

**KONGUNADU ARTS AND SCIENCE COLLEGE (AUTONOMOUS)  
COIMBATORE – 641 029**

**Course Name: M.Sc Chemistry**

**Curriculum and Scheme of Examination under CBCS**

(Applicable to students Admitted from the Academic year 2014 – 2015 onwards)

Semester	Course code / Q.P.Code	Title of the Course	Instruction hours/cycle	Exam. Marks			Duration of Exam (Hrs)	Credits
				CIA	ESE	Total		
<b>I</b>	14PCH101	C.P.-1- Organic Chemistry - I	6	25	75	100	3	5
	14PCH102	C.P. 2 - Inorganic Chemistry - I	6	25	75	100	3	5
	14PCH1N1	NME-1 Non-Major Elective - I	5	25	75	100	3	5
		C.Pr.1 - Organic Chemistry Practical - I	4	-	-	-	-	-
		C.Pr.2 - Inorganic Chemistry Practical-I	4	-	-	-	-	-
		C.Pr.3 - Physical Chemistry Practical - I	5	-	-	-	-	-
<b>II</b>	14PCH203	C.P. 3 - Organic Chemistry - II	6	25	75	100	3	5
	14PCH204	C.P. 4 - Physical Chemistry - I	6	25	75	100	3	5
	14PCH2N2	NME-2 Non-Major Elective - II	5	25	75	100	3	5
	12PCH2CL	C.Pr.1 - Organic Chemistry Practical - I	4	40	60	100	6	3
	12PCH2CM	C.Pr.2 - Inorganic Chemistry Practical-I	4	40	60	100	6	3
	12PCH2CN	C.Pr.3 - Physical Chemistry Practical - I	5	40	60	100	6	4
<b>III</b>	14PCH305	C.P. 5 - Inorganic Chemistry - II	5	25	75	100	3	4
	14PCH306	C.P. 6 - Physical Chemistry - II	5	25	75	100	3	4
	14PCH307	C.P. 7 - Spectroscopy	5	25	75	100	3	4
	14PCH3E1	ME-1 - Major Elective - I	5	25	75	100	3	5
		C.Pr.4 - Organic Chemistry Practical - II	3	-	-	-	-	-
		C.Pr.5 - Inorganic Chemistry Practical-II	3	-	-	-	-	-
		C.Pr.6 - Physical Chemistry Practical- II	4	-	-	-	-	-
	Project Work	5 <sup>@</sup>	-	-	-	-	-	
<b>IV</b>	14PCH408	C.P.8 - Organic Chemistry - III	5	25	75	100	3	4
	14PCH409	C.P.9- Inorganic Chemistry-III	5	25	75	100	3	4
	14PCH410	C.P.10 - Physical Chemistry - III	5	25	75	100	3	4
	14PCH4E2	ME- 2 - Major Elective - II	5	25	75	100	3	5
	12PCH4CO	C.Pr.4 - Organic Chemistry Practical - II	3	40	60	100	6	3
	12PCH4CP	C.Pr.5 - Inorganic Chemistry Practical-II	3	40	60	100	6	3
	14PCH4CQ	C.Pr.6 - Physical Chemistry Practical- II	4	40	60	100	6	4
12PCH4Z1	Project Work & Viva -Voce	5 <sup>@</sup>	40	<b>160</b>	200 <sup>#</sup>	-	6	
<b>Total</b>						<b>2200</b>		<b>90</b>

**Major Electives papers**

**(2 papers are to be chosen from the following 4 papers)**

1. Physical Methods in Chemistry
2. Polymer science & Technology
3. Green and Nano Chemistry
4. Bio inorganic chemistry

**Non-Major Electives papers**

**(2 papers are to be chosen from the following 4 papers)**

1. Environmental chemistry
2. Scientific thesis writing & paper presentation
3. Agricultural Chemistry
4. Industrial Products

**Abstract**

S.No	Particulars of the Courses	No of courses	Marks	Credits	Total	
					Marks	Credits
01	<b>Core</b>				1800	70
	i. Theory	10	1000	44		
	ii. Practicals	06	600	20		
	iii. Project work	01	200	06		
02	Major Electives	02	200	10	200	10
03	Non-Major Electives	02	200	10	200	10
		<b>Total</b>			<b>2200</b>	<b>90</b>

**Extra credit courses**

JOB ORIENTED COURSE								
Semester	Course code / Q.P.Code	Title of the Course	Instruction	Exam. Marks			Duration of Exam(Hrs)	Credits
				CIA	ESE	Total		
	12PCH0J1	JOC - Pharmaceutical Chemistry	4	-	100	100	3	2
ADVANCED LEARNER COURSES (UNDER SELF STUDY SCHEME)								
	14PCH0D1	ALC- 1 Chemistry of Corrosion and its Prevention	-	-	100	100	3	2
	12PCH0D2	ALC- 2 Medicinal Chemistry	-	-	100	100	3	2
	14PCH0D3	ALC- 3 Food Chemistry	-	-	100	100	3	2

**CBCS – Choice Based Credit System:**      **CIA – Continuous Internal Assessment:**

**ESE – End-of-Semester Examination:**

25 % CIA is applicable to all subjects except JOC and ALC, which are considered as extra credit courses.

@ Project work is carried out outside the college hours in semesters III and IV

**JOC** is conducted for 4 hours per cycle outside the college hours.

Semester	Course code	Course Title
I	14PCH101	C.P-1 Organic Chemistry - I

**Credits: 5****Total teaching hours: 90****Objectives:**

- To motivate the students to comprehend a knowledge on aromaticity and reaction mechanism.
- To enable the students to elucidate the structure of some terpenoids compounds.
- On successful completion of the syllabus, the students should have learnt about addition reactions, electrophilic nucleophilic substitution reactions and name reactions.

**UNIT I: AROMATICITY****(18 hrs)**

Huckel's rule – aromaticity in 5, 6, 7 and 8 membered rings (recall). Aromatic systems with electron numbers other than six – systems of two electrons, four electrons (anti aromaticity), eight electrons, ten electrons and more than ten electrons- homo and heteroaromatic compounds – annulenes and hetero annulenes.

Structure and stability of carbocations, carbanions, free radicals, carbenes, nitrenes. Reaction mechanism: – study of intermediates, isotopic labeling, stereo chemical studies and cross over experiments, linear free energy relationship – Hammett equation – Hammonds postulate-Taft equation.

**UNIT II: ADDITION REACTIONS & ELECTROPHILIC SUBSTITUTION (18 hrs)**

Electrophilic and Nucleophilic additions – mechanism of addition of halogens and hydrogen halides on carbon – carbon double bond system. Aromatic Electrophilic Substitution-Arenium ion mechanism – orientation and reactivity in monosubstituted benzene rings – benzene rings with more than one substituent – effect of leaving group– o/p ratio.

Aliphatic electrophilic substitution:  $S_{E1}$ ,  $S_{E2}$  and  $S_{Ei}$  mechanisms. Structure reactivity relationship, solvent effect

**UNIT III: ELIMINATION REACTIONS & NUCLEOPHILIC SUBSTITUTION (18 hrs)**

Elimination - Mechanism –  $E1$ ,  $E2$ ,  $Ei$ ,  $E1CB$  mechanisms-evidences, stereochemistry of eliminations, orientation, Hoffman and Saytzeff rules, elimination vs. substitution, pyrolytic elimination.

Aromatic Nucleophilic substitution – mechanism –  $S_{NAr}$  –  $S_{N1}$  –  $S_{Ni}$ , Benzyne – Reactivity – effect of substrate, leaving group and attacking nucleophile.

Neighbouring group mechanism – NGP by  $\pi$  and  $\sigma$  bonds (non classical carbocations) – Reactivity – effect of substrate, attacking nucleophile, leaving group and reaction medium – substitution at vinylic, trigonal and allylic carbons.

**UNIT IV: SELECTED ORGANIC NAME REACTIONS****(18 hrs)**

Stark enamine reaction, Michael addition, Mannich reaction, Sharpless asymmetric epoxidation, Ene reaction, Hunsdiecker reaction, Shapiro reaction, Baeyer-villegar oxidation, Chichibabin reaction, Meerwin- Ponndorf-verly reduction, Robinson annelation, Birch reduction, aldol addition and condensation.

**UNIT – V: TERPENES****(18 hrs)**

Isolation and classification of terpenes, structural elucidation and synthesis of Camphor, Zingiberene, Eudesmol, Abeitic acid.

**REFERENCE BOOKS**

1. Jerry March, Advanced Organic Chemistry, Wiley eastern limited, Fourth Edition, New Delhi, 1999.
2. I.L. Finar – Organic Chemistry, Vol.I, 6<sup>th</sup> Edition, Addison Wesley Longman Ltd.
3. I.L. Finar – Organic Chemistry, Vol.II, 5<sup>th</sup> Edition, Addison Wesley Longman Ltd.
4. W.Carruthers., Modern Methods of Organic synthesis, Publisher, Cambridge University Press, 2004
5. J.N.Gurtu and R.Kapoor, Organic reactions and reagents, S. chand & Co. (P)
6. Clayden, Greeves, Warren, Organic Chemistry, Oxford University Press, 2001.
7. P.S. Kalsi- Organic Reaction Mechanism, New Age international publishers, India, 2000.
8. V.K.Ahluwalia and Rakesh kumar Parashar-Organic reaction mechanisms, 3<sup>rd</sup> edition, Narosa publishing house.
9. O. P. Agarwal – Natural product Chemistry, 20<sup>th</sup> Edition, Goel Publishing house
10. F.A.Carey, Organic Chemistry-Part-B-Reactions and synthesis, Plenum press, 5<sup>th</sup> edition 1997.
11. Raj. K. Bansal, Organic Reaction Mechanism, Tata McGraw Hill, New Delhi, 1990.
12. P.Sykes, A Guidebook to Mechanism in Organic Chemistry, 6<sup>th</sup> edition, Orient Longman Private limited, New Delhi, 1988
13. O.P.Agarwal, Organic Chemistry, Edition, 4. Publisher, Goel Pub. House, 1975.
14. Jagdamba Singh, L. D. S. Yadav - Advanced Organic Chemistry, Second Revised edition, Pragati Prakashan Educational publications, Meerut, India, 2006.
15. Gurdeep Chatawal – Organic Chemistry of Natural Products Vol I & II, Himalaya Publishing House, 2001

Semester	Course code	Course Title
I	14PCH102	C.P-2 Inorganic Chemistry - I

**Credits: 5****Total teaching hours: 90****Objectives:**

- To introduce the principles and applications of solid state and nuclear chemistry.
- On successful completion of the syllabus, the students should have learnt about periodic properties and f block elements, nuclear model, modes of decay and detection, measurement of radio activity, nuclear reactors and applications

**UNIT I: PERIODIC PROPERTIES AND THEORY OF ACIDS AND BASES (18 hrs)**

Periodic properties of atoms – ionization energy – electron affinity – Pauling's and modern scales of electronegativity – Acid-base concept – measure of acid and base strength – non-aqueous solvents  $\text{NH}_3, \text{H}_2\text{SO}_4, \text{HF}, \text{N}_2\text{O}_4, \text{SO}_2$  – superacids – hard and soft acids bases – theory and applications.

**UNIT II: STRUCTURE AND BONDING (18 hrs)**

Introduction– close packing of atoms and ions – bcc, fcc and hcc voids –radius ratio rule – derivation – its influence on structures – structures of NaCl, CsCl, rutile, fluorite, antiferite, zinc blende, wurtzite,– spinels – normal and inverse spinels and perovskite – lattice energy of ionic crystals – Madelung constant – Born Haber cycle and its applications. VSEPR theory with applications to inorganic compounds.

Solid state defects - Stoichiometric and non-stoichiometric defects- electrical properties of solids – insulators –intrinsic and extrinsic semiconductors (n and p type), band theory - superconductors.

**UNIT – III SOLID STATE AND CRYSTALLOGRAPHY (18 hrs)**

Lattices and unit cells- the crystal systems and Bravais lattices – Miller indices and labeling of planes – symmetry properties – crystallographic point groups and space groups. Fundamentals of X-ray diffraction – powder and rotating crystal methods – systematic absences and determination of lattice type – analysis of X-ray data for cubic system – structure factor and fourier series–electron and neutron diffraction.

**UNIT IV: NUCLEAR CHEMISTRY (18 hrs)**

Radioactivity – decay constant – half-life period – artificial transmutation – G.M. Counter – Scintillation counter – nuclear forces – nuclear fission and fusion reactions – nuclear models-single particle –liquid drop – nuclear accelerators – linear accelerators – cyclotron, synchrocyclotron, betatron – nuclear reactors – fast breeder reactors – power reactors - radioisotopes and their applications-radioactive isotopes as tracers, analytical, medicinal, agriculture.

