NORTH MAHARASHTRA UNIVERSITY, JALGAON

SCHOOL OF CHEMICAL SCIENCES

(Academic Flexibility Since-2009)

SYLLABUS

for

MASTER OF SCIENCE in CHEMISTRY

With

Specialization in

POLYMER CHEMISTRY

M.Sc. II (Semester III and IV)

(Choice Based Credit System, 60:40 Pattern)

w. e. f. June 2016

SYLLABUS FOR SECOND YEAR

M. Sc. Chemistry (With Specialization in POLYMER CHEMISTRY)

w. e. f. JUNE 2016

Course Structure for Second Year

Semester – III

Courses Code	**: Title**	**Marks**
PC 301:	Principles of Polymerization	100
PC 302:	Characterization Techniques for Polymers	100
PC 303:	Industrial Polymers and Paint Technology	100
PC 304:	Physical and Mechanical Properties of Polymers	100

Practical Course

PC 004:	Laboratory Course in Polymer Chemistry- I	100

Semester - IV

Courses Code	**: Title**	**Marks**
PC 401:	Processing of Polymers	100
PC 402:	Special Topics in Polymers	100
PC 403:	Synthetic polymers and additives	100

Project & Practical Courses

PC 005:	Laboratory Course in Polymer Chemistry - II	100
PC 006:	Project	100

*The projects will be initiated in the beginning of Semester III and the examination will be conducted at the end of Semester IV.

Educational Tour:

Organizing educational tour aiming at giving practical exposure to II year students is expected (at their own cost).

In-plant Training:

Students are expected to undergo one month practical training (at their own cost) in relevant industries. The said training is proposed after II / III semester.

Semester - III

PC 301 Principles of Polymerization (60 h. and 100 Marks)

Unit-I (12 h)

A. Mechanisms of Polymerization: (02 h)

Step growth polymerization, chain polymerization, Z-N polymerization

B. Step Polymerizations (10 h)

Reactivity of functional groups, kinetics of step polymerization, molecular weight control in linear polymerization, process condition, multi-chain polymerization, cross-linking, step copolymerization.

Unit- II (12 h)

Radical Chain Polymerization:

Nature of radical chain polymerization- comparison of chain and step polymerisation, radical versus ionic chain polymerisation, structural arrangement of monomer units – possible modes of propagation, experimental evidence, synthesis of head to head polymers, Kinetics of radical chain polymerisation, Initiation (various methods), Mode of termination - chain transfer to monomer, initiator, chain transfer agent, Inhibition & retardation.

Unit- III (12 h)

A. Ring Opening Polymerizations: (08 h)

Polymerization mechanism of cyclic ethers, cyclic amides, N-carboxy- and amino acid anhydrides, cyclosiloxanes.

B. Newer Techniques in Polymerization: (04 h)

Metathesis polymerization, Atom Transfer Radical Polymerization (ATRP), Group Transfer Polymerization (GTP), Reversible Addition Fragmentation Termination (RAFT) polymerization.

Unit- IV (12 h)

Ionic Chain Polymerization :

A. Cationic polymerization of alkenes:- Initiation- protonic acids, Lewis acids, other initiators, Propagation, Termination- chain transfer to monomer, spontaneous termination, combination with counter ion, chain transfer to polymer, other transfer and termination reactions, Kinetics, Commercial importance's of cationic polymers.

B. Anionic polymerization of alkenes:- Initiation- nucleophilic initiators, electron transfer, Propagation, Termination- polymerization without termination, termination by impurities and deliberately added transfer agents, spontaneous termination, Kinetics.

Comparison between cationic, anionic & radical polymerization.

Unit- V **(12 h)**

Chain Copolymerization:

Introduction, Importance of chain copolymerization, Types of copolymers, Copolymer composition, Methods of determination of reactivity ratios, Reactivity ratio and copolymerization behavior, Radical copolymerization, Rates of copolymerization.

