Spectroscopy and Fluorimetry

Energy level and selection rules, effect of substituents, effect of conjugation, conformation and geometry, the Woodward-Fisher rules, the Fisher-Kuhn rules, applications of UV with reference to different electronic systems. Derivative spectroscopy and its applications. Fluorescence and chemical structure, fluorescence intensity, factors affecting fluorescence, instrumentation, comparison of fluorometry with spectrophotometry, applications of fluorimetry in pharmaceutical analysis.

2. **Spectrofluorimetry**: Fluorescence, Phosphorescence, Chemiluminescence- Theory, instrumentation and applications.

3**. Infra-Red spectroscopy**:

The Hook's law and calculation of stretching frequencies for different types of bonds and their bond strengths, coupled interactions, hydrogen bonding, examination of infrared spectrum, survey of important functional groups with examples, radiation source, detectors used, sample handling, quantitative applications, qualitative applications with special reference to stereochemical aspects and hydrogen bonding, Near-IR spectroscopy, absorption and reflectance spectrophotometry, instrumentation, applications, Far Infrared spectroscopy. Introduction to FTIR and its applications. Raman spectroscopy Introduction, theory and polarization measurement, rules of selection and polarization, instrumentation, applications in pharmaceutical sciences. Comparison of Infrared and Raman spectra.

4. **Optical Rotatory Dispersion**:

a. Principle, plain curves, Cotton effect, Circular dichroism and. Measurement of rotation angle in ORD and applications.

b. Principles and application of light, Phase contrast, Scanning and Transmission electron microscopy, Cytometry and Flow cytometry.

5. Nuclear Magnetic Resonance spectroscopy:

Nuclear Magnetic Resonance Spectroscopy 1H-NMR spectroscopy Magnetic equivalence, failure of the N+1 rule, chemical shifts, local diamagnetic shielding, hybridization effects, magnetic anisotropy, mechanism of spin-spin coupling, the origin of spin-spin splitting, Pascal's triangle, the coupling constant, protons on oxygen, nitrogen and sulphur, diastereomeric protons, chemical shift reagents, long range coupling, spin decoupling methods, nuclear over Hauser effect. Correlation NMR spectrometry: introduction to 1H -1H cosy and 1H -13C cosy and its applications. Introduction and applications of 2D NMR; solid state NMR. 13 C-NMR spectroscopy.

Introduction, peak assignments, off resonance decoupling, selective proton decoupling; chemical shift equivalence; chemical shifts; spin coupling. Spectrometry of other important nuclei Introduction to 15N, 19F, 31P, basic concepts.

Electron Spin Resonance Spectroscopy

Introduction, derivative curves, g values, hyperfine splitting, ESR instrumentation, ESR spectra of free radicals, applications.

6. Mass spectroscopy:

Basic principle and theory involved; instrumentation, type of ions; various ion sources, electron impact source, chemical ionization sources, field ionization sources, desorption sources, mass analysers, double focusing, quadripole, time of flight, ion trap analyzer, ionization, fragmentation, rearrangements, mass spectra of representative compounds, recognition of molecular ion peak, metastable peak, isotopic peaks, applications.

7. X- ray Crystallography: Production of X rays, Different X ray methods, Braggs law, Rotating crystal technique, X ray powder technique, Types of crystals, Interpretation of diffraction patterns and applications of X-ray diffraction

8. Chromatographic methods: Introduction, classifications,

a) Liquid chromatography, instrumentation, materials, column selection, resolution optimization and efficiency parameters. HPLC detectors, modes of HPLC, Ion –pair, Ion exchange, Size exclusion, Supercritical, gel-permeation, flash chromatography, applications.

b) High Performance Liquid Chromatography: Partition, adsorption, ion exchange, size exclusion; pharmaceutical applications of HPLC and LC-MS. Super critical fluid chromatography; brief introduction to HPTLC.

c) Gas Chromatography: Gas liquid chromatography, gas solid chromatography, instrumentation and applications (GC-MS and GC-FTIR). Column parameters, Resolution, Liquid Phases Derivatisation and detectors, Derivatization as a means of sampling of thermosensitive compounds.

d) Capillary electrophoresis.: Introduction, methods and applications.

9. Radio Immuno Assay and ELISA for some drugs.

10.Thermal methods: Thermo Gravimetry (TG), Differential Scanning Calorimetry (DSC), Differential Thermal Analysis (DTA).