**UNIT V: CHEMISTRY OF f-BLOCK ELEMENTS****(18 hrs)**

Lanthanide series – electronic configuration – oxidation states – magnetic properties – colour – ionic radii – lanthanide contraction – chemical reactivity and complex formation – extraction of a mixture of lanthanides from monazite sand – separation of lanthanides – ion exchange method. Actinide series – sources of actinide – preparation of transuranic elements – electronic configurations – oxidation state – colour and complex formation – extraction of thorium from monazite sand and isolation of uranium from pitchblende- comparison of lanthanides and actinides, uses of lanthanides and actinides.

**REFERENCE BOOKS:**

1. H.J. Arnika, Essential of Nuclear chemistry 4<sup>th</sup> Edition, 1997, New Age International Publishers.
2. U. N. Dash, Nuclear Chemistry 1<sup>st</sup> Edition, 1971.
3. Gurdeep Raj, Advanced Inorganic Chemistry, Vol-I & II Goel Publishing House.
4. Lesly Smart Elain, Moore, Solid State Chemistry, Edition, 2, reprint. Publisher, Chapman & Hall, 1995.
5. Malik, Tuli, Madan , Selected topics in inorganic chemistry, 5<sup>th</sup> edition, S. Chand.
6. Azaroff.L. Introduction to Solids, Tata McGraw Hill Publishing Company, 1995.
7. Cotton F.A.and G.Wilkinson, Advanced Inorganic Chemistry, Fifth edition, John Wiley & Sons, Inc., 1988.
8. James E.Huheey, Inorganic Chemistry, Fourth edition, HarperCollins College Publishers, 1993.
9. Lee J. D, Concise Inorganic Chemistry, Fifth edition, ELBS, 1994.
10. Basolo, and Pearson, Ralph. G, Mechanism of Inorganic Reactions- A study of metal complexes in solution. Wiley Eastern, New Delhi,1984.
11. Keith F. Purcell and John C.Kotz, Inorganic Chemistry, W.B.Saunders Company, 1997.
12. Jolly, William L, Modern inorganic chemistry, Mcgraw-Hill, New York, 1985.

Semester	Course code	Course Title
II	14PCH203	C.P-3 Organic Chemistry - II

**Credits: 5****Total teaching hours: 90****Objectives:**

- To give a thorough introduction to the study of organic photochemistry.
- To enable a comprehensive knowledge on conformational analysis and stereochemistry, concerted reactions and pericyclic reactions of organic compounds to the students,
- To give an idea about functional group interconversions.
- On successful completion of the syllabus, the students should have understood the mechanism of elimination reactions, free radical reactions, isolation, general structural elucidation and general bio synthesis of alkaloids.

**UNIT – I: CONFORMATIONAL ANALYSIS AND STEREOCHEMISTRY (18 hrs)**

Fischer- Newman and Sawhorse projection-R and S notation: stereochemistry of sulphur and nitrogen compounds, geometrical isomerism – E & Z configuration - stereoselective and stereospecific synthesis- asymmetric synthesis -conformation and reactivity in cyclic systems – cyclohexanes (mono,di-substituted), decalins, perhydrophenanthrene, perhydroanthracene, conformation and reactivity in acyclic systems.

**UNIT – II: ORGANIC PHOTOCHEMISTRY: (18 hrs)**

Laws of photochemistry: Beer-Lambert, Grothus-Draper laws, light absorption, electronic excitation, quantum yield, physical and chemical actinometry, Jablonski diagram, photosensitization, photophysical processes, energy transfer, photochemical reactions of ketones, Norrish type I and type II reactions, Paterno-Buchi reaction, photoreduction, photo oxidation, Cis and trans isomerization, photochemistry of arenes and di- $\pi$  methane rearrangement, Zimmerman rearrangement.

**UNIT – III: CONCERTED REACTIONS: (18 hrs)**

Conservation of orbital symmetry – Woodward-Hoffman selection rule for electrocyclic reaction, cycloaddition reaction, sigmatropic rearrangement.

Electrocyclic reactions – 1,3-diene and 1,3,5-triene, analysis of stereochemistry using correlation diagram and FMO method.

Cycloadditions: ( $\pi 2s + \pi 2s$ ) Correlation and FMO approach, ( $\pi 2s + \pi 4s$ )- Diels-Alder reactions – analysis of stereochemistry by correlation diagram and FMO methods.

Sigmatropic rearrangements – analysis of sigmatropic rearrangements by FMO method-1,3&1,5-sigmatropic rearrangements – other sigmatropic shifts- Cope and Claisen rearrangements, the perturbation theory of pericyclic reactions. (Basic ideas only), 1,3 dipolar addition.

**UNIT-IV: SYNTHETIC METHODOLOGY****(18 hrs)**

Retro synthetic approach - synthons – guidelines for disconnections - functional group interconversion- one group c-x disconnection –1,1- 1,2 and-1,3-two group c-x disconnections- one group disconnection C-C, alcohols, carbonyl,– regio selectivity – use of acetylenes, aliphatic nitro compounds in organic synthesis- reversal of polarity- order of events.

**UNIT – V: ALKALOIDS****(18 hrs)**

Isolation and general structural methods of elucidation of alkaloids, structural elucidation and synthesis of Morphine, Reserpine, Atropine and Quinine. Biosynthesis of alkaloids (General principles only).

**REFERENCE BOOKS:**

1. P. S. Kalsi. Stereochemistry, Conformation and Mechanism (3<sup>rd</sup> edn.), John Wiley (1995).
2. Ernest.L.Eliel, Stereochemistry of carbon compounds, McGraw-Hill, New York, 1962. Xv-486 pp.
3. D. Nasipuri, Stereochemistry of organic compounds, Publisher, New Age International, 1994.
4. Jerry March, Advanced organic chemistry, 4<sup>th</sup> Edition, A Wiley Interscience Publication
5. Jagdamba Singh, L. D. S. Yadav, Organic Synthesis, Pragati Prakashan Educational Publications, Meerut, India, 2006.
6. J.M. Coxon and B. Halton, Organic Photochemistry, Cambridge University Press; 2<sup>nd</sup> edition, 1974.
7. Jagdamba singh, Photo Chemistry, Publisher, New Age International, 2005.
8. Stuart Warren, Organic Synthesis- The disconnection approach, Wiley; Student edition, 1984.
9. N. J. Turro, Molecular photochemistry, W.A. Benjamin, Inc; 1st edition, 1965.
10. W.A. Pryer, Introduction to free radical chemistry, Prentice-Hall, 1966
11. C.H. DePuy and D. Chapmann, Molecular reactions and photochemistry, Prentice Hall, 1972
12. Jagdamba Singh, L. D. S. Yadav, Advanced Organic Chemistry, Pragati Prakashan Educational publications, Meerut, India, 2004
10. O. P. Agarwal, Natural product Chemistry, 20<sup>th</sup> Edition, Goel Publishing house
11. Gurdeep Chatawal, Organic Chemistry of Natural Products Vol I & II, Himalaya Publishing House, 2001.



Semester	Course code	Course Title
II	14PCH204	C.P-4 Physical Chemistry - I

**Credits: 5****Total teaching hours: 90****Objectives:**

- To motivate the students to comprehend a knowledge on symmetry elements and symmetry operations.
- To introduce the principles of chemical kinetics to allow exploration of gas-phase and liquid-phase reactions.
- On successful completion of the syllabus, the students should have learnt the concepts of Group theory, chemical kinetics, catalysis and adsorption.

**UNIT – I GROUP THEORY-I:****(18 hrs)**

Symmetry elements and symmetry operations, identity element, centre of symmetry, plane of symmetry, proper and improper axes of symmetry, groups – definition, properties, types of groups- Abelian group, non-abelian group, sub group, isomorphic group – similarity transformation and classes – group multiplication table for  $C_{2v}$  and  $C_{3v}$  point group – symmetry classification of molecules into point groups (Schoenflies symbol only). Group theory and dipole moment.

Matrices: definition of matrix, types -square, diagonal, null, unit, row, column, symmetric and skew symmetric- addition and subtraction of matrices – matrix representations of symmetry operations.

**UNIT – II-GROUP THEORY-II****(18 hrs)**

Representation of point groups - definition, types (reducible and irreducible representations), the Great orthogonality theorem, significance and its consequences (proof not needed), character tables-construction of the character table for  $C_{2v}$  and  $C_{3v}$  point group, reduction of reducible representations.

Application of group theory to bonding: hybridization scheme for orbital in  $AB_3$  (planar),  $AB_4(T_d)$ ,  $AB_5(D_{3h})$  and  $AB_6(O_h)$  type of molecules.

Group theory and vibrational spectroscopy – direct product representation, vibrational modes as basis for group representation, symmetry selection rule for IR and Raman spectra (mutual exclusion principle), classification of vibrational modes.

**UNIT – III CHEMICAL KINETICS-I****(18 hrs)**

Theories of reaction rates – Arrhenius theory, collision theory- classical collision theory, modified collision theory, weaknesses of collision theory, Absolute reaction rate or Transition state theory, statistical mechanical derivation of the rate equation, thermo dynamical formulation of reaction rate, comparison of collision theory and absolute reaction rate theory.

Reactions in solutions: collision in solution, Cage effect, salt effect- primary salt effect and secondary salt effects, significance of salt effect. Effect of pressure on rates of reactions in solutions, Linear Free Energy Relationship (LFER) - Hammett equations, Kinetic Isotope effects.

#### **UNIT – IV CHEMICAL KINETICS-II**

**(18 hrs)**

Homogenous catalysis – specific and general acid-base catalysis, Bronsted catalysis law, acidity functions, enzyme catalysis – Michaelis-Menton law – influence of pH and temperature on enzyme catalysis.

Surface phenomenon and heterogenous catalysis – adsorption and free energy relation at interfaces - physisorption and chemisorptions, adsorption isotherms – Langmuir, Freundlich, BET and Gibb’s adsorption isotherm, measurement of surface area, kinetics of heterogeneous catalysis - Langmuir-Hinshelwood, Langmuir-Rideal (Rideal-Eley) mechanisms.

#### **UNIT -V POLYMER KINETICS**

**(18 hrs)**

Classification of polymers-kinetics and mechanism of polymerization-free radical, ionic and co-ordination, Ziegler-Natta polymerization-degree of polymerization-molecular weights and their determination-average molecular weight –number average and weight average molecular weight-sedimentation and viscosity average molecular weights – kinetics of free radical chain polymerization (derivation of rate equation, kinetic chain length and degree of polymerization), process of polymerization – bulk, solution, suspension and emulsion.

#### **REFERENCE BOOKS**

1. Gurdeep Raj, Chemical kinetics, 6<sup>th</sup> Edition, Goel Publishing House
2. K.V.Raman, Group Theory and its applications to chemistry, Tata McGraw Hill publishing company Ltd,1996.
3. P.K.Bhattacharya, Group theory and its chemical applications, Publisher, Himalaya Publishing House, 1986. Length, 205 pages.
4. V. R. Gowariker & N. V. Viswanathan, Polymer Science 1<sup>st</sup> Edition, New Age International Private Ltd.
5. W. J. Moore, Physical Chemistry, 5<sup>th</sup> Edition, Orient Longman Ltd
6. P.W.Atkins, Physical Chemistry, 6<sup>th</sup> Edition, Oxford University Press.
7. A. A.Frost and R. G. Pearson, Kinetics and mechanism, Wiley Eastern Pvt. Ltd.
8. F. A. Cotton, Chemical applications of group theory, 3<sup>rd</sup> Edition, A Wiley Interscience Publication
9. Veera Reddy, Symmetry and Spectroscopy of molecules, New Age International (1998).
10. K. J. Laidler, Chemical kinetics, 2<sup>nd</sup> Edition, Tata McGraw Hill Ltd.

Semester	Course code	Course Title
I & II	12PCH2CL	C.Pr-1 Organic Chemistry Practical- I

**Credits: 3****Total Hours: 120****Objectives**

- To make the students aware about separation of mixture of organic compounds and analyzing the unknown compounds.
- To allow the students to know and practice the techniques of preparation of some organic compounds.

**A. Analysis of two component organic mixtures**

(Separation and characterization of individual compounds)

Note: Each student has to complete the analysis of minimum of FIVE Mixtures during the course

**B. Single stage Preparations****1. Hydrolysis:**

Preparation of Salicylic acid from Methyl Salicylate.

**2. Acetylation:**

Preparation of Acetanilide from Aniline.