Recommended Books

1. Principles of Polymerization: G. Odian, John Wiley & Sons, 2001.
2. Polymer Chemistry: M. P. Stevens, 2nd Ed., Oxford Univ. Press., (1990)
3. Principles of Polymer Chemistry, A. Ravve, Plenum Press, New York and London, 1995.
4. Principles of Polymerisation, P. Bahadur, N. V. Sastry, Narosa Publishing House, New Delhi, 2002.
5. Principles of Polymer Systems, F. Rodriguiz, C. Cohen, C. Ober, L. A. Archer, 5th edn., Taylor & Francis, New York, 2003.
6. Polymer Chemistry-properties and applications, Andrew Peacock, Allison Calhoun, Hanser Publishers, Munich, 2006.
7. Polymer Science, V. R. Gowarikar, New Age International Pvt. Ltd., New Delhi, 1997.

PC 302: Characterization Techniques for Polymers (60 h. and 100 Marks)

Unit- I (12 h)

Classification of Polymers :

Homopolymers, co-polymers, linear polymers, branched polymers, cross linked or three dimensional polymers, block co-polymers, organic- inorganic polymers, natural and synthetic polymers, chain and step growth polymers, thermoplastic and thermoset, based on applications - fibers, foams, adhesives and elastomers, based on performance – commodity and engineering polymers.

Unit- II (12 h)

Identification of Polymers :

Preliminary tests, Elemental analysis, solubility chart, Specific end group analysis (Acid value, Hydroxyl Value, Iodine value, Epoxy value, SAP Value, Amine value) Spectroscopic analysis (IR & NMR). Solubility chart for identification of polymers, Specific chemical tests for various polymers and group analysis.

Unit- III (12 h)

A. Polymer Molecular Weights: (06 h)

Molecular weight determination using viscometry, osmometry, light scattering, ultracentrifuge, gel permeation chromatography and End group analysis.

B. Thermal Analysis of Polymers: (06 h)

Introduction, instrumentation and applications of DTA, TGA, DSC and TMA, pyrolytic gas chromatography

Unit-IV (12 h)

A. Viscoelastic behavior: (06 h)

Introduction, linear viscolastic behavior, Maxwell and Kelvin vigat model, mechanical spectra.

B. Spectroscopic characterization: (06 h)

(Detail experimentation is not expected here) Fundamentals, experimental and applications of following techniques to polymers. UV-visible spectroscopy, IR and Raman spectroscopy, Nuclear Magnetic (proton & carbon), NMR of polymers in the solid state, two dimensional NMR spectroscopy, Methods to study tacticity, sequence determination of polymers by NMR. MALDI-TOF.

Unit- V **(12 h)**

A. Characterization and Analysis of Polymer Surfaces: (09 h)

Light (optical) microscopy, electron microscopy (SEM & TEM), x ray diffraction, Atomic force microscope (AFM).

B. Electrical properties of polymers: (03 h)

Dielectric strength, dielectric constant, volume resistivity, dissipation factor and loss factor.

Recommended Books

1. Experiments in Poly. Sci., Collins Bares, F. W. Billmeyer, Wiely Interscince, 1973.
2. Physical Chemistry of Macromolecules. D.D. Deshpande,Vishal Publications, Jalandhar, 1989.
3. Physical Chemistry of Polymers - Hiemenzs.
4. Mechanical Properties of Polymers & Composites L. E. Nielsen, Marcel Dekker.
5. Polymer Chemistry: M. P. Stevens, 2nd Ed., Oxford Univ. Press., (1990).

PC 303 : Industrial Polymers and Paint Technology (60 h. Marks-100)

Part A Industrial Polymers

Unit-I (12 h)

A. Basic Concepts of Polymers (06 h)

History, Trends, and General Polymer Background, Concept of functionality and reactivity, Degree of polymerization.

B. Techniques of Polymerization (06 h)

Bulk, Solution, Emulsion, Suspension and Interfacial polymerization.

Unit- II (12 h)

General Chemistry, Technology of Production, Properties and Applications of Chain growth polymers

a. Polyethylene (HDPE, MDPE, LDPE, LLDPE, UHMWPE, chlorinated PE),
b. Polypropylene (PP),
c. Polyisobutylene (PIB)),
d. Acrylics (PMMA & PAN)
e. Polyvinyles (PVC, PVDC & CPVC),
f. Polystyrene & copolymer (HIPS, SBR, SAN & ABS)
g. Poly(vinyl acetate)

Unit- III (12 h)

General Chemistry, Technology of Production, Properties and Applications of Step growth polymers:

a. Phenol formaldehyde (PF- Novolak and resol)
b. Urea formaldehyde (UF)
c. Melamine formaldehyde(MF)
e. Polyamides:- Nylon-6, Nylon-6, 6 & Kevlar.

