

UNIVERSITY OF MUMBAI

No.UG/ 334 of 2004

CIRCULAR:

A reference is invited to the scheme of papers at the B.Sc. degree course under the revised pattern vide this office Circular No. UG/31 of 1999 dated 21st January, 1999 and the Principals of the affiliated colleges in Science are hereby informed that the recommendation made by the Board of Studies in Chemistry at its meeting held on 22nd December, 2003 has been accepted by the Academic Council at its meeting held on 3rd January, 2004 vide item No.4.31 and that in accordance therewith, the syllabus in the subject of Chemistry (3 and 6 Units) at the T.Y. B.Sc. course has been revised as per Appendix and that the same will be brought into force with effect from the academic year 2004-2005.

Mumbai 400 032

11th August, 2004

for I/c REGISTRAR

To,

The Principals of the affiliated colleges in the faculty of Science.

A.C.4.31/03.01.2004

No.UG/334-A

of 2004

11th August, 2004.

Copy forwarded with Compliments for information to :-

- 1) The Dean, Faculty of Science.
- 2) The Chairman, Board of Studies in Chemistry.

for I/c REGISTRAR

Copy to:-

The Director, Board of College and University Development, the Controller of Examinations, the Deputy Registrar (Eligibility and Migration Section), the Director of Students Welfare, the Personal Assistants to the Vice-Chancellor, the Pro-Vice-Chancellor, the Registrar and the Assistant Registrar, Administrative sub-center, Ratnagiri for information.

The Controller of Examinations (10 copies), the Finance and Accounts Officer (2 copies), the Registrar, Enrolment, Eligibility and Migration Section (5 copies), the Deputy Registrar, Statistical Unit (2 copies), the Deputy Registrar, Affiliation Section (2 copies), the Director University Computer Center (IDE Building), Vidyanagari, (2 copies) the Assistant Registrar, Academic Authorities Unit (2 copies) and the Assistant Registrar, Management Council (2 copies)

They are requested to treat this as action taken report on the concerned resolution adopted by the Academic Council referred to in the above Circular and that no separate Action Taken Report will be sent in this connection. the Assistant Registrar Constituent Colleges Unit (2 copies), BUCT (1 copy), the Deputy Account, Unit V (1 copy), the In-charge Director, Centralize Computing Facility (1 copy), the Receptionist (1 copy), the Telephone Operator (1 copy), the Secretary MUASA (1 copy), the Superintendent, Post-Graduate Section (2 copies), the Deputy Registrar, Special Cell (one copy)

Nirm/Waghil/11804



UNIVERSITY OF MUMBAI



Revised Syllabus

for

T.Y.B.Sc. (Chemistry)

3 Units and 6 Units

(with effect from the academic year 2004-2005)

EXAMINATION PATTERN – 6 UNITS

THEORY

Each paper will be of 3 hours duration and of 100 marks. Each paper will have two sections of 50 marks each.

PRACTICALS

There will be one Practical Examination for 200 marks (Core component) to be held for 28 hours, per batch of 40 candidates, spread over four days. Groups will move in rotation.

First Day: Group A –

Physical Chemistry Experiments (Non-Instrumental and Instrumental) Candidates have to perform one Non-Instrumental equipment (20 marks) and one Instrumental experiment (20 marks).

Journal – 4 marks

Viva voce – 6 marks

Total $20+20+4+6=50$ marks

Second Day: Group B –

Inorganic Chemistry Practicals

1) Gravimetric Analysis / Inorganic preparation and characterisation – 25 marks.

2) Titrimetric Analysis - 15 marks

Journal - 4 marks

Viva voce - 6 marks

Total $25+15+4+6=50$ marks

Third Day: Group C –

Organic Chemistry Practicals

1) Organic Separation - 25 marks

2) Organic Preparation - 15 marks

Journal - 4 marks

Viva voce - 6 marks

Total $25+15+4+6=50$ marks

Fourth Day: Group D –

Analytical Chemistry Practicals

1) Non instrumental experiment - 20 marks

2) Instrumental experiment - 20 marks

Journal - 4 marks

Viva voce - 6 marks

Total $20+20+4+6=50$ marks

Fifth Day: Group E –

In continuation of the fourth day practical, examination for 80 marks under applied component will be held.

- 1) A student is expected to submit a journal certified by the Head of the department / Head of the institution.
- 2) A student will not be permitted to appear at the practical examination unless he/she produces a certified journal. If the journal is lost, the student should produce a certificate from the Head of the department / Head of the institution stating that he / she has satisfactorily completed the practical work.

EXAMINATION PATTERN – 3 UNITS

THEORY

1. There will be 2 papers of 3 hours duration and of 100 marks each. Each paper will have two sections of 50 marks each.

Paper I	Section I – Physical Chemistry	- 50 marks
	Section II – Inorganic Chemistry	- 50 marks
Paper II	Section I – Organic Chemistry	- 50 marks
	Section II – Analytical Chemistry	- 50 marks

PRACTICALS

There will be one Practical Examination for 100 marks (Core component) to be held for 14 hours, per batch of 40 candidates, spread over two days Groups will move in rotation.