**3. Bromination:**

Preparation of p-Bromoacetanilide from Acetanilide.

**4. Nitration:**

Preparation of m-dinitrobenzene from nitrobenzene.

**5. Benzoylation:**

Preparation of Benzanilide from Aniline.

**6. Oxidation:**

Preparation of Benzoic acid from Benzaldehyde.

7. Preparation of Glucose penta acetate.

8. Preparation of Diphenyl hydration from Benzil and urea.

**REFERENCES**

1. Gnanprakasam and Ramamurthy, Organic Chemistry Laboratory Manual, Ananda Book Depot, Chennai.
2. NK Vishnoi, Advanced Practical Organic Chemistry, Vikas Publishing House, 1992.
3. R. Jagmohan Advanced Practical Organic Chemistry, Vol. I & II.

**Distribution of Marks**

Internal (Maximum 40)	ESE (Maximum 60)
1. CIA Practical exam – 25	1. Qualitative analysis – 30
2. Observation note book – 10	2. Preparation of an organic compound – 10
3. Attendance – 5	3. Record – 10
	4. Viva-Voce - 10

Semester	Course code	Course Title
I & II	12PCH2CM	C.Pr-1 Inorganic Chemistry Practical- I

**Credits: 3****Total Hours: 120****Objectives**

- To give an idea to the students about the separation and analysis of cations from the mixture of common and rare cations.
- To allow the students to know and practice the techniques in preparation of some inorganic complexes.
- To make the students apply colorimetric principle in estimation of metal ions.

**A. Semimicro Qualitative Analysis:**

Analysis of mixtures of common metal cations and the following less familiar metal cations - Thallium, Tungsten, Selenium, Tellurium, Molybdenum, Cerium, Thorium, Titanium, Zirconium, Vanadium, Beryllium, Uranium and Lithium.

**Note:** A minimum of FIVE inorganic mixtures, each containing of two common and two less familiar metal cations has to be analyzed by each student during the course.

**B. Preparation of complexes**

**Any Five preparations selected from the following list:**

Lead tetraacetate, Dipyrindiniumhexachloroplumbate, Hydroxylaminehydrochloride, Ortho and para – hydroxy phenyl mercuric chloride, Potassium cupric chloride, Chrome alum Copper (I) Chloride, Trithio urea copper(I), Potassium trioxalato – aluminate(III), Potassiumtrioxalatochromate(III), Potassiumtrioxalatoferrate(III), hexaminecobalt(III)chloride, Chloropentamminechromium(III)chloride, Aquo pentammine chromium (III) nitrate, Tetramminecopper(II)Sulphate, Ammonium hexachloro stannate (IV).

**C. Colorimetric Estimations (using photoelectric colorimeter)**

Estimation of Copper, Iron, Nickel, Manganese and Chromium

**TEXT BOOKS**

1. V.V.Ramanajum, Semimicro Qualitative Inorganic Analysis.
2. V.Venkateswaran, R.Veerawamy and A.R. Kulandaivelu, Principles of Practical Chemistry Sultan Sultan Chand & Sons. (1997) Edition II
3. S.Giri. D.N. Bajpai.and O.P. Panday, Practical Chemistry Vol.I & II, S.Chand & Co

**Distribution of Marks**

Internal (Maximum 40 marks)	ESE (Maximum 60 marks)
1. CIA Practical exam – 25	1. Qualitative analysis – 20
2. Observation note book – 10	2. Preparation of an Inorganic compound – 10
3. Attendance – 5	3. Colorimetric Estimation - 10
	4. Record – 10
	5. Viva-Voce - 10

Semester	Course code	Course Title
I & II	12PCH4CQ	C.Pr-1 Physical Chemistry Practical- I

**Credits: 4****Total Hours: 150****Objectives:**

- To promote an awareness about potentiometric titrations to the students.
- On successful completion of the syllabus, the students should have known to interpret, evaluate and report upon observations and experimental results of determination of molecular weight, partition coefficient, unknown composition in Simple Eutectic System and acid-base, precipitation and redox titrations.

**Non Electrical Experiments****1. Properties of Matter-**

Simple Eutectic System- determination of unknown compositions

**2. Molecular weight determination-**

Determination of Molecular weight by Rast's macro method

**3. Partition coefficient-**Determination of Equilibrium Constant for the reaction  $KI + I_2 \leftrightarrow KI_3$ **Electrical Experiments –Potentiometric Titrations:****A. Acid-Base titrations**(using quinhydrone electrode )

- Titration of Strong acid against Strong base
- Titration of Weak acid against Strong base
- Titration of mixture of(strong & weak) acids against Strong base
- Determination of pH (acidic solutions)
- Determination of pKa of weak acid

**B. Precipitation titrations** (using silver electrode)

- Titration of Potassium chloride against Silver nitrate
- Titration of mixture of halides (chloride and iodide) against Silver nitrate

**C. Redox titrations**

- Titration of Potassium Iodide against Potassium Permanganate
- Titration of Ferrous Ammonium Sulphate against Potassium dichromate

**REFERENCES**

- S.R. Palit and S.K. De, Practical Physical Chemistry, Science Book Agency, Calcutta
- P.C. Sharma and Agarwal, Practical Chemistry, Goel Publishing House, Meerut.
- V. Venkateswaran and A.R. Kulaindaivelu, Practical Physical Chemistry S.Chand & Co.
- Yadav, Practical Physical Chemistry S.Chand & Co

Internal (Maximum 40 marks)	ESE (Maximum 60 marks)
1. CIA Practical exam – 25	1. Experiment – 40
2. Observation note book – 10	2. Record – 10
3. Attendance – 5	3. Viva-Voce - 10

Semester	Course code	Course Title
III	14PCH305	C.P-5 Inorganic Chemistry - II

Credits: 4

Total teaching hours: 75

**Objectives:**

- To promote an awareness about bonding in coordination complexes to the students.
- To allow the students to get introduced to acid base concepts and chemistry of some important solvents.
- On successful completion of the syllabus, the students should have known about theories of bonding in inorganic complexes and application, substitution reaction mechanism of coordination complexes, electron transfer mechanism of coordination complexes and magnetic behavior.

**UNIT-I: INTRODUCTION TO CO-ORDINATION COMPOUNDS (15 hrs)**

Recall the nomenclature of coordination compounds- types of ligands - coordination number – geometries– stereochemistry and isomerism–constitutional, geometrical and optical- coordination numbers 4 and 6 –theories of bonding - CFT – crystal field splitting in octahedral, square planar, tetrahedral complexes – CFSE- factors influencing the magnitude of  $\Delta_0$  – applications of CFT – Jahn-Teller distortions - limitations - LFT and MOT- applications to octahedral complexes – ( $\sigma$  - bonding) – tetrahedral, square planar complexes – comparison of different theories - stabilization of unusual oxidation states by coordination, applications of ORD.

**UNIT II: MAGNETIC PROPERTIES & ELECTRONIC SPECTRA OF METAL COMPLEXES (15 hrs)**

Magnetic properties of tetrahedral and octahedral complexes- spin cross over rule - microstates of electron configuration in free atoms and ions –term symbols for equivalent and non-equivalent electrons- possible term symbols for given configuration –  $p^2$  -  $d^2$  – splitting of terms in square planar, tetrahedral , octahedral fields- Electronic spectra of various complexes – selection rules - spin orbit coupling -assignment and intensities of transitions – Orgel ( $d^1$  to  $d^9$  octahedral and tetrahedral complexes) and Tanabe Sugano diagrams( $d^1$  , $d^6$  complexes and its applications)- calculation of  $\Delta_0$  and  $\beta$  and Racah parameters – examples from  $d^2$  ,  $d^3$  ,  $d^7$  ,  $d^8$  octahedral complexes- CT spectra of metal complexes.

**UNIT III: REACTION MECHANISM OF METAL COMPLEXES – I (15 hrs)**

Ligand substitution reactions in octahedral, square planar complexes- labile and inert complexes– dissociation, association mechanism – Mechanism of hydrolysis reactions – acid hydrolysis – base hydrolysis – anation reactions – trans effect –trans influence–trans effect and its application-theories of trans effect- Thermodynamic and kinetic stability of complexes –

factors affecting stability of metal complexes – experimental determination of stability constant of complexes.

**UNIT IV: REACTION MECHANISM OF METAL COMPLEXES – II (15 hrs)**

Electron transfer reactions – one electron transfer reactions – inner sphere mechanism – outer sphere mechanism - two electron transfer reactions – complementary and non – complementary electron transfer reactions -synthesis of coordination compounds using electron transfer reactions-- metal assisted reactions – Aldol condensation – ester hydrolysis – phosphate ester, aminoesters and amide hydrolysis – template effect – synthesis of macrocyclic ligands – reaction of coordinated ligand .

**UNIT V: CHARACTERIZATION OF INORGANIC COMPOUNDS (15 hrs)**

NQR- Principle-effect of magnetic field (Zeeman Effect) on spectral characteristics-applications- biomolecules. Photoelectron spectroscopy-Theory of XPS and UPS-determination of ionization potential- chemical identification of elements-ESCA-chemical shift.

F<sup>19</sup>, P<sup>31</sup> NMR, IR and Raman applications in the structural problem solving of inorganic compounds.

**REFERENCE BOOKS:**

1. Cotton F.A.and G.Wilkinson, Advanced Inorganic Chemistry, Fifth edition, John Wiley & Sons, Inc., 1988.
2. James E.Huheey, Inorganic Chemistry, Fourth edition, HarperCollins College Publishers, 1993.
3. Lee J. D, Concise Inorganic Chemistry, Fifth edition, ELBS, 1994.
4. Basolo, and Pearson, Ralph. G, Mechanism of Inorganic Reactions- A study of metal complexes in solution. Wiley Eastern, New Delhi,1984.
5. Keith F. Purcell and John C.Kotz, Inorganic Chemistry, W.B.Saunders Company, 1997.
6. Malik, Tuli, Madan , Selected topics in inorganic chemistry, 5<sup>th</sup> edition, S. Chand&Co., New Delhi.
7. Russel S. Drago, Physical Methods in Inorganic Chemistry, Affiliated East-West Press Pvt. Ltd., New Delhi, 1968.
8. S. FA. Kettle, Co-ordination Compounds
9. H.J. Emeleus and A.J. Sharpe, Modern aspects of Inorganic Chemistry, 1973, ELBS.

Semester	Course code	Course Title
III	14PCH306	C.P-6 Physical Chemistry - II

**Credits: 4****Total teaching hours: 75****Objectives:**

- To enable a comprehensive knowledge on quantum mechanics to the students.
- To give a thorough introduction to the study of electrochemistry.
- On successful completion of the syllabus, the students should have understood quantum theory, Schrödinger equation, approximation methods, theories of double layer and electrophoresis.

**UNIT – I: FUNDAMENTALS OF QUANTUM CHEMISTRY: (15 hrs)**

Success of quantum theory and the failure of classical mechanics in explaining black-body radiation, photo-electric effect and the H-atom spectrum - DeBroglie's matter waves, Heisenberg's uncertainty principle. Postulates of quantum mechanics, the time-dependent and time-independent Schrodinger equations, Born's interpretation of the wave function and requirements of the acceptable wave function. Operators- sum and product, commutator, linear, Hamiltonian and angular momentum- eigen functions and eigen values, correspondence between physical quantities in classical mechanics and operators in quantum mechanics, quantization of angular momentum and its spatial orientation, average (expectation) values.

**UNIT – II: QUANTUM MECHANICS OF SIMPLE SYSTEMS (15 hrs)**

Particle in a 1-D and 3-D box- quantization of energy, normalization of wave function, orthogonality. Harmonic oscillator model of a diatomic molecule, solving of Schrodinger equation for the one-dimensional harmonic oscillator, illustration of the uncertainty principle and correspondence principle with reference to harmonic oscillator. Rigid rotor model of a diatomic molecule, solving of Schrodinger equation for a rigid rotor, Schrodinger equation for the H – atom (or H - like species) separation of variables (solving of radial equation is not needed but nature of solution is given).

**UNIT – III: APPLICATIONS OF QUANTUM CHEMISTRY (15 hrs)**

Electron spin, He atom and the Pauli principle, antisymmetric nature of the wave functions, Slater determinants, approximate wave function of many electron atoms.

Need for approximation methods - The perturbation theory (first order only), application of the perturbation method to He atom, the variation method, application of variation method to He atom, Born – Oppenheimer approximation, treatment of the  $H_2^+$  ground state by LCAO–MO method.