PRACTICALS

1. Practical based on instrumental methods of analysis. A sufficient training will be given through exercises using different kinds of spectral analysis.

2. Microbial analysis of Vitamins and Anti-biotics

3. Pharmacological Bioassay of some drugs.

REFERENCE BOOKS

1. Willard, H.H., Merrit, L.L., Dean, J.A., Settle P.A., Instrumental Methods of Analysis, Van Nostrand.
2. Skoog, D.A., Heller, F.J., Nieman, T.A., Principles of Instrumental Analysis, WB Saunders.
3. Hunson, J.W., ed. Pharmaceutical Analysis, Modern Methods, part A & B, Marcel Dekker.
4. Schirmer, R.E., ed. Modern Methods of Pharmaceutical Analysis, Vols 1, 2. Boca Raton F.L., CRC Press.
5. Mann, C.K., et al., Instrumental Analysis Harper & Row.
6. Jaffe, H.H., Orchin M., Theory & Applications of Ultraviolet Spectroscopy, Willy.
7. Silverstein, Spectrometric identification of Organic Compounds, Willy.
8. Bovey, F., Jelinski, L., Miran, P., Nuclear Magnetic Resonance Spectroscopy, Sau: Diego Academic.
9. Stothers, J.B., Carbon-13 NMR.Spectroscopy, Academic.
10. Gordy, W., Theory & Applications of Electron Spin Resonance, Willy.
11. Haswell, S.J., ed. Atomic Absorption Spectroscopy, Elsevier.

12. Ardrey, R.E., Pharmaceutical Mass Spectra, Pharmaceutical Press, London.
13. Budzikiewicz, et al., Interpretation of Mass Spectra of Organic Compounds, Holden-Day San Francisco.
14. Beckett and Stenlake, Practical Pharmaceutical Chemistry, CBS.
15. Stahl, E., Thin Layer Chromatography- A laboratory Handbook, Springer-Verlag
16. Giddings, J.C., Principles and Theory- Dynamics of Chromatography, Marcel Dekker.
17. Sethi, P.D., Quantitative Analysis of Pharmaceutical formulations, CBS Publishers, New Delhi.
18. Kemp William, Organic spectroscopy, Pal grave, New York.
19. Kalsi, P.S., Spectroscopy of organic compounds, New age publishers, New Delhi.
20. Gross - Mass Spectrometry
21. WHO - Quality Assurance of Pharmaceuticals, Vol. I, II.
22. Sethi, P.D., HPLC, Quantitative Analysis of Pharmaceutical Formulations, CBS Publishers, Delhi.
23. Sethi, P.D., HPTLC, Quantitative Analysis of Pharmaceutical Formulations, CBS Publishers, Delhi.
24. Haffmann, Chromatography.
25. Sethi and Charcgankar, Identification of Drugs in Pharmaceutical Formulations by TLC.
26. Robert D. Braun, Introduction to Instrumental Analysis.
27. Wilfried, M.A. Niessen- Liquid Chromatography-Mass Spectrometry.
28. Harry G. Brittain, Spectroscopy of Pharmaceutical Solids.
29. George, S., Steroid Analysis in Pharmaceutical Industry.
30. Higuchi, Pharmaceutical Analysis.
31. Bidingmeyer, Practical HPLC Methodology and Applications.
32. Hoffmann, Mass Spectrometry: Principle and Application.
33. Scott, Techniques and Practice of Chromatography.
34. Wilkins, Identification of Microorganism by Mass Spectrometry.
35. Wu, Handbook for Size Exclusion Chromatography and related Techniques.
36. Silverstein RM and Webster FX. Spectrometric Identification of Organic Compounds. John Wiley and Sons, New York. Latest Edition.
37. Chatten LG. Pharmaceutical Chemistry, Vol. I & II. Marcel Dekker, New York. Latest Edition.
38. James WD and Kenneth HT. Analytical Chemistry by Oipen Learning: Thermal Methods. John Wiley and Sons, New York. Latest Edition.
39.Abraham RJ, Fisher J and Bftus P. Introduction to NMR Spectroscopy. John Wiley and Sons, New York. Latest Edition.
40. Pavia DL, Lampman GM and Kriz GS. Introduction to Spectroscopy. Harcourt College Publishers, Orlando. Latest Edition.