Part B Paint Technology

Unit- IV (12 h)

A. Paints – Introduction and Definitions of paints, pigments, varnishes, lacquers, Anatomy of paints, functions & requirements of constituents of paints, classification of paints on the basis of order of application/ methods of curing / nature of solvent/ uses etc.

B. Paint Properties - color, tinting strength, reducing power, pigments classification of pigments, pigments properties-oil absorption, refractive index, particle size shape, bleeding, resistance to light and heat.

Unit-V (12 h)

A. Manufacture of Paints (05 h)

Ball mill, triple roll mill, bead mill, titrator, high speed and heavy-duty disperser.

B. Important Resins or Modifications of Resins for Paints and Coatings (07 h)

a. Epoxy Resins (BPA based resin, curing agents & flame retardant epoxy resins)
b. Alkyds – Introduction of alkyds, different components of it, Modification with rosin, maleic anhydride, acrylics, vinyls, imides etc.
c. Polyester resins - Unsaturated polyester resins
d. Modification of phenolics such as novolac-epoxy oil soluble and oil reactive Modification of aminor resins (UF & MF) with alcohols and phenols.

Recommended Books:

1. Polymer Chemistry - M. P. Stevens, 2nd Ed., Oxford University Press, 1990.

2. Poly. Synthesis - Stanley R. Sandler, Wolf Karo, Vol. 1, Academic Press, Inc., California, 1994.

3. Introduction to Polymer Chemistry - R.B. Seymour, Marcel Dekker, 3rd Ed., (1992)

4. Polymer Chemistry-properties and applications, Andrew Peacock, Allison Calhoun, Hanser Publishers, Munich, 2006.

5. Polymer Science and Technology of Plastics and Rubbers, Premamoy Ghosh, Tata McGraw-Hill Publishing Company Ltd., New Delhi, 1996.

6. Encyclopedia of Chemical Technology, Kirk and Othmer.

7. Plastics Materials, J. Brydson, Butterworths, &th Edn., London, 1999.

8. Polymer Chemistry, Ayodhya Singh, Campus Books, 2006.

9. Organic Polymer Chemistry, V. Jain, IVY Publishing House, New Delhi,

10. Outlines of Paint Technology, W. M Morgan 3rd edn CBS Publishers.

11. Paints, Coatings and solvents, Dieter Stoye, Werner Freitag, Wiley VCH Pub.

PC 304: Physical and Mechanical Properties of Polymers (60 h. and 100 Marks)

Unit-I (12 h)

A. Nomenclature of Polymers. (06 h)

Nomenclature based on source, nomenclature based on structure (non IPUAC), nomenclature based on structure IPUAC, trade names and non-names.

B. Phase States and Phase Transition of Polymers (06 h)

General Concept of phase state and phase transition, crystallizability of polymers, melting temperature of polymers, amorphous polymers

Unit-II (12 h)

Transition of Polymer from the Rubber-like to the Glassy and Viscofluid States

Relaxation nature of glass transition, mechanism of glass transition, methods of determining the glass transition temperature of polymers, effect of molecular mass of polymers on its glass transition temperature and on flow temperature, relationship between Tg and Tm of polymers, chemical constitution of polymers and glass transition temperature.

Unit-III (12 h)

A. Polymer-Low-Molecular Liquid Systems (06 h)

True solution of polymers, gels of polymers, colloidal dispersion of polymers, preparation of polymers solution and their refining, fractionation of polymers, resistance of polymeric material to solvents.