**UNIT – IV: ELECTROCHEMISTRY-I**

**(15 hrs)**

Interionic attraction theory, Debye-Huckel-Onsager equation, derivation, verification and validity of DHO equation, Falkenhagen effect, Wien effect, activity and activity co-efficient, ionic strength, Debye-Huckel limiting law and its applications.

Electrokinetic phenomena: theories of double layer - Helmholtz-Perrin, Gouy-Chapmann & Stern theories - Butler-Volmer equation.

**UNIT – V: ELECTROCHEMISTRY-II**

**(15 hrs)**

Electrolytic oxidation and reduction, voltametry, cyclic voltametry and polarography, current-voltage relationship, dropping mercury electrode, diffusion current, factors affecting diffusion current, Ilkovic equation (derivation not necessary), half-wave potentials, applications of polarography, amperometric titrations.

Fundamental principles of coulometric methods, constant current and controlled – potential methods, primary and secondary titrations – simple applications.

**REFERENCE BOOKS:**

1. R. K. Prasad, Quantum Chemistry, New Age International Publishers, 2001.
2. S. Glasstone, Introduction to electrochemistry, 10<sup>th</sup> Edition, East West Press Private Ltd.
3. B.R. Puri & L R. Sharma, Advanced Physical Chemistry, 2009 Edn., Milestone Publishers & Distributors
4. Ira. N. Levine, Quantum Chemistry, Prentice Hall; 5<sup>th</sup> edition 1999
5. Ira. N. Levine, Physical Chemistry, 3<sup>rd</sup> Edition, McGraw-Hill Book Company, 1971
6. P. W. Atkins, Physical Chemistry, 6<sup>th</sup> Edition, Oxford University Press
7. A.K. Chandra, Quantum chemistry, Tata McGraw-Hill, 1974.
8. W. J. Moore and R. G. Pearson, Kinetics and mechanism, Wiley 3<sup>rd</sup> edition, 2004.
9. Mc. Quarrie and Simon, Physical Chemistry: A molecular Approach, Viva Publishing House New Delhi, 2001.
10. W. J. Moore – Physical Chemistry, Wiley; 3<sup>rd</sup> edition, 2004.
11. L. I. Andropov, Theoretical Electrochemistry, Mir Publishers, Moscow.

Semester	Course code	Course Title
III	14PCH307	C.P- 7 Spectroscopy

**Credits: 4****Total teaching hours: 75****Objective**

- To interpret and solve problems using various spectra.
- Spectroscopic methods are very useful in structural determination of unknown compounds. On successful completion of the syllabus, the students should have acquired knowledge in various spectroscopic methods.

**UNIT - I: MICROWAVE AND IR SPECTROSCOPY****(15 hrs)**

Rotational microwave spectroscopy- Rigid diatomic molecule-selection rule-effect of isotopic substitution-non rigid rotator-force constant-centrifugal distortion constant D – application of rotational spectra.

IR Spectroscopy- The vibrating diatomic molecule-the simple harmonic oscillator- selection rules-the diatomic rotator-vibration of polyatomic molecule (fundamental vibrations and their symmetry)-overtone and combination frequencies - Molecular vibrations -factors influencing vibrational frequencies- - force constant-identification of functional groups, hydrogen bonding and IR spectra, finger print region - Fermi Resonance -applications of infrared to organic compounds.

**UNIT – II: UV AND VISIBLE SPECTROSCOPY****(15 hrs)**

Theory- laws of photochemistry - electronic spectra of diatomic molecules-Born-Oppenheimer approximation- intensity of vibrational electronic spectra– Franck-Condon principle-selection rules–dissociation energy- Fortrat diagram-predissociation-types of transition-auxochromes and chromophores, Woodward-Fieser rules for calculating absorption maximum of dienes, polyenes and  $\alpha$ ,  $\beta$ -unsaturated ketones.

**UNIT – III: MASS SPECTROMETRY****(15 hrs)**

Presentation of mass spectrum-instrumentation-double focusing mass spectrometer-ion source-mass analyzers-ion detectors, types of ions-molecular ion, fragment ion, rearrangement ion, metastable ion, odd and even electron ions, molecular ion peak, base peak and metastable ion peak, determination of molecular formula-Nitrogen Rule, isotopic peak abundance, Retro-Diels Alder Reaction, McLafferty rearrangement, Ortho elimination- double hydrogen rearrangement, double bond and ring equivalence.

Fragmentation associated with functional groups (aliphatic and aromatic) – hydrocarbons, unsaturated hydrocarbons, aldehydes, ketones, carboxylic acids, esters, amides, alcohols, thiols, amines, ethers, sulphides and halides

**UNIT – IV: NUCLEAR MAGNETIC RESONANCE -<sup>1</sup>H NMR (15 hrs)**

Magnetic properties of nuclei – theory of nuclear resonance, Instrumentation, Relaxation mechanisms (spin-spin & spin-lattice)- Chemical shifts- Electronegative effect, shielding effect, Hydrogen bonding effect, Anisotropy, spin-spin coupling, geminal, vicinal, Long range, deuterium exchange – solvents used in NMR, non-first order NMR spectra- AB, ABC, A<sub>2</sub>B<sub>2</sub>, and ABX spectra, simplification of complex spectra- chemical shift reagents, double resonance (NMDR), magnetic field strength, Nuclear Overhauser Effect (NOE), dynamic NMR Applications of NMR to organic compounds.

**UNIT – V: <sup>13</sup>C NMR (15 hrs)**

Sensitivity, differences between <sup>13</sup>C NMR and <sup>1</sup>H NMR, measurement of <sup>13</sup>C NMR spectra, solvents, Types of <sup>13</sup>C NMR spectra - fully coupled, proton noise decoupled (fully decoupled), off resonance decoupled spectrum, DEPT, intensity of signals, carbon chemical shift- inductive effect, resonance effect, hydrogen bonding, heavy atom effect, substituent effects  $\gamma$ -gauche effect,  $\gamma$ -Anti effect.

2D NMR spectroscopy: Theory, basic components of two-dimensional experiment, Homonuclear Correlation Spectroscopy (H, H-COSY), Heteronuclear correlation (C,H-COSY) spectrum.

Solving problems using IR, UV, NMR and mass spectra for simple organic molecules.

**REFERENCE BOOKS**

1. C.N. Banwell, Fundamentals of molecular spectroscopy, 3<sup>rd</sup> Edition, Tata McGraw Hill Publishing Company Ltd
2. Jagmohan, Organic Spectroscopy Principles and Applications, second edition, Narosa publishing house (2005)
3. Y.R. Sharma, Elementary Organic Spectroscopy, 3<sup>rd</sup> Edition, S. Chand & Company Ltd.
4. Silverstein, Bassler and Morrill, Spectrometric identification of organic compounds, 5<sup>th</sup> Edition, John Wiley and Sons, INC
5. W. Kemp, Organic Spectroscopy, 3<sup>rd</sup> Edition, Mc Millan Press Ltd
6. P.S. Kalsi, Spectroscopy of organic compounds, Wiley Eastern Ltd.
7. K. Veera Reddy, Symmetry and Spectroscopy of molecules, New Age International (1998).
8. Dudley H. Williams, Ian Fleming, Spectroscopic methods in organic chemistry, 5<sup>th</sup> Edition,
9. Tata McGraw Hill Education Private Ltd.
10. D.L. Pavia, G.M. Lampman, George S. Kriz, Introduction to spectroscopy, Brooks Cole; 3<sup>rd</sup> Edition, 2000
11. F. Sheinmann, An introduction to spectroscopic methods for identification of organic compounds, Vol. I and II, Pergamon Press, 1975.

Semester	Course code	Course Title
IV	14PCH408	C.P- 8 Organic Chemistry -III

**Credits: 4****Total teaching hours: 75****Objectives**

- To foster an awareness in the student the ideas of molecular rearrangement and oxidation and reduction reactions of organic compounds.
- To introduce steroids and to enable the students to elucidate their structures.
- On successful completion of the syllabus, the students should have acquired knowledge about the classification, characterization of proteins, vitamins, non-steroidal, antifungal, antibacterial drugs and some heterocyclic compounds.

**UNIT-I MOLECULAR REARRANGEMENTS (15 hrs)**

Introduction, nucleophilic, free radical and electrophilic rearrangements

1, 2 – rearrangement - Wagner – Meerwein, Acid –catalysed rearrangement - Arndt-Eistert synthesis- Base –catalysed rearrangement –Favorskii, Carbon to Carbon migration of other groups - Neber rearrangement-Carbon to Nitrogen migration - Hofmann rearrangement, Curtius rearrangement, Lossen rearrangement, Schmidt rearrangement, Beckmann rearrangement  
Nitrogen to carbon, oxygen to carbon, sulphur to carbon migration of groups- Stevens, Wittig.

**Unit – II OXIDATION AND REDUCTION (15 hrs)**Oxidation: Selenium dioxide, periodic acid, aluminium t-butoxide, peroxides and peroxyacids, PCC (Corey's reagent), MnO<sub>2</sub>, OsO<sub>4</sub>, Jones reagent, copper chromite.Reduction: Complex metal hydrides such as LiAlH<sub>4</sub>, NaBH<sub>4</sub>, and trialkyl tin hydride-BH<sub>3</sub> / THF, 9-BB N- Dissolving metal reduction – Clemenson and Wolff-Kishner reduction.**UNIT – III: STEROIDS (15 hrs)**

Introduction, structural elucidation of Cholesterol (synthesis not necessary), structural elucidation and synthesis of Estrone (Arndt-Eistert synthesis), Testosterone and Progesterone (synthesis from Cholesterol), introduction and structures of Bile acids, biosynthesis of steroids (General principles only).

**UNIT – IV: PROTEINS (15 hrs)**

Classification and characteristics of proteins – synthesis of polypeptides (Bergmann's synthesis) - protecting agents, solid phase peptide synthesis, structure and their biological importance of RNA and DNA.

Vitamins-Introduction-structure, synthesis and their importance in biological systems of Vitamin- A, B1, B2, C &amp; D

**UNIT– V: HETEROCYCLIC COMPOUNDS**

**(15 hrs)**

Structure and synthesis of flavone, isoflavone, purines (adenine and guanine) and anthocyanins (cyanin and pelargonin).

Reagents: Gilman's reagent, lithium diisopropylamide (LDA), dicyclohexylcarbodiimide (DCC), 1, 3-Dithiane, Woodward and Prevost hydroxylation, DDQ, Baker's yeast.

**REFERENCE BOOKS:**

1. R.K. Mackie, D.M. Smith and R. A. Aitkin – Guide book to organic synthesis, Longman Group United Kingdom; 2 Sub editions, 1990.
2. Jerry March, Advanced Organic Chemistry, Wiley eastern limited, Fourth Edition, New Delhi, 1999.
3. Clayden, Greeves, Warren, Organic Chemistry, Oxford University Press, 2001.
4. F.A.Carey, Organic Chemistry-Part-B-Reactions and synthesis, Plenum press, 5<sup>th</sup> edition 1997.
5. Acheson – Introduction to heterocyclic compounds, 2<sup>nd</sup> Edition, Wiley Eastern Ltd.
6. Alan R Katritzky –The Principles of heterocyclic Chemistry, Chapman and Hall, 1971
7. R K Bansal, Heterocyclic Chemistry, Wiley Eastern, 1990.
8. T.L Gilchrist., Heterocyclic Chemistry, 1<sup>st</sup> edition, John Wiley & Sons, 1985.
9. I. L Finar – Organic Chemistry Vol. I & II, Longman Publishing Group; 1998.
10. O. P. Agarwal – Natural product Chemistry, 20<sup>th</sup> Edition, Goel Publishing house
11. Gurdeep Chatawal – Organic Chemistry of Natural Products Vol I & II, Himalaya Publishing House, 2001.
12. E.E. Conn, P.K Stumpf and Doi, Biochemistry, John Wiley, 1992.

Semester	Course code	Course Title
IV	14PCH409	C.P- 9 Inorganic Chemistry -III

**Credits: 4****Total teaching hours: 75****Objectives**

- To create an awareness in the student the fundamental concepts of inorganic photochemistry and bioinorganic chemistry.
- To allow the students to get introduced to the study of organometallic complexes.
- On successful completion of the syllabus, the students should have acquired knowledge in the nature, preparation and properties metal carbonyl complexes, photochemistry of metal complexes and various applications and the role metals in biological systems.

**UNIT – I INTRODUCTION OF METAL CARBONYLS (15 hrs)**

Definition of organometallic compound – 18 electron rule – EAN rule – classification of organometallic compound – the metal carbon bond types – ionic bond – sigma covalent bond – electron deficient bond – dative bond. Metal carbonyls - methods of preparation, structure, reactions- metal carbonyl bonding- IR spectroscopy of metal carbonyls. Carbonylate ions, carbonyl hydrides, carbonyl halides, Vaska's complex.