PREFORMULATION AND PRODUCTION MANAGEMENT(PCS102)

1. PREFORMULATION STUDIES

Introduction, Consideration of physico-chemical properties of new drug molecules for different dosage forms. Aqueous solubility, organic solubility, intrinsic solubility, methods of enhancement of solubility-surfactants, pH, co-solvency, solid dispersion, complexation. Techniques for the study of crystal properties and polymorphism - DSC, TGA, PXRD, Optical microscopy, hot stage microscopy. Excipient compatibility studies, Preformulation stability studies.

2. COMPACTION, COMPRESSION, AND CONSOLIDATION

Compression, consolidation, decompression, compaction of powders with a particular reference to distribution and measurement of forces within the powder mass undergoing compression. Influence of compression force on the properties of tablets. Effect of particle size, moisture content, lubrication etc. on strength of tablets. A brief study on formulation aspects of tablets such as mouth dissolving tablets, dispersible tablets, chewable tablets and medicated lozenges.

3. QUALITY BY DESIGN, DESIGN OF EXPERIMENTS, FORMULATION BY DESIGN

USFDA's view of QbD, Elements of QbD, QbD tools, Design of experiments –Methods and applications Optimization techniques: Concept of optimization, optimization parameters, classical optimization. Statistical design (Simplex and factorial design)

4. STABILITY TESTING - DRUGS AND DOSAGE FORMS

Solid state drug stability, dosage form stability, accelerated stability testing, shelf life calculations, strategies for prolonging shelf life. Effect of packaging materials on dosage form stability. Basic principles of ICH, stability testing of new drug substance and formulations, photostability testing and oxidative stability, role of containers in stability testing. WHO stability guidelines.

5. cGMP, ISO 9000 & 14000 SERIES, VALIDATION

ISO 9000 & 14000 series, guide to Phamaceutical manufacturing facilities, cGMP considerations with emphasis on documentation practices.

Validation- General concepts, types, approaches to validation and scope of validation. Relationship between calibration, validation & qualification. Validation master plan, qualifications of utilities - HVAC systems, validation of water systems. Validation of manufacturing process for sterile and non-sterile products (briefly protocols and reports), Equipment qualification and cleaning validation.

6. INVENTORY MANAGEMENT

Costs in inventory, inventory categories- special considerations, selective inventory control, reorder quantity methods and EOQ, inventory models, safety stock – stock out, lead time – reorder time methods, modern inventory management systems, inventory evaluation.

7. MATERIAL MANAGEMENT

Materials–quality and quantity, value analysis, purchasing–centralized and decentralized, vendor development, buying techniques, purchasing cycle and procedures, stores management, salvaging and disposal of scrap and surplus. Selection of material handling systems, maintenance of material handling equipment, unit-load, pelletization and containerization, types of material handling systems.

8. PILOT PLANT SCALE UP TECHNIQUES

Scale up of batches for product development, layout of pharmaceutical pilot plant, organization structure, personnel, activities. Pilot plant of tablets, capsules, solutions, dispersions, semisolids, and parenterals. Protocols for technology transfer. Process automation technology (PAT) in Pharmaceutical manufacturing. Introduction to SUPAC guidelines.

9. IPR AND REGULATORY GUIDELINES

Definition, Need for patenting, Types of Patents, Conditions to be satisfied by an invention to be patentable, Introduction to patent search. Parts of patents. Filling of patents. The essential elements of patent; Guidelines for preparation of laboratory note book, Non-obviousness in Patent. Brief introduction to Trademark protection and WHO Patents. IPR's and its types, Major bodies regulating Indian Pharmaceutical sector, CDSCO. WHO, USFDA, EMEA, TGA, MHRA, MCC, ANVISA regulatory requirements for contract research organization. Regulations for Biosimilars. Role of GATT, TRIPS, and WIPO.

10. INDUSTRIAL HAZARDS AND PLANT SAFETY

Industrial accidents, mechanical hazards, electrical hazards, chemical hazards, gas hazards, dust explosion, fire and explosion hazards, prevention and control of all these hazards, safety management. Industrial pollution and Control measurements.