B. Mechanical Tests and Polymer Transitions (06 h)

Standards and standards organizations Mechanical tests : creep tests, stress relaxation tests, stress-strain tests, compression, flexural test, dynamic mechanical tests

Unit-IV (12 h)

Other Mechanical Properties :

Fatigue, Friction, Abrasion resistance, Hardness and Indentation Tests, Melt Flow Index, Impact test, Gloss, Gas permeability, Environmental stress cracking (ESC), Flame Retardancy (LOI), Opacity

Unit-V (12 h)

Conventional composites and Nanocomposites of polymers

Introduction to Composite Systems, Conventional fillers, particulate filled composites, fiber filled composites, Nano composites - Nano Sized Fillers, Types and Advantages of Nanosized fillers,
General approaches of making nanocomposites

Recommended Books

1. Physical Chemistry of Polymers - A. Tager, Mir Pub., 2nd Ed., (1978)

2. Principles of Polymer Chemistry, P. J. Flory, Asian Books Pvt. Ltd., First Indian Edn., 2006.

3. Polymer Chemistry The Basic Concepts – Paul C. Hiemenzs, Marcel Dekker, New York, 1984.

4. Physical Chemistry of Macromolecules –D. D. Deshpande, Vishal Publication, Jalandhar, 1997.

5. Polymer Science – V. R. Gowarikar, N. V. Viswanathan, Jayadev Shreedhar, New Age International, India (1997).

6. Polymer Science and Technology, J. R. Fried, Printice Hall of Indian Pvt. Ltd., New Delhi, 2000.

7. Handbook of Plastics Testing Technology, Vishu Shah, Wiley Interscience Publications, 2nd Edition, 1998.

PC 004: Laboratory Course in Polymer Chemistry- I (Marks-100)

(Minimum 14 practicals are necessary)

1. Study of various polymerization techniques – Bulk, Solution, Suspension, emulsion polymerization

2. Synthesis of polyesters.

3. Kinetics of catalyzed and uncatalyzed polyesterification reaction

4. Preparation of Urea formaldehyde resin

5. Preparation of Phenol formaldehyde resin – novolak and resol

6. Preparation of Melamine formaldehyde resin

7. Preparation of alkyd resin

8. Preparation of epoxy resin

9. Preparation of varnish, distemper, primer, undercoat and topcoat

10. Characterization of surface coating viscosity, gloss, impact resistance, cross cut adhesion, scratch resistance and hiding power.

11. Preparation of polysulphide resin.

12. Preparation of nylon 66

13. Preparation of P.F. ion exchange resin

14. Preparation of poly (vinyl acetate) from PVA

15. Modification of PS to chloromethylated PS

16. Preparation of cellulose acetate

17. Determination of epoxy equivalent

18. Determination of saponification value

19. Determination of acid value

20. Determination of hydroxyl value

21. Determination of isocyanate content

22. Determination of iodine value

References:

1. Experiments in Polymer Science, D. G. Hundiwale, V. D. Athawale, U. R. Kapadi, V. V. Gite, New Age International Pvt. Ltd., New Delhi, 2009.

2. Polymer Chemistry-Practical Approach in Chemistry, F. J. Davis, Oxford University Press, Oxford, 2004.

3. Polymer Science – V. R. Gowarikar, N. V. Viswanathan, Jayadev Shreedhar, New Age International Pvt. Ltd., New Delhi, 1997.

4. Principles of Polymerisation, P. Bahadur, N. V. Sastry, Narosa Publishing House, New Delhi, 2002.

Semester - IV

PC 401: Processing of Polymers: (60 h and 100 Marks)

Unit-I (12 h)

Extrusion

General features of single screw extruder; Mechanism of flow, Analysis of flow in extruder, General features of twin screw extruders and other techniques based on extruder

Unit-II (12 h)

Injection Molding

Introduction, details of the process, moulds, structural foam injection molding, sandwich molding, Reaction injection molding, injection blow molding, injection Molding of thermosets.

Unit-III (12 h)

A. Thermoforming, Analysis of thermoforming (3 h)

B. Calendaring

Introduction, Types of calendars and configurations, Material used in calendaring, Analysis of calendaring **(3 h)**

C. Rotational Molding (3 h)

Introduction, material used in it, applications.

D. Compression molding (3 h)

Introduction, Principle, Downstroke and Upstroke compression presses, compression mold platens, molding materals, types of molds, advantages and disadvantages, troubleshooting.