**UNIT – II  $\pi$  COMPLEXES-STRUCTURE AND BONDING (15 hrs)**

Synthesis, reactions, bonding and structure in metal alkyl, alkene, alkyne, allyl and dienyls complexes. Carbene, carbyne and carbide complexes. carbocyclic pi compounds- synthesis, reactions, bonding and structure of cyclopentadienyl complexes, arene complexes, complexes formed by 7 and 8 member aromatic rings.

**UNIT – III ORGANOMETALLIC COMPOUNDS-CATALYSIS (15 hrs)**

Organometallic compounds in catalysis – coordinative unsaturation – acid base behaviour reaction – migration of atoms or groups from metal to ligand – insertion reaction – reactions of coordinated ligands-CO, NO and Arenes- Olefin metathesis– isomerisation of alkenes – hydrogenation (Wilkinson's catalyst) – hydroformylation and hydrosilation of alkenes – carbonylation of methanol and methyl acetate- Synthesis gas

**UNIT – IV BIOINORGANIC CHEMISTRY (15 hrs)**

Bioinorganic chemistry – metal ions in biology – metalloporphyrins(heme and non-heme proteins) – cytochromes, hemoglobin, myoglobin, chlorophyll, ferridoxins, rubredoxins, blue copper proteins, enzymes- Vitamin B<sub>12</sub> and B<sub>12</sub> coenzymes (structure and functions) – nitrogen fixation(invivo and invitro) – chelate therapy, antitumour agents - cis-platin.

**UNIT – V INORGANIC POLYMERS**

**(15 hrs)**

Chains – catenation, silicones, silicates, isopoly anions, sulphur nitrogen chains. Rings - Borazines, Cyclophosphazenes (synthesis ,structure, bonding and properties). and – sulphur, nitrogen ring compounds .Homocyclic rings – sulphur rings and cyclophosphines. Cages – phosphorus cage compounds, Boron Cage Compounds – wade’s theory – closo, nido and arachno structures of boranes and carboranes. Clusters - dinuclear, trinuclear, tetranuclear, hexanuclear and organometallic clusters (structure only).

**REFERENCE BOOKS**

1. Cotton F.A.and G.Wilkinson, Advanced Inorganic Chemistry, Third edition, Wiley Eastern
2. Lee J. D, Concise Inorganic Chemistry, Fifth edition, Chapman & Hall Ltd.
3. W.L. Jolly – Modern Inorganic chemistry, McGraw-Hill Education – Europe, 1991.
4. J.E. Huheey – Inorganic chemistry, 2<sup>nd</sup> Edition, Harper & Row Publishers
5. D.F. Shriver, P.W. Atkins and C.H. Longford, – Inorganic chemistry, Oxford Univ Press, 2<sup>nd</sup> edition, 1995.
6. S.F.A. Kettle – Coordination compounds, Thomas Nelson & Sons Ltd, 1969.

Semester	Course code	Course Title
IV	14PCH410	C.P-10 Physical Chemistry - III

**Credits: 4****Total teaching hours: 75****Objectives**

- To stimulate students, create and sustain their interest in physical chemistry by providing a thorough introduction to the study of chemical and statistical thermodynamics.
- To foster an awareness in the student the fundamental concepts of photochemistry.
- On successful completion of the syllabus, the students should have acquired knowledge in the third law of thermodynamics, probability theorems, distribution laws, partition functions and principles of photochemistry.

**UNIT - I CHEMICAL THERMODYNAMICS****(15 hrs)**

A general review of enthalpy, entropy and free energy concepts, thermodynamics of systems of variable compositions-partial molar quantities and their determination-chemical potential-Gibbs Duhem equation-Duhem Margules equation-fugacity and its determinations-activity and activity coefficients- determination of solvent activity by vapour pressure method, cryoscopic method. Equilibrium Thermodynamics- Gibbs Phase rule and its application to two component simple eutectic systems - three component systems.

**UNIT – II STATISTICAL THERMODYNAMICS-I****(15 hrs)**

Third law of thermodynamics, probability and third law, need for third law, Nernst heat theorem and other forms stating third law, thermodynamic quantities at absolute zero, statistical meaning of third law and apparent exceptions.

Theories of probability, theories of permutations and combinations, thermodynamic probability, thermodynamic probabilities of systems in equilibrium, Boltzmann expression for entropy, Stirling's approximation, states of maximum thermodynamic probability, thermodynamic probabilities of systems involving energy levels.

**UNIT – III STATISTICAL THERMODYNAMICS-II****(15 hrs)**

Quantum statistics: Distribution laws- Maxwell-Boltzmann distribution law - Evaluation of alpha and beta in M.B. distribution law, Bose-Einstein distribution law, Entropy of Bose-Einstein gas, Bose-Einstein Condensation, Fermi-Dirac distribution law, Entropy of a Fermi-Dirac gas, Plank distribution law for black-body radiation, negative absolute temperature, heat capacities of solids - Einstein's and Debye's theories of heat capacities of solids.



**UNIT – IV STATISTICAL THERMODYNAMICS-III****(15 hrs)**

Partition function – definition, justification of nomenclature, micro canonical and canonical ensembles, equipartition principle, molecular partition function and canonical partition functions, relation between the total partition function of a molecule and the separate partition function, partition function - translational, rotational, vibrational and electronic, effect of molecular symmetry on rotational partition function, Ortho and para hydrogen, evaluation of thermodynamic properties E, H, S, A, G, Cp and Cv from monoatomic and diatomic ideal gas molecule partition functions, calculation of equilibrium constants of reactions involving ideal gases from partition functions.

**UNIT V PHOTOCHEMISTRY****(15 hrs)**

Physical properties of the electronically excited molecules-Excited state Dipole moment-Excited state acidity constants-pK\* values-Geometry of some electronically excited molecules-Types of photophysical pathways-Fluorescence emission-Phosphorescence-Photophysical kinetics of unimolecular processes-Stern-Volmer equation-quenching-Delayed fluorescence-study of excited states –Flash photolysis-chemiluminescence.

**REFERENCE BOOKS**

1. M.C. Gupta, Statistical thermodynamics , Wiley Eastern Limited (1990).
2. Rajaram, Kuriacose, Thermodynamics,Shoban Lal&Co,4<sup>th</sup> edition,2006.
3. Andrew Maczek, Statistical Thermodynamics, Oxford University Press, 1998.
4. K.K.Rohatgi, Mukherjee, Fundamentals of Photochemistry, Wiley eastern limited,Revised edition,1992.
5. Glasstone, Thermodynamics for chemists, Van Nostrands (1964).
6. F.T. Wall, Chemical Thermodynamics, Freeman and Company (1965).
7. Gurdeep Raj, Advance Physical Chemistry, Goel Publishing House.
8. W. J. Moore, Physical Chemistry, 5<sup>th</sup> Edition, Orient Longman Ltd
9. P. W. Atkins, Physical Chemistry, 6<sup>th</sup> Edition, Oxford University Press.

Semester	Course code	Course Title
III & IV	12PCH4CO	C. Pr- 4 Organic Chemistry Practical-II

Credits: 3

Total teaching hours: 90

**Objectives:**

- To attain knowledge in estimating organic compounds quantitatively.
- To learn and practice the methods of preparation of some organic compounds.

**A. Quantitative estimations:**

Estimation of phenol, aniline, ethyl methyl ketone, Glucose (iodimetry method and Bertrand's method).

**B. Preparations:**

1. Benzanilide from benzophenone
2. Acetyl salicylic acid from methyl salicylate
3. Preparation of m- nitrobenzoic acid from methyl benzoate
4. Preparation of p- nitroaniline from acetanilide
5. Preparation of p-bromo acetanilide from aniline

**C. Extraction and estimations:** (Not for ESE examination)

1. Lactose from milk
2. Caffeine from tea
3. Nicotine from tobacco extract
4. Citric acid or ascorbic acid from a tablet of from a natural source.

**D. Analysis of oil:** (Not for ESE examination)

Reichert – Meisel value, saponification value and acetyl value.

**REFERENCES:**

1. B.B. Day and M.V. Sitaram and T.R. Govindachari, Laboratory Manual of Organic Chemistry, Allied Publishers Limited.
2. Gnanprakasam and Ramamurthy, Organic Chemistry Laboratory Manual Ananda Book Depot, Chennai.
3. Jagmohan, Advanced Practical Organic Chemistry Vol. I & II

**Distribution of marks**

Internal (Maximum 40 marks)	ESE (Maximum 60 marks)
1. CIA Practical exam – 25	1. Quantitative analysis - 25
2. Observation note book – 10	2. Preparation of an Organic Compound – 15
3. Attendance – 5	3. Record – 10
	4. Viva-Voce – 10

Semester	Course code	Course Title
III & IV	12PCH4CP	C. Pr- 5 Inorganic Chemistry Practical-II

Credits: 3

Total teaching hours: 90

**Objectives:**

- To get an idea about the industrial analysis of alloys.
- To know and apply the principle of complexometric titration using EDTA method.
- To understand some chromatographic techniques.
- To learn about the preparation and properties of Inorganic complexes
- To get an idea about the quantitative analysis of mixture of cations using volumetric and gravimetric principles.

**A. Industrial analysis: (Not for ESE)**

Analysis of any two of the following alloys  
Brass, Bronze, Stainless steel, Solder & Type metal.

**B. Titrimetry:** Complexometric titration involving EDTA.  
Estimation of Calcium, Magnesium, Nickel, Zinc and Hardness of water

**C. Chromatography:** Column, Paper, thin layer and ion – exchange. (Demonstration only)

**D. Preparation:**

Analysis and study of the properties of at least five coordination complexes.  
(single stage / two stage preparations)

**E. Quantitative estimation:**

Mixture of cations involving volumetric and gravimetric estimation:  
Copper & Nickel, Iron & Nickel, Iron & Magnesium and Calcium & Barium

**REFERENCES**

1. V.Venkateswaran, R.Veerarwamy and A.R. Kulandaivelu, Principles of Practical Chemistry Edn II Sultan Chand & Sons (1997)
2. Giri. S, Bajpai. D.N. and O.P Panday, Practical Chemistry Vol. I & II, S.Chand & Co.
3. J. Bassart, R.C. Denny, G.H. Jeffery and Mendham, Vogel's text book of qualitative Inorganic Analysis, 4<sup>th</sup> Edn. The ELBS & Longman.

**Distribution of marks**

Internal (Maximum 40 marks)	ESE (Maximum 60 marks)
1. CIA Practical exam – 25 2. Observation note book – 10 3. Attendance – 5	1. Quantitative analysis (volumetric and gravimetric estimations –15+15)- 30 2. Preparation - 10 3. Record – 10 4. Viva-Voce – 10

Semester	Course code	Course Title
III & IV	14PCH2CN	C. Pr- 6 Physical Chemistry Practical - II

Credits: 4

Total teaching hours: 120

**Objectives:**

- To arm the future chemist with the knowledge of electrical conductance measurement and conductometric titrations.
- On successful completion of the syllabus, the students should have gained knowledge to make and record observations on conductometric titrations and chemical kinetics.

**Electrical Conductance measurements**

- Determination of cell constant
- Verification of Debye-Huckel Onsager equation
- Ostwald's dilution law
- Verification of Kohlrausch's law
- Solubility Product of sparingly soluble salt

**Conductometric Titrations**Acid-Base titrations

- Strong Base Vs Weak Acid
- Strong Base Vs Mixture of (weak and strong) Acids
- Buffer Vs Strong acid

Precipitation titrations

- AgNO<sub>3</sub> Vs mixture of halides (KCl & KI)
- BaCl<sub>2</sub> Vs MgSO<sub>4</sub>

**Chemical Kinetics**

- Acid hydrolysis of an ester – Relative strength of acids
- Reaction kinetics of KI and K<sub>2</sub>S<sub>2</sub>O<sub>8</sub>
- Primary salt effect over KI-K<sub>2</sub>S<sub>2</sub>O<sub>8</sub> reaction
- Iodination of acetone

**Adsorption**

- Adsorption of oxalic acid on charcoal

**REFERENCES**

- S.R. Palit and S.K. De, Practical Physical Chemistry, Science Book Agency, Calcutta
- P.C. Sharma and Agarwal, Practical Chemistry, Goel Publishing House, Meerut.
- Venkateswaran and Kulaindaivelu, Practical Physical Chemistry S.Chand & Co
- J.B. Yadav, Advanced Practical Physical Chemistry, Goel Publishing house, Meerut.