PRACTICALS

1. Preformulation study of tablet formulation using various diluents
2. Preformulation study of tablet formulation using various binders.
3. To study the effect of surfactants/Co-solvents on the solubility of drugs.
4. To study the effect of various excipients on the compressibility of tablets.
5. Preparation and evaluation of Diclofenac sodium gel containing different gel bases.
6. Study of the effects of pH on rheological characteristics of carbopol gels using Brookefield viscometer.
7. cGMP considerations for tablets.
8. cGMP considerations for injectables.
9. Preparation and comparative evaluation with marketed product for efficiency of neutralizing property of antacid suspensions.
10. Process validation of tablets.
11. Equipment qualification of an analytical instrument.

12. Equipment qualification of processing equipment.
13. Cleaning validation of an equipment.
14. Designing of plant layouts for tablets and parenterals.
15. Stability studies of dosage form at 30°C±2, 65±5 %RH and 40°C±2, 75±5% RH.

REFERENCE BOOKS

1. Theory and Practice of Industrial Pharmacy By Lachmann and Libermann , Latest edition.
2. Modern Pharmaceutics by Gillbert and S. Banker 4th Edition .
3. Pharmaceutical Process Validation: By Fra R. Berry and Robert A. Nash, Vol 57, 2nd edition
4. Applied Production and Operation Management By Evans, Anderson and Williams GMP for pharmaceuticals Material Management by K.K. Ahuja Published by CBS publishers

5. Pharmaceutical Preformulations by J.J Wells
6. Pharmaceutical Dosage Forms: Tablets vol 1-3 by Leon Lachmann
7. Text book of Remington's Pharmaceutical sciences Vol I and II, 21st edition
8. Physical Pharmaceutics by Alfred Martin, 4th edition
9. Bentley's textbook of Pharmaceutics-Rawbins
10. ISO 9000-Norms and explanations
11. GMP for pharmaceuticals- Willing S.H. Marcel and Dekker
12. Pharmaceutical powder compaction technology by Goran Alderborn, 1996. Marcel and Dekker
13. D and C act by Vijay Malik, Latest edition, Eastern book company, Lucknow

BIOPHARMACEUTICS AND PHARMACOKINETICS(PSC103)

1. **ABSORPTION OF DRUGS**
   Structure of cell membrane, Gastro-intestinal absorption of drugs, mechanisms of drug absorption, Factors affecting drug absorption: Biological, Physiological, Physico-chemical and Pharmaceutical. Absorption of drugs from non-per oral routes, Methods of determining absorption: *In-vitro, in-situ* and *in-vivo* methods.

2. **BIOAVAILABILITY**
   Objectives and consideration in bioavailability studies, Concept of equivalence, Measurement of bioavailability, Determination of the rate of absorption, Bioequivalence protocol and its importance, Bioequivalence studies.

3. **DISSOLUTION**
   BCS Classification, Noyes-Whitney's dissolutions rate law, Study of various approaches to improve dissolution of poorly soluble drug, *In-vitro* dissolution testing models, *In-vitro* release kinetic models, similarity and dissimilarity factors, biowaivers, *In-vitro- In –vivo* correlation.

4. **PHARMACOKINETICS**

   Basic considerations, Pharmacokinetic models, Compartment modeling: One compartment model - IV bolus, IV infusion, Extravascular; Multi Compartment models; Two compartment model - IV bolus, IV infusion, Extravascular, Three Compartment model in brief, Application of Pharmacokinetics in new drug development and designing of dosage forms and Novel drug delivery systems.

5. **NON-LINEAR PHARMACOKINETICS**
   Causes of non-linearity, Detection of non – linearity, Michaelis-Menten equation, Estimation of K_m and V_{max} with respect to individualization of a drug therapy.

6. **NON-COMPARTMENT PHARMACOKINETICS**
   Statistical moment theory, MRT for various compartment models, Physiological pharmacokinetic models.

7. **DRUG DISTRIBUTION**
   Factors affecting drug distribution, Volume of distribution, Protein binding- factors affecting, significance and kinetics of protein binding and drug displacement interactions.

8. BIOTRANSFORMATION

Phase I (oxidative, reductive and hydrolytic reactions) and Phase II reactions (conjugation), factors affecting biotransformation.

9. EXCRETION OF DRUGS

Renal and non-renal excretion. Concept of clearance- renal clearance, organ clearance and hepatic clearance.

10. DOSAGE REGIMEN

Multiple dosing with respect to I.V and oral route, concept of loading dose, maintenance dose, accumulation index, adjustment of dosage in renal and hepatic impairment, individualization of therapy, Therapeutic Drug Monitoring.