Unit-IV (12 h)

A.Transfer molding (2 h)

Introduction, Description of process, Advantages and disadvantageas, comparison with compression moulding

B. Processing of reinforced thermoplastics & thermoset Manual Processing Methods, Semi-Automatic Processing Methods. **(5 h)**

C. The effects of processing (5 h)

Microstructural changes, Shrinkage & distortion, Residual stresses

Unit-V **(12 h)**

A. Processing of fibres (6 h)

wet processing, dry processing, melt processing

B. Methods for Polymer coatings (6 h)

Introduction, type of coatings, coating methods- roll coating, powder coating, spray coating, vaccum coating, electrodeposition

Recommended Books

1. Plastics Engineering, R.J. Crawfold, Maxwell- Macmillon International Ed. Science & Technology of Polymer Films, O.J. Sweeting, Vol. II, Noyes, 1971

2. Pulp and Paper- Chemical Technology Vol. I, II, III, J.P. Casey, 3rd Ed. Interscience, 1980.

3. Polymer Processes, C.E. Schildnecht, Wiley Interscience, 1956.

4. Encyclopedia of Polymer Science and Technology, Vol. 1 to XIV, H.F. Mark and N. Gaylord, Interscience, 2nd Ed. 1988.

5. Rubber Technology, C.M. Blow, Butter worth, London, 1980.

6. Text book of Polymer Chemistry, Dr. M. S. Bhatnagar, S Chand publication,2008.

7. Polymer Processing Technology, B. R. Gupta, Asian book PVT LTD.

PC 402: Special Topics in Polymers (60 h and 100 Marks)

Unit-I (12 h)

A.Polymer Recycling (05 h)

Introduction, Classification of recycling- primary, secondary, tertiary and quaternary recycling of plastics. Recycling codes

B. Natural Polymers (07 h)

Structure, properties and applications of shellac, lignin, starch and proteins.

Unit_II (12 h)

A. Rubbers: (08 h)

Natural rubber (polyisoprene cis), Gutta percha (polyisoprene trans)

Synthetic rubber:- Manufacture and physical properties of synthetic rubbers such as SBR, PBR, Nitrile, Butyl and Neoprene.

B. Chemical Modifications of Cellulose and Polystyrene (04 h)

Cellulose, polystyrene (ion exchange resins)

Unit-III (12 h)

A. Inorganic Polymers (06 h)

Polymer based on Boron, Silicon, Nitrogen, Phosporous, Co-ordination polymers.

B. Conducting and Biodegradable Polymers (06 h)

Polyaniline,
Poly(vinyl pyrolidone)
Poly(lactic acid) and its derivatives

Unit-IV (12 h)

Basics with examples of Polymer liquid crystals, Polyelectrolytes, Telechelic polymers, Ionomers biomedical applications of polymers (Hydrogels, transplantation, scaffolding, etc.) and hyperbranched and dendritic polymers.

Unit-V (12 h)

A. Non Petroleum based Raw Materials for Polymers – (06 h)

Vegetable oils (castor oil), terpenes, phenolics, carbohydrates, adipic acid, caprolactone, propane diol

B. Water Soluble Polymers.

Poly(ethylene oxide), poly(acrylic acid), polyacrylamide, polyethylenimine. (06 h)

Recommended Books

1. Principles of Polymerization: G. Odian, John Wiley & Sons, 2001.

2. Dendrimers and Hyperbranched Polymers Synthesis to Applications, N. Karak, S. Maiti, MD Publications Pvt. Ltd., New Delhi, 2008.

3. Dendrimers and Dendrons Concepts, Synthesis and Applications, G. R. Newkome, C. N. Moorefiled, F. Vogtle, Wiley-Vch, Germany, 2001

4. Polymer Chemistry-An Introduction, M. P. Stevens, Oxford University Press, 1990.

5. Polymer Chemistry-properties and applications, Andrew Peacock, Allison Calhoun, Hanser Publishers, Munich, 2006.

6. Principles of polym, P. Bahadur, N. V. Sastry, Narosa Publishing House, New Delhi, 2002.

7. Nabil Mustafa – "Plastics Waste Management" Marcel Dekker Inc.,1993.

8. Chandra R. and Adab A., Rubber and Plastic Waste, CBS Publishers & Distributors, New Delhi, 1994.

PC 403: Synthetic Polymers and Additives (60 h. and 100 Marks)