**Distribution of marks**

Internal (Maximum 40 marks)	ESE (Maximum 60 marks)
1. CIA Practical exam – 25	1. Experiment- 40
2. Observation note book – 10	2. Record – 10
3. Attendance – 5	3. Viva-Voce – 10

Semester	Course code	Course title
III & IV	12PCH4Z1	Project work & viva-voce

**Credits: 6**

### COMPONENT FOR PROJECT

CIA / ESE	Particulars	Project Out of 200 Marks
CIA	Project Review	30
	Regularity	10
	<b>Total Internal Marks</b>	<b>40</b>
*ESE	Project Report Present	120
	Viva Voce	40
	<b>Total External Marks</b>	<b>160</b>
<b>Total Marks(CIA+ESE)</b>		<b>200</b>

Note: - The Project work dissertation evaluation and viva-voce examination will be conducted jointly by the Internal and External Examiners

**JOB ORIENTED COURSE**

Semester	Course code	Course Title
	12PCH0J1	JOC – Pharmaceutical chemistry

**Credits: 2****Teaching hrs (out of class hours): 30****Objectives**

- To give the students a thorough introduction to the study of drugs.
- To educate the students and to create an awareness about first aid.
- On successful completion of the syllabus, the students should have been aware of the causes, treatment and prevention of some common diseases, biological role of some elements, the structure, uses and adverse effects of analgesics, antiseptics and disinfectants.

**UNIT –I THE NATURE AND SOURCES OF DRUGS****(6 hrs)**

Terminologies used in pharmaceutical chemistry-pharmacy, pharmacology, bacteria, virus, fungi, chemotherapy, pharmacopeia and toxicology, biological and chemical classification of drugs, metabolism of drugs-biotransformation-oxidative reaction-hydroxylation, oxidative dealkylation, oxidative deamination and hydrolytic (hydrolysis) reactions, conjugation reactions-glucuronide conjugation, aminoacid conjugation, sulphate conjugation, methylation and N-acetylation, routes of administration and the process of adsorption of drugs.

**UNIT –II FIRST AID FOR ACCIDENTS****(6 hrs)**

Aims and rules of first aid, first aid treatment for cuts/abrasions/ bruises, bleeding, fracture, burns, fainting and poisonous bites, clinical symptoms of poisoning and basic therapeutic treatment, common poisons and their antidotes-acid, alkali, disinfectants, hallucinogens, alcohol, mercury and salicylate poisoning, articles to be kept in a standard first aid box.

**UNIT –III COMMON DISEASES****(6 hrs)**

Some common diseases: Causes, treatment and prevention of malaria, filarasis, plague, diphtheria, whooping cough, influenza, measles, mumps, common cold, tuberculosis(T.B), cholera, typhoid, dysentery, jaundice, asthma, epilepsy, piles and leprosy. Biological role of following elements and their compounds: potassium, calcium, iodine, copper and zinc.

**UNIT – IV BLOOD AND DIABETES**

**(6 hrs)**

Composition of Blood: Plasma, RBC, WBC, platelets(thrombocytes)-their functions.  
Blood pressure: Primary and secondary hypertension-hypotension-measurement of blood pressure. Anaemia: Causes and control-sign, symptoms & types-antinaemic drugs.  
Diabetes: Types-diabetes insipidus and diabetes mellitus-juvenile & adult, control of diabetes-insulin structure and sources, oral hypoglycemic drugs - tolbutamide, chlorpropamide, glibenclamide, biguanides (penformin and metformin)

**Unit – V THERAPEUTIC AGENTS**

**(6 hrs)**

Structure, uses and adverse effects of Analgesics agents: morphine, pethidine and methadone. Antipyretic-anti-inflammatory agents: aspirin, methyl salicylate, para acetamolphenacetin, analgin, indomethacin & ibuprofen. Antiseptic and disinfectants: distinction between disinfectants and antiseptics, standardization of disinfectants and antiseptics, source, structure and uses of the following compounds-cresols, thymol, chloroxylenol, chloramines-T, crystal violet, methylene blue, nitromersol, dequalinium chloride and formalin.

**REFERENCE BOOKS**

1. Jayashree Ghosh, A Text Book of Pharmaceutical Chemistry 3<sup>rd</sup> Edn 2008, S.Chand & Co Ltd.,
2. L.M.Atherden, Text Book of Pharmaceutical Chemistry, 8<sup>th</sup> Edn, 1995, Oxford University Press
3. C.R.Chatwal, Pharmaceutical Chemistry Vol. I & II, III Edn, 2007, Himalaya Publishing House

**(SELF STUDY COURSES)****ADVANCED LEARNER COURSES**

<b>Semester</b>	<b>Course code</b>	<b>Course Title</b>
	<b>14PCH0D1</b>	<b>ALC- 1 Chemistry of Corrosion and its Prevention</b>

**UNIT – I INTRODUCTION TO CORROSION**

Definition of corrosion cost of corrosion, importance of corrosion studies – classification of corrosion – expressions for corrosion rate – corrosion principles – electrochemical principles of corrosion – Faradays Laws, types of electrochemical cells, concentration cells. Thermodynamic principles of corrosion – Standard electrode potentials and thermodynamic corrosion theory – Galvanic series of metals and alloys.

**UNIT – II KINETICS**

Kinetics of electrochemical corrosion – importance of kinetics, graphical presentation of kinetic data, exchange current density, polarization of electrodes, concentration polarization, activation polarization and resistance polarization. Mixed potential theory. Applications of electrodes kinetics to experimental observation

**UNIT-III PASSIVITY**

Kinetics of passivity – introduction – electrochemical behavior of active / passive metals, flade reactivation potential, criteria for selecting a metal exhibiting passivity, factors influencing electrochemical behavior and corrosion rate of metals exhibiting passivity, theories of passivity.

**UNIT – IV FORMS OF CORROSION**

Different form of corrosion and the factors influencing atmospheric, intergranular, pitting, galvanic, crevice, stress, soil). Protection against corrosion - design improvement, changes of metal, change of environment, change of metal potential, use of coatings.

**UNIT – V MONITORING TECHNIQUES**

Interpretation and measurement of corrosion – potential measurements, corrosion current measurements using rotating disc electrode, polarization measurements (polarization break, Tafel and linear)- two electrode system, three electrode system, advantages, disadvantages and precautions in usage, Corrosion behavior diagram.

**TEXT BOOK**

1. Raj Narayan, An introduction to metallic corrosion and its prevention, Oxford and IBH Publishing Co.



Semester	Course code	Course Title
	12PCH0D2	ALC- 2 Medicinal chemistry

**Credits: 2**

### **UNIT- I INTRODUCTION TO MEDICINAL CHEMISTRY**

Introduction-medicinal chemistry-modern medicinal chemistry-chronology of drug introductions-development of various classes of drugs-cell structure-types of molecules in the cell affected by drugs-protein binding.

### **UNIT- II GENERAL PRINCIPLE OF DRUG ACTION**

Definition of drugs-classification of drugs-characteristics of different routes to drug administration-absorption of drug-distribution of drug-mode of drug action-mechanism of drug action-drug receptors-drug-receptor bonds-excretion.

### **UNIT- III PHYSIO CHEMICAL PARAMETERS IN RELATION TO BIOLOGICAL ACTIVITY**

Introduction-physical properties-solubility,partition coefficient,ionization and pka values-hydrogen bonding-surface activity-applications-complexation-redox potential-steric features of drug-conformational isomers-optical isomers-bioisosterism-classical bioisosterers-nonclassical bioisosterers.

### **UNIT –IV DRUG DESIGN AND DRUG-TARGET INTERACTION**

Drug design-Fundamentals and objectives of QSAR-variation of substituents-alkyl and aromatic substituents-extension of the structure-chain extensions/contractions-ring expansions/contractions-ring variations-ring fusions-isosterers-simplification and rigidification of the structure-conformation blockers-X-ray crystallographic studies-molecular modeling studies-drug design by nuclear magnetic resonance- a case study-oxaminquine.

### **UNIT -V THERAPEUTIC AGENTS**

Structure Activity Relation (SAR) of antibiotics cephalosporins, streptomycin, tetracycline, erithromysin and chloremphenicol-SAR of antimalarial drug cinchonine-SAR of anticancer drug cisplatin-cardiovascular drugs-definition and categories-synthesis and use of diuretic drug chloemerodrin Hg<sup>197</sup>-antiparkinsonism drug biperiden hydrochloride-antipsychotics and the structure of reserpine-antithyroid drugs-drugs to combat aids.

#### **REFERENCE BOOKS**

1. Rama Rao Nadendla, Medicinal chemistry, Pharmamid press.
2. K.Illango, P.Vanitha, Text book of medicinal chemistry-Volume I &II- First edition, Keerthi publishers.
3. Ashutosh kar- Medicinal chemistry-4<sup>th</sup> edition-New age international publishers
4. Graham L. Patrick, An Introduction to Medicinal Chemistry, 2<sup>nd</sup> edition-Oxford University Press.

Semester	Course code	Course Title
	14PCH0D2	ALC- 3 Food chemistry

**Credits: 2**

#### **UNIT – I FUNCTIONS OF FOOD**

Food – definition, functions, basic food groups, chemical composition and nutritive value of some common food stuffs (cereals, pulses, vegetables and fruits, eggs, milk and meat).

#### **UNIT – II IMPORTANT NUTRIENTS IN FOOD**

Nutrients – definition, properties and nutritive value of some important nutrients (carbohydrates, proteins, fats, vitamins, minerals and water).

#### **UNIT – III FOOD ADDITIVES**

Some important food additives – antioxidants, chelating agents, colouring agents, flavouring agents, curating agents, emulsifiers, leavening agents, anticaking agents, humectants, non-nutritive sweeteners, thickeners, stabilizers, preservatives.

#### **UNIT – IV FOOD PRESERVATION**

Food spoilage, methods of food preservation, preservation of food by – low temperature, high temperature, preservatives, osmotic pressure, dehydration, food irradiation.

#### **UNIT – V FOOD ADULTERATION AND FUTURE FOODS**

Adulteration – definition, types of adulterants – intentional and incidental adulterants, metallic contaminants, food laws, organic foods, low cost nutrient supplement, packaging of foods, nutrition labeling.

#### **REFERENCE BOOKS**

1. B. Srilakshmi, Food science, New Age International, V edition, 2010.
2. Lillian H. Meyer, Food chemistry, CBS publishers and distributors.

**MAJOR ELECTIVE COURSE – 1**

Semester	Course code	Course Title
III or IV		ME Physical Methods in Chemistry

**Credits: 5****Total teaching hours: 75****Objectives**

- To introduce the principles of error analysis to the students.
- To enable the students to attain knowledge on various chromatographic techniques and thermoanalytical methods.
- On successful completion of the syllabus, the students should have gained knowledge in ESR and Mossbauer spectroscopy, AAS and polarimetry.

**UNIT – I ERROR ANALYSIS****(15 hrs)**

Errors – determinate and indeterminate errors, accuracy and precision, mean, median, average deviation, standard deviation, relative standard deviation, standard deviation for 'Sample' and 'Population of data'-rejection of measurements- Quotient test -confidence limits, confidence interval, tests of significance - t-test and f-test -minimization of errors- significant figures, rounding off the numerical expressions, reporting of analytical data.

**UNIT- II CHROMATOGRAPHIC METHODS****(15 hrs)**

Basic principles, theories, instrumentation, experimental procedures and application of following chromatographic techniques – Paper (PC), Thin Layer (TLC), Column (CC), Gel Permeation (GPC), Gas (GC) and High Performance Liquid Chromatography (HPLC), Ion-exchange chromatography.

**UNIT – III THERMAL ANALYSIS****(15 hrs)**

Introduction - different types of thermo analytical methods. Thermo gravimetric analysis (TGA) - principle – factors influencing thermograms. Derivative thermogravimetry (DTG) - principle – factors influencing thermograms. TGA instruments – precautions in the use of thermo balance. Differential thermal analysis (DTA) – principle – instrumentation – applications – thermometric titrations-principle-instrumentation and applications. Differential scanning calorimetry (DSC) - principle - instrumentation and applications.

**UNIT –IV ESR & MOSSBAUER**

**(15 hrs)**

Electron spin resonance- Theory – derivative curves-‘g’ values, Kramer’s degeneracy-zero field splitting – hyperfine splitting – isotropic and anisotropic systems – identification of free radicals – applications.

Mossbauer spectroscopy-Principle and theory-Isomer shift – quadruple interactions – magnetic interactions – applications.