PRACTICALS

Improvement of dissolution characteristics of slightly soluble drugs by Solid Dispersion.

1. Improvement of dissolution characteristics of slightly soluble drugs by Solvent deposition.
2. Improvement of dissolution characteristics of slightly soluble drugs by complexation.
3. Improvement of dissolution characteristics of slightly soluble drugs by solvent evaporation.
4. Comparison of dissolution studies of two different conventional marketed products of same drug. - 2 experiments
5. Influence of polymorphism on solubility.
6. Influence of polymorphism on dissolution.
7. Protein binding studies of a highly protein bound drug.
8. Protein binding studies of a poorly protein bound drug.
9. Permeation study of drug through biological membrane.
10. Calculation of Ka, Ke, $t_{1/2}$, C_{max}, and T_{max} for two sets of data. -2 experiments
11. Calculation of bioavailability from urinary excretion data for two drugs. -2 experiments
12. Calculation of AUC and bioequivalence from the given data for two drugs. -2 experiments

REFERENCE BOOKS

1. Biopharmaceutics and Clinical Pharmacokinetics by Milo Gibaldi, 4th edition, Philadephia, Lea and Febiger, 1991.
2. Bio pharmaceutics and Pharmacokinetics-A Treatise, By D. M. Brahmankar and Sunil B.Jaiswal, Vallabh Prakashan Pitampura, Delhi
3. Applied Biopharmaceutics and Pharmacokinetics by Shargel. L and Yu ABC, 2nd edition, Connecticut, Appleton Century Crofts, 1985.
4. Textbook of Biopharmaceutics and Pharmacokinetics, Dr. Shobha Rani R. Hiremath, Prism Books Pvt Ltd, Bangalore, 2000
5. Biopharmaceutics and Clinical Pharmacokinetics by Milo Gibaldi, 2nd edition, Marcel Dekker Inc., New York,1982.
6. Current Concepts in Pharmaceutical Sciences: Biopharmaceutics, Swarbrick. J, Lea and Febiger, Philadelphia,1970.
7. Cilincal Pharmacokinetics, Concepts and Applications: By Malcolm Rowland and Thomas, N. Tozen, Lea and Febrger, Philadelphia, 1995.
8. Dissolution, Bioavailability and Bioequivalence, By Abdou H.M, Mack, Publishing Company, Pennsylvania 1989.
9. Biopharmaceutics and Clinical Pharmacokinetics-An introduction 4th edition Revised and expanded by Rebort F Notari Marcel Dekker Inc, New York and Basel, 1987.
10. Biopharmaceutics and Relevant Pharmacokinetics by John. G. Wagner and M. Pernarowski, 1st edition, Drug Intelligence Publications, Hamilton, Illinois,1971.
11. Encyclopedia of Pharmaceutical Technology, Vol 13, James Swarbrick, James, C. Roylan, Marcel Dekker Inc, New York 1996.

SARVAPALLI RADHAKRISHNAN UNIVERSITY, BHOPAL (M.P.)

ADVANCES IN DRUG DELIVERY SYSTEMS(PSC 104)

1. CONCEPTS OF CONTROLLED RELEASE DRUG DELIVERY SYSTEMS

Introduction, concept, advantages & disadvantages. Factors to be considered for designing controlled release dosage forms. Dissolution, Diffusion, Combination of dissolution and diffusion controlled drug delivery systems. Evaluation of CRDF.

2. POLYMER SCIENCE

Polymer: Introduction, classification, general synthesis and evaluation techniques. Appplication of polymers in drug delivery.

3. APPROACHES TO CONTROLLED DRUG DELIVERY SYSTEM

Classification of rate-controlled drug delivery systems. Rate-programmed release, activation-modulated and feedback regulated drug delivery systems. Effect of system parameters on controlled drug delivery. Hydrodynamically balanced systems, Osmotic pressure controlled, pH controlled, ion exchange controlled systems.

4. MUCO ADHESIVE DRUG DELIVERY SYSTEMS

Concepts, advantages and disadvantages, structure of oral mucosa, transmucosal permeability, theories of muco adhesion and muco adhesive polymers, mucosal membrane models, permeability enhancers. Development and evaluation of buccal, nasal, pulmonary, rectal, vaginal and ocular drug delivery systems and their applications.