Part A: Synthetic Polymers

Chemistry, Technology of Production, Properties and Applications of

Unit-I **(12 h)**

Thermoplastic Polymers

Polyester:- PET, PBT

Polycarbonate

Poly(amides)

Fluorocarbons (PTFE)

Unit-II **(12 h)**

Thermosetting Polymers

Silicone - oil, rubber and resin

Unsaturated polyesters

Polyurethanes

Unit-III **(12 h)**

A. Modified Polymers (05 h)

Poly(vinyl alcohol),

Poly(vinyl acetals)

B. High Performance Thermoplastics (07 h)

PEEK,PPS, PPO, PEAK

Part B: Polymer Additives

Unit-IV **(12 h)**

A. Fillers

B. Plasticizers

C. Antioxidants

D. Heat Stabilizers

Unit-V **(12 h)**

A. Ultraviolet Stabilizers

B. Flame Retardants

C. Colorants

D. Miscellaneous Additives (lubricants)

E. Processing aid material

Recommended Books:

1. Encyclopedia of PVC, 2nd Ed., Edited by I Nass, Marcel Dekker Inc., New York.

2. Encyclopedia of Chemical Technology - Kirk and Othemer, Vol.- John Wiley

3. Rubber Chemistry and Technology – Britson

4. Additives for Plastic- Raymond B. Seymour

5. Plastics Materials, J. Brydson, Butterworths 4th Edn., London, 1989

6. Polymer Chemistry - M. P. Stevens, 2nd Ed., Oxford University Press, 1990.

7. Introduction to Polymer Chemistry - R.B. Seymour, Marcel Dekker, 3rd Ed., (1992)

8. Polymer Science and Technology of Plastics and Rubbers, Premamoy Ghosh, Tata McGraw-Hill Publishing Company Ltd., New Delhi, 1996.

9. Encyclopedia of Chemical Technology, Kirk and Othmer.

10. Plastics Materials, J. Brydson, Butterworths, &th Edn., London, 1999.

11. Organic Polymer Chemistry, V. Jain, IVY Publishing House, New Delhi,

PC 005: Laboratory Course in Polymer Chemistry- II **(Marks-100)**

(Minimum 14 practical are necessary)

1. Identification of polymers by flame tests & chemical test

2. Mastication of rubbers using two roll mill.

3. Vulcanization of rubbers using two roll mill.

4. Compression molding of thermoplastics

5. Study of injection molding of thermoplastics

6. Measurement of Tensile strength, Impact strength, Melt flow Index, Hardness, Flammability.

7. Determination of abrasion resistance

8. NMR studies of polymers.

9. IR studies of polymers

10. Study of extrusion

11. Coating of polymer films

12. Analyzing the coated film (Gloss, Scratch resistant, flexibility)

13. Determination of K value of PVC.

14. Determination of Chlorine content of PVC.

15. Determination of solvent absorption and equilibrium swelling

16. Viscosity measurement by Brook filed viscometer.

17. Determination of Heat distortion temperature and Vicat Softening Temperature.

18. Determination of static coefficient of friction

19. Determination of Number average molecular weight (VPO)

20. Molecular weight measurement by viscometry.

21. Thermal study of polymers by DTA, TGA, DSC. TMA.

22. Study of Mechanical and Rheological Properties of polymer composites filled with Nanoparticles using Brabander Plastograph EC.

References:

1. Experiments in Polymer Science, D. G. Hundiwale, V. D. Athawale, U. R. Kapadi, V. V. Gite, New Age International Pvt. Ltd., New Delhi, 2009.

2. Polymer Chemistry-Practical Approach in Chemistry, F. J. Davis, Oxford University Press, Oxford, 2004.

3. Polymer Science – V. R. Gowarikar, N. V. Viswanathan, Jayadev Shreedhar, New Age International Pvt. Ltd., New Delhi, 1997.

4. Principles of Polymerisation, P. Bahadur, N. V. Sastry, Narosa Publishing House, New Delhi, 2002.

PC 006: Project Work **(Marks-100)**

Students are required to work for a specific project under supervision of concerned faculty member. The allotment of the topic will be done in the initial period of third semester, so that students can start their work in the third semester itself. Each student is supposed to work for at least 60 hours for his/her project. At the last he/she has to submit his/her project report and present the work done at the time of viva voce.+