**UNIT- V ATOMIC ABSORPTION SPECTROMETRY & POLARIMETRY (15 hrs)**

AAS-Principle- instrumentation – detection of metals & non-metals, interference, detection limit & sensitivity and applications. Flame Emission spectrometry- Principle, instrumentation, methodology and applications. Comparison between AAS and FES.

Polarimetry – Plane polarized light – optical activity of molecules – polarimeter and its uses. ORD and CD spectrometry, circular birefringence, circular dichroism, optical rotatory dispersion, Plain curves, anomalous curves - cotton effect – axial haloketone rule and octant rule – application. .

**REFERENCE BOOKS**

1. Gurdeep R. Chatwal & S.K. Anand, Instrumental Methods of Chemical Analysis, 2003, Himalaya Publishing House.
2. B.K.Sharma, Instrumental methods of Chemical analysis, Goel Publishing house, 18<sup>th</sup> edition, 1999.
3. Gary D. Christian, Analytical Chemistry, 6<sup>th</sup> edition, John Wiley & Sons, Inc., 2004.
4. R. De Braun, Instrumental methods of chemistry, 1<sup>st</sup> Edition, McGraw – Hill Book Company
5. D.A. Skoog, D.M. West, F.J. Holder and S.R. Grouch, Analytical chemistry an Introduction 6<sup>th</sup> Edition, Saunders College publishing
6. H.H. Willard, L.L. Merrit and J.A. Dean, Instrumental method of analysis, 7<sup>th</sup> Edition, CBS Publishers & Distributors
7. B.K. Sharma, Chromatography, Goel, Publishing House.
8. R.S. Drago, Physical methods in Inorganic chemistry, 1<sup>st</sup> Edition, W. B. Saunders Company.

**MAJOR ELECTIVE COURSE - 2**

Semester	Course code	Course Title
III or IV		ME- Polymer Science and Technology

**Credits: 5****Total teaching hours: 75****Objectives**

- To stimulate students to have in-depth knowledge in polymer chemistry.
- To introduce the structure, properties and uses of various polymers, fibres and elastomers.
- On successful completion of the syllabus, the students should have acquired a clear idea about various properties of polymers, fibres, elastomers and their applications in industries.

**UNIT – I POLYMER****(15 hrs)**

Introduction-Definitions-Industrial Polymers-Plastics-Fibers-Rubber-Coatings and adhesives-Chemical structure and properties of polymers-Glass Transition Temperature(T<sub>g</sub>) Stereochemistry- crystallinity- Mechanical properties-thermal Stability-Flammability and Flame resistance-Chemical resistance-Degradability-Electrical Conductivity- Nonlinear Optic Properties. Degrading agencies and mechanism of degradation: Thermal, mechanical, ultrasonic degradation, degradation by high-energy radiation, photo degradation, oxidative and hydrolytic degradation.

**UNIT – II INDIVIDUAL POLYMERS****(15 hrs)**

Production, properties and uses of ethenic polymers – polythene (HDPE & LDPE), polypropylene, polystyrene, PVC, polyvinylacetate, polyvinylalcohol, polymethylmethacrylate and polyacrylonitrile. Production-properties and uses of polycondensation polymers – phenol-formaldehyde, urea-formaldehyde and epoxy resins. Polymer additives: Fillers, Antioxidants, thermal and UV-stabilizers, lubricants, colorants, flame retardants, blowing agents, and Plasticizers – effect of plasticizers on T<sub>g</sub>.

**UNIT – III, FABRICATION PROCESS:****(15 hrs)**

One-dimensional processes – application of coatings and adhesives, Two-dimensional processes – Casting (Die casting, rotational and film casting), Cladding, Lamination and Extrusion (flat film and Blown film extrusion) processes. Three-dimensional processes – Moulding (Compression, Injection, Reaction injection, Blow, Transfer, and Rotational moulding) processes, Forming (atmosphere pressure and Fluid pressure forming) processes and Foaming process.

**UNIT – IV FIBRE TECHNOLOGY**

**(15 hrs)**

Production, properties and uses of natural and synthetic fibres, cellulosic fibre, polyamide fibre, polyester fibres and acrylic fibres. Classification and properties of textile fibres – criteria for fibre formation, orientation of molecules on drawing. Spinning processes–melt spinning, dry spinning and wets pinning. Treatment of fibres – sizing, dyeing, finishing, scouring and lubrication.

**UNIT – V ELASTOMER TECHNOLOGY**

**(15 hrs)**

Structure and properties of elastomers – vulcanization – Chemistry of vulcanization – sulphur and nonsulphur types of vulcanization –Elastomer properties and compounding. Synthetic rubbers – GRS(Buna-S), N-butyl rubber, nitrile rubber, sulphide rubber, urethane rubber and silicone rubber. Applications of Polymers in Industry: Membrane applications of polymeric materials-Biomedical applications-Drug delivery-artificial organs-Electronic applications-Conducting polymers.

**REFERENCE BOOKS:**

1. F. W. Billmeyer – Text book of polymer science, 3<sup>rd</sup> Edition, John Wiley & Sons
2. V.R.Gowariker & N. V.Viswanathan, 1<sup>st</sup> Edition, New Age International Private Ltd.
3. J.R.Fried,Polymer Science & Technology, 2<sup>nd</sup> Edition, Prentice Hall of India Private Ltd.
4. B. P. Corbman, Textiles Fiber to Fabric, 6<sup>th</sup> Edition, McGraw Hill Book Company
5. George Odian, Principles of Polymerization, 3<sup>rd</sup> Edition, John Wiley & Sons, INC
6. Malcolm P.Stevens, Polymer Chemistry, an introduction, Oxford University Press,3<sup>rd</sup> edition,1999.

**MAJOR ELECTIVE COURSE – 3**

Semester	Course code	Course Title
III or IV		ME- Green and nano chemistry

**Credits: 5****Total teaching hours: 75****Objectives**

- To introduce the concepts of green chemistry to the students.
- To stimulate the students to know about green synthesis.
- On successful completion of the syllabus, the students should have gained knowledge on principles of green chemistry, microwave assisted reactions and ultrasound assisted reactions.

**UNIT – I GREEN CHEMISTRY PRINCIPLES (15 hrs)**

Definition, need for green chemistry, twelve basic principles of green chemistry-planning a green synthesis in a chemical laboratory— concept of atom economy – rearrangement reaction– addition reaction – substitution reaction – elimination reaction - concept of selectivity – chemo selectivity - regio selectivity – enantioselectivity – diastereoselectivity

**UNIT – II GREENER SOLVENTS & REACTIONS (15 hrs)**

Green solvents – super critical carbondioxide, solvent-less reactions, selection of appropriate solvent-fundamentals of closed vessel heating- Water as greener solvent- reactions in ionic-liquid, solvent free reaction- solid supported organic synthesis, phase transfer catalyst (PTC), use of microwaves and sonication in organic reactions.

**UNIT – III SUPRAMOLECULAR CHEMISTRY (15 hrs)**

Definition: Host guest compounds, coordination, lock and key analogy, chelate and macrocyclic effects, Preorganisation and complementarity, Nature of supramolecular interactions: Ion-Ion interactions, Ion-dipole interactions, Dipole-dipole interactions, Hydrogen bonding, cation- $\pi$  interactions,  $\pi$ - $\pi$  stacking, Van der waals force, Close packing in the solid state, Hydrophobic effects. Supramolecular host design. Template and self-assembly: Biochemical, Coordination compounds Catananes and rotaxanes.

**UNIT – IV NANO SCIENCE (15 hrs)**

Introduction- definition-types-quantum dots, wires and wells, nano rods, fullerenes and carbon nanotubes - nanowires and crystals, nano composites and clusters – properties of nano materials- Physical methods of preparation of Nano Structured Materials – Bottom up and Top down approaches– plasma arching, chemical vapour deposition, electrodeposition, sol-gel synthesis, ball-milling and use of natural nano particles.

**UNIT –V SYNTHESIS CHARACTERISATION AND APPLICATIONS OF NANOMATERIALS**

**(15 hrs)**

Chemical reduction (borohydride, citrate and polyol), high temperature thermal decomposition, liquid-liquid interface reaction, solution state polymerization-Experimental Techniques - Instrumentation, principle and applications of Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM), -Powder XRD-Applications of Nanomaterials- catalysis, environmental and biomedical (drug delivery) applications. Nanomaterials-environmental hazards.

**REFERENCE BOOKS**

1. V. Kumar, An Introduction to Green Chemistry, Vishal Publishing Co
2. V.K. Ahluwalia, Green Chemistry, Ane Books In
3. T. Pradeep, Nano-The Essentials, Tata McGraw-Hill Publishing Company Limited, 2nd Edition, 1998.
4. Richard Booker& Earl Boysen Nanotechnology, Wiley Publishing, 2006.
5. Mick Wilson, Kamali Kannangara Geoff Smith, Michelle Simmons, Buckhard Raguse, Nano Technology, Overseas press, 2008.
6. Mark Ratner, Daniel Ratner, Nanotechnology, Pearson Education, 2006.
7. S. Shnmugam, Nanaotachnology, MJP Publishers, 2010
8. V S. Muralidharan, A. Subramania, Nanoscience and technology, Ane books pvt, 2010.
9. Charles P. Poole, Frank J Owens, Introduction of nanotechnology, 2009.
10. Challa S S R Kumar, Josef Hormes, Carola Leuschner, Nanofabrication towards biomedical application, Wiley publications, 2007.



**MAJOR ELECTIVE COURSE – 4**

Semester	Course code	Course Title
III or IV		ME- Bioinorganic Chemistry

**Credits: 5****Total teaching hours: 75****Objectives**

- To motivate the students to study about the role of metal ions in biological systems.
- To enable the students to know the structure, function and physiology of Haemoglobin and myoglobin.
- On successful completion of the syllabus, the students should have learnt about electron transfer, respiration, photosynthesis, function of metalloenzymes and the applications of metals in medicine.

**UNIT –I METAL STORAGE, TRANSPORT AND BIOMINERALISATION (15 hrs)**

Metals in biological systems-trace and ultra trace metals-the roles of metal ions in biological systems-structurally defined sites-the entatic state-iron storage-ferritin- haemosiderin-synthetic iron-oxo aggregates-iron transport-transferrin-siderophores.

**UNIT- II DIOXYGEN MANAGEMENT (15 hrs)**

Hemoglobin and myoglobin – dioxygen binding, transport and utilization – the binding of dioxygen to myoglobin – the physiology of myoglobin and hemoglobin – structure and functions of hemoglobin – other biological dismutases – oxidases and oxygenases – tyrosinase – methane monooxygenase – dioxygenases.

**UNIT -III ELECTRON TRANSFER, RESPIRATION AND PHOTOSYNTHESIS (15 hrs)**

Ferredoxins – rubredoxins – synthetic models e-s proteins – blue copper proteins – cytochromes – photosynthesis – chlorophyll and photosynthetic reaction center – photosynthetic pathway – manganese and photosystem II.

**UNIT -IV METALLOENZYMES (15 hrs)**

Enzymes – structure and function – zinc enzyme – carboxypeptidase and carbonic anhydrase – iron enzymes – catalase, peroxidase and cytochrome P-450 – copper enzymes – superoxide dismutase – molybdenum oxotransferase enzymes – xanthine oxidase – vitamin B<sub>12</sub> and the coenzyme – nitrogenase.

**UNIT- V METALS IN MEDICINE**

**(15 hrs)**

Metal deficiency and disease – metals used for diagnosis and chemotherapy with reference to anticancer drugs – toxic effects of metals – function and toxicity of the elements in biological systems – antibiotics and related compounds – chelate therapy – metal complexes as probes of nucleic acids.

**REFERENCE BOOKS**

1. I. Bertini, H.B.Gray, S.J. Lippard and J.S. Nalentine , Bioinorganic Chemistry; University Science Books.
2. Dr. Asim K. Dass, Bioinorganic Chemistry 2007. Books and Allied (P) Limited.
3. J.E.Huheey, E.A.Kieter, R.L.Keiter, Inorganic Chemistry 4<sup>th</sup> Edition, Addison Wesley ,Publishing Company.

**NON-MAJOR ELECTIVE COURSE -1**

Semester	Course code	Course Title
I or II		NME- Environmental Chemistry

**Credits: 5****Total teaching hours: 75****Objectives**

- To create awareness among the students about various environmental issues like pollution of air, water and soil which threaten the mankind.
- To motivate the students to know the measures to prevent and control pollution.
- On successful completion of the syllabus, the students should have learnt about various pollution, their sources, effects and control measures.