5.TRANSDERMAL DRUG DELIVERY SYSTEMS

Rationale behind transdermal drug delivery, Permeation through skin, factors affecting permeation, basic components of TDDS, formulation approaches used in development of TDDS and their evaluation, permeation enhancers. Iontophoresis, sonophoresis and magnetophoresis.

6. PARENTERAL CONTROLLED RELEASE DRUG DELIVERY SYSTEMS

Approaches for injectable controlled release formulations. Development and evaluation of Implantable drug delivery systems, subcutaneous, intramuscular and intrauterine implants.

7. NANO DRUG DELIVERY SYSTEMS

Formulation, development and evaluation of Nanoparticles- Polymeric nano particles, Nano crystals, Solid Lipid Nanoparticles (SLN), Metal Nanoparticles. Vesicular Systems-Liposomes, Transferosomes, Ethosomes, Niosomes, Virosomes. Carbon Nano Tubes (CNT) and Dendrimers. Safety issues related to nano drug delivery systems.

8. TARGETED DRUG DELIVERY

Concept, advantages and disadvantages, types of targeting and applications. Monoclonal antibodies- hybridoma cell production, diagnostic and therapeutic applications – cancer and autoimmune diseases. Problems related to monoclonal antibodies.

PRACTICALS

Comparative evaluation of marketed sustained release tablets and data treatment.

1. Preparation and evaluation of matrix tablets using natural polymers.
2. Preparation and evaluation of matrix tablets using synthetic polymers.
3. Preparation and evaluation of microspheres by solvent evaporation.
4. Preparation and evaluation of muco- adhesive microspheres by ionic gelation method.
5. Preparation and evaluation of microspheres by temperature change method.
6. Preparation and evaluation of microcapsules by wax embedded method.
7. Preparation and evaluation of buccal patches.
8. Preparation and evaluation of buccal tablets.
9. Preparation and evaluation of transdermal films.
10. Evaluation of the effect of various permeation enhancers on transdermal drug delivery.
11. Preparation and evaluation of hydrodynamically balanced tablets.
12. Preparation and evaluation of ocular *insitu* gel.

REFERENCE BOOKS

1. Chien YW., Novel drug delivery systems, 2nd edition, revised and expanded, Marcel Decker, Inc., New York, 1992.
2. Robinson JR., Lee VHL. Controlled drug delivery systems, Marcel Decker, Inc., New York,1992.
3. John Wiley and sons, Inc, Encyclopedia of controlled delivery, Editor-Edith Mathiowitz, Published by Wiley Interscience Publication, New York/Chichester/Weinheim
4. Jain NK., Controlled and novel drug delivery, CBS Publishers & Distributors, New delhi,First edition 1997 (reprint in 2001)
5. Vyas SP., Khar RK., Controlled drug delivery-concepts and advances, Vallabh Prakashan, New Delhi, first edition 2002.
6. Indian Pharmacopoeia 2010. Volume-I, II & III, Indian Pharmacopoeia Commission. New Delhi.
7. United States Pharmacopoeia, US Publications, US
8. British pharmacopoeia
9. Howard C. Ansel, Nicholas G., Popovid loyd, Allen junior BI. Pharmaceutical dosage forms & drug delivery systems. Waverly pvt, Ltd, New Delhi, Sixth edition
10. Leon Lachman, Lieberman, Kanig JL., Theory and Practice of Industrial Pharmacy, Varghese Publishing House, Bombay, 3rd Edition, 1987.
11. Banker and Rhodes, Modern Pharmaceutics, Marcel Decker Inc., New York, 2nd Edition, 1990.
12. Ansel HC., Introduction to Pharmaceutical Dosage Forms and Drug Delivery Systems, Lippincott Williams and Wilkins, New York, 7th Edition, 2000.
13. Remington, the Science and Practice of Pharmacy, Lippincott Williams, 21st Edition, 2000.
14. Patrick J. Sinko. Lippincott Williams and Wilkins. Martin's physical pharmacy and pharmaceutical sciences. Fifth edition.
15. Wilium Alfred Martin P, Bustamante AH., Chun. Physical Pharmacy, B. I. Waverly Pvt Ltd, new Delhi, 4th edition 1995
16. S.Bharath. Pharmaceutical Technology-Concepts and Applications, Pearson Education in South Asia, First edition,2013.