**UNIT-I ENVIRONMENT****(15 hrs)**

Definition-components of -segments: atmosphere and its structure: troposphere, stratosphere, mesosphere, ionosphere and exosphere, hydrosphere, lithosphere and biosphere, ecosystem-types, components and biogeochemical cycles (brief aspects only)-sulphur, phosphorus, carbon-hydrogen, oxygen nitrogen and hydrological cycles.

**UNIT-II AIR POLLUTION****(15 hrs)**

Composition of air, Classification of pollutants-gaseous pollutants-oxides of N,S and C, hydrocarbons and particulates(sources, reactions in the atmosphere, effects on plants/human beings and control measures), monitoring and control of air pollution-CO sensor-Green house effect-definition-major sources of green house gases-consequences of green house effect, Global warming- Ozone layer depletion – mechanism-Chlorofluro carbons (CFC), Smog-photochemical smag, Acid rain-theory of acid rain-effects of acid rain-prevention and control.

**UNIT – III WATER POLLUTION****(15 hrs)**

Sources of water pollution sewage & domestic wastes, industrial effluents, agricultural discharges, fertilizers, detergents, toxic metals, siltation, thermal and radioactive materials. Types of water pollution -ground water, surface water, lake water, river water and sea water pollution and their harmful effects. Effects of oil pollution in marine water. Eutrophication – types, effects and its control measures. Control measures of water pollution.

**UNIT – IV SOIL POLLUTION**

**(15 hrs)**

Types of soil and their characteristics. Sources of soil pollutants and their detrimental effects-industrial, urban wastes, radioactive materials, agricultural products, chemical & metallic wastes and biological agents. Diseases caused by soil pollution. Remedial measures for soil pollution.

Thermal Pollution:- definition-sources-nuclear power plants, thermal power plants, industrial effluents, domestic & municipal sewage. Harmful effects of thermal pollution.

**UNIT –V RADIOACTIVE POLLUTION**

**(15 hrs)**

Radio activity and kinds of radiation. Natural and anthropogenic sources of radiation. Harmful biological effects of ionizing, non-ionizing (unit of measurement REM), micro wave, radio frequency, x-ray etc. radiation. Disposal methods of radioactive wastes from nuclear power plants, low level and high level nuclear waste - biomedical waste.

Noise Pollution: definition. Sources, effects and control. Units of sound-dB

**REFERENCE BOOKS**

1. B.K.Sharma, Environmental Chemistry 2010 Edn, GOEL Publishing Company
2. A.K De, Environmental Chemistry, Wiley Eastern Ltd
3. G.S.Sodhi, Fundamentals of Environmental Chemistry, Narosa Publishing House

**NON-MAJOR ELECTIVE COURSE -2**

Semester	Course code	Course Title
I or II		NME- Scientific Thesis Writing & Paper Presentation

**Credits: 5****Total teaching hours: 75****Objectives**

- To introduce students to the research prospectus and thesis/dissertation writing process with the focus on both the rhetorical framework and grammatical patterns germane to these tasks and the purpose of the research project.
- To focus on the communication problems encountered in researching and writing a thesis.
- On successful completion of the syllabus, the students should have trained themselves how to write a thesis.

**UNIT – I INTRODUCTION****(15 hrs)**

Writing introduction of thesis- General introduction and chapter introduction - example of organization of the thesis in general introduction – example of statement of aims and objectives in a general introduction – introduction of a chapter in a thesis

Writing review of literature – need for review of literature – review process and bibliography – locating literature – publications – reading the literature – placement of review of literature in a thesis – organizing and writing literature review – time period covered in the review – contents of a review — use of tabular format in review – focus of the organization – revision of the draft.

**UNIT – II TABLES AND FIGURES****(15 hrs)**

Writing materials and methods – General guidelines – details required about the chemical material. Writing results – voice, tense and style – topical sentence – sequence – structure – content...Preparation of table – tabular form – introduction and placement of a table – table format – numbering of table – title of the table – the stub – box heading – unit of measurements – footnotes.

Preparation of figures – introduction – introduction and placement of figures – numbering of figures – caption of figures – preparation of statistical diagrams – preparation of photographs and microphotographs.

**UNIT - III DISCUSSION**

**(15 hrs)**

Writing discussion – style of writing discussion – sequence of discussion – structure and content of discussion – key findings and interpretation – discussion of methodology – comparison of results – discussion of the significance of the result – discussion of unexpected result – discussion of unexpected result – discussion in the absence of pertinent literature – conclusion of discussion – structured format of discussion – an example of discussion

Writing abstract, keywords, summary and synopsis of thesis.

**UNIT – IV FORMATTING**

**(15 hrs)**

References citing and listing – introduction – different systems of reference citation – name year system – citation in the text – listing references- citation sequence system – alphabet number system.

Formatting and typing thesis – introduction – paper – margins – paragraph indentations – widow and orphan lines – spacing – alignment – hyphenation – fonts – pagination – format of a thesis .

**UNIT - V MANUSCRIPT PREPARATION**

**(15 hrs)**

Preparing manuscript for presentation – poster presentation – poster size – poster Vs. oral presentation – preparation of poster – poster printing – displaying the poster – presenting the poster. Preparing for oral presentation – preparation of the script – timings – using visual aids – presentation style.

Journal article – nature and purpose – journal as a medium of communication – decision prior to publication – preparing manuscript – from manuscript to publication.

**REFERENCE BOOKS:**

1. N. Gurumani, Scientific thesis writing and paper presentation, 2010 MJP publishers.
2. Hans Fridrich Ebel, Claus Bliefert, Willaim E. Russey, The art of scientific writing, Wiley, VCH, 2004.

**NON-MAJOR ELECTIVE COURSE – 3**

Semester	Course code	Course Title
I or II	NME-	Agricultural Chemistry

**Credits: 5****Total teaching hours: 75****Objectives**

- To introduce students to the concepts of agricultural chemistry.
- To focus on the preparation, applications and toxic effects of fertilizers and pesticides.
- On successful completion of the syllabus, the students should have known about the principles of soil science, applications and hazards of fertilizers, pesticides, fungicides and herbicides.
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**UNIT – I SOIL SCIENCE-1****(15 hrs)**

Introduction, definitions of soils, properties of soils – physical properties, chemical properties, mechanical components, soil as a three-phase system, soil profile, soil structure. soil density, soil color, texture, mechanical analysis, functions of sand, slit and clay, textural grouping of soils, soil water, moisture content of soil, wilting coefficient, soil air, soil temperature, soil mineral matter, soil colloids.

**UNIT – II SOIL SCIENCE-2****(15 hrs)**

Ion exchange reactions in soil: Cation exchange – anion exchange, soil fertility, theories of nutrient supply- solution theory – contact exchange theory- soil organic matter- soil humus – soil organisms, carbon cycle, nitrogen cycle, carbon- nitrogen ratio, soil pH, types of soil acidity, determination of soil pH – electrometric method – dye methods, buffer action, nutrient elements, availability of nutrients and soil pH, acid soils, alkaline and alkaline soils, reclamation.

**UNIT – III FERTILIZERS-1****(15 hrs)**

Introduction, requisites of a good fertilizer, classification of fertilizers, nitrogenous fertilizers – effect of nitrogen on plant growth and development – importance of nitrogenous fertilizers – classification of nitrogenous fertilizers. Preparation and uses of some nitrogenous fertilizers - ammonium sulphate, ammonium nitrate, ammonium sulphate – ammonium nitrate, sodium nitrate, calcium nitrate, aqueous ammonia, calcium ammonium nitrate, urea, calcium cyanamide.

**UNIT – IV FERTILIZERS-2**

**(15 hrs)**

Phosphate fertilizers: Introduction, deficiency symptoms, kinds of phosphate fertilizers, super phosphate, bone meal, basic slag, rock phosphate, and dicalcium phosphate.

Potassium fertilizers – functions of potassium in the plants, deficiency symptoms, classification into chlorine and non chlorine forms, manufacturing processes and properties of potassium fertilizers – potassium chloride, potassium nitrate.

Complex fertilizers- introduction, manufacture, composition, calculation of fertilizer formulae.

**UNIT – V PESTICIDES**

**(15 hrs)**

Introduction, classification of pesticides- general methods of preparation and applications (outline only), toxicity. Insecticides – introduction, insect killer and repellents. Preparation and action- Nicotine, pyrethrum, rotenone, chlorohydrocarbons, methoxychlor.

Fungicides – sulphur and its compounds, copper compounds, Bordeaux mixture. Herbicides – introduction, classification, inorganic herbicides- arsenic compounds, boron compounds, cyanamide and thiocyanates, chlorates organic herbicides – chlorinated compounds, pyridine compounds.

**REFERENCE BOOK**

1. R. Lakshmanan, Agricultural chemistry, V.V publications. Thanjavur
2. A. Mariakulandai, T.S. Manickam, Chemistry of fertilizers and manures, Asia publishing house, 1975.



**NON-MAJOR ELECTIVE COURSE – 4**

Semester	Course code	Course Title
I or II		Industrial products

**Credits: 5****Total teaching hours: 75****Objectives**

- To introduce students to the concepts of Industrial products.
- To focus on the preparation, applications of glass, cement, fertilizer, paints and pigments.

**UNIT –I GLASS****(15 hrs)**

Physical and chemical properties of glass. Raw materials used in the manufacture. Steps used for the manufacture-formation of batch materials, melting, shaping, annealing and finishing. Chemical reactions in the furnace. Pot furnace and tank furnace. Regenerative and recuperation types. Variety of glasses-silica, optical, borosilicate, lead, safety, pyrex, alkali silicate, photochromic and glass wool.

**UNIT –II CEMENT****(15 hrs)**

Types of cement. Types of Portland cement. Raw materials-manufacturing process – wet and dry process-types of kiln and reactions in kiln- composition of clinker-additives added during grinding-setting, curing and hardening of cement-physiochemical transformations. Properties of cement Mortars and concrete-RCC.

**UNIT –III FERTILIZERS****(15 hrs)**

Plant nutrients-primary, secondary and micro nutrients. Need for fertilizers-classification of fertilizers. Source of fertilizers-natural and artificial. Nitrogenous fertilizers-ammonium nitrate, ammonium sulphate and urea. Phosphate fertilizers-phosphate rocks-normal super phosphate-triple super phosphate. Potassium fertilizers-NPK fertilizers.

**UNIT –IV PAINTS AND PIGMENTS****(15 hrs)**

Paints :- Definition-classification-constituents-manufacture-requirements of a good paint. Paint failure. Types of paints-emulsion paints-latex-luminescent-fire retardant-heat resistant. Methods of applying paint. Paint removers. Varnishes - types and classes. Lacquers, solvents, thinners and oils. Pigments:-white pigments- manufacture-white lead(electrolytic method)-zinc oxide(French process)-titanium dioxide(chlorine method). Blue pigment-ultramarine. Red pigment-red lead. Green pigment-chrome green. Yellow pigment-chrome yellow.

**UNIT –V RUBBER AND ALLIED PRODUCTS****(15 hrs)**

Natural rubber-types and classification-latex-coagulation-refining of crude rubber-vulcanization (sulphur and non-sulphur)-properties of vulcanized rubber. Synthetic rubber-manufacture and uses of-Buna-S(from petroleum), Neoprene, Butyl rubber, silicone rubber and poly urethane.

**REFERENCE BOOKS**

1. B.K.Sharma, Industrial Chemistry, GOEL Publishing Company.
2. G.T. Austin, Industrial Chemistry, Shteves chemical process Industries 5<sup>th</sup> Edition.
3. B.N. Chakarabarthi, Industrial Chemistry, Oxford and IBH publishing house.

**QUESTION PAPER PATTERN FOR CIA AND ESE**

**Theory (including electives except JOC and ALC)**

**Maximum marks 75**

**Section – A (10 X 1 = 10 marks)**

Q.No.1 to 10: Multiple choice types alone with four distracters each

**Section – B (5 X 5 = 25 marks)**

Q.No.11 to 15: either or / short notes type questions (one question ‘a’ or ‘b’ from each unit)

**Section – C (5 X 8 = 40 marks)**

Q.No.16 to 20: either or / essay type questions (one question ‘a’ or ‘b’ from each unit)

**QUESTION PAPER PATTERN FOR ESE**

**JOC and ALC**

**Maximum marks 100**

**Section – A (10 X 1 = 10 marks)**

Q.No.1 to 10: Multiple choice types alone with four distracters each

**Section – B (5 X 6 = 30 marks)**

Q.No.11 to 15: either or / short notes type questions (one question ‘a’ or ‘b’ from each unit)

**Section – C (5 X 12 = 60 marks)**

Q.No.16 to 20: either or / essay type questions (one question ‘a’ or ‘b’ from each unit)

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