First Day: Group A –	I) Physical-Chemical experiment	20marks
	Journal	2 marks
	Viva voce	3 marks
	Total 20+2+3=25 marks	

	II) Organic Chemistry experiment	20marks
	Journal	2 marks
	Viva voce	3 marks
	Total 20+2+3=25 marks	

Second Day: Group B –	I) Inorganic Chemistry experiment	20marks
	Journal	2 marks
	Viva voce	3 marks
	Total 20+2+3=25 marks	

	II) Analytical Chemistry experiment	20marks
	Journal	2 marks
	Viva voce	3 marks
	Total 20+2+3=25 marks	

Third Day: Group C –

In continuation of the second day Practical examination for 80 marks under applied component will be held.



1. A student is expected to submit a journal certified by the Head of the Department / Head of the institution.
2. A student will not be permitted to appear at the practical examination unless he / she produces a certified journal. If the journal is lost, the student should produce a certificate from the Head of the department / Head of the institution stating that he / she has satisfactorily completed the practical work.

Rules for personal safety:

- a) For eye protection, safety goggles must be worn in the laboratory at all times. If the student wears contact lenses, full protection goggles, which provide total seal around eyes, must be worn. All students are expected to wear safety goggles.
- b) A long sleeved, knee length laboratory coat is recommended. Long pants and closed-toed shoes must be worn for individual safety. Loose clothing, open style shoes and sandals are prohibited. Long hair must be contained. Each student will have to get his/her own necessary protection items.
- c) Prior to the practical examination, the teacher-in-charge will check all protective equipment to ensure that they are in order.
- d) Pipetting by mouth should preferably be avoided. Use of pro-pipette bulbs is recommended.
- e) All laboratories should be equipped with safety chart, adequate first aid requirements and fire extinguishers.

UNIVERSITY OF MUMBAI
Revised Syllabus
For
T.Y.B.Sc. Chemistry – 3 AND 6 Units.
(From the Academic Year 2004 – 2005)

Syllabus at T.Y.B.Sc. in the subject of Chemistry (6 Units) under the revised pattern to be brought into force with effect from the academic year 2004-2005.

All topics should be dealt with in S.I.Units.

Paper I – Physical Chemistry

50 Marks

60 Lectures

Numerical problems are expected on all the topics

SECTION I (3 AND 6 UNITS)

100 Marks

120 Lectures

UNIT – I 1. Chemical Thermodynamics

8L

- 1.1 Phases in Equilibria: Variation in vapour pressure of a liquid with temperature, Clapeyron equation, Clapeyron – Clausius equation.
- 1.2 Colligative Properties of Solutions: Study of lowering in vapour pressure – Raoult's law (derivation not expected), thermodynamic derivations for elevation in boiling point and depression in freezing point.
- 1.3 Partial molal quantities, Gibbs – Duhem equation

2. Crystalline State

7L

- 2.1 Laws of crystallography, Elements of symmetry, lattice planes, unit cell, Weiss and Miller indices, Characteristics of simple cubic, face-centred cubic and body-centred cubic systems. Inter-planar distances in cubic crystals.
- 2.2 X-rays and production of monochromatic X-rays. Bragg's equation and X-ray diffraction method of studying crystals. Structure of NaCl. Determination of Avogadro's number. Elementary idea of defects in crystals – Frenkel defect and Schottky defect.

UNIT – II 3. Electrochemistry – Electrochemical Cells

15L

- 3.1 Classification of cells – Chemical and concentration cells, concentration cells with transference, concentration cells without transference, liquid junction potential, use of salt bridge.
- 3.2 Determination of thermodynamic parameters from EMF measurements – free energy change, enthalpy change, entropy change and equilibrium constant for the cell reaction.
- 3.3 Ionic strength, variation of activity coefficient with concentration, Debye-Huckel limiting law (derivation not expected).
- 3.4 Application of EMF measurements in the determination of:
 - i) activity coefficient
 - ii) pH using quinhydrone and glass electrodes,

- iii) solubility and solubility product of sparingly soluble salts using chemical cells and concentration cells,
- iv) formula of Ag-NH_3 complex ion.

UNIT – III 4. Spectroscopy

15L

Electromagnetic radiation, quantisation of energy. Bohr frequency condition, interconversion of units, term values (E/hc), regions of the electromagnetic spectrum and processes associated with each region.

4.1 Rotational spectra of diatomic molecules

Rigid rotor, moment of inertia, energy levels, selection rules, nature of spectrum, determination of bond length.

Effect of isotopic substitution on the rotational spectra.

4.2 Vibrational spectra of diatomic molecules:

Harmonic oscillator : energy levels, selection rules, nature of spectrum, determination of force constant. Anharmonic oscillator : energy levels, selection rules, nature of spectrum, fundamental band, overtones.

4.3 Vibrational Rotation spectra of diatomic molecules:

Energy levels of a vibrating rotor, selection rules, nature of the spectrum. R and P branches. Introduction to infrared spectra of simple molecules like water and CO_2 .

4.4 Raman Spectroscopy:

Explanation of Raman effect using quantum theory :

Rayleigh scattering. Raman scattering – Stokes lines and Anti-Stokes' lines. Raman shift.

Complementary information obtained from Raman spectra – rule of mutual exclusion.

UNIT – IV 5. Nuclear Chemistry

11L

5.1 Detection and measurement of nuclear radiation:

Scintillation counter and Geiger-Muller counter

5.2 Radioactive equilibrium, determination of half life period for elements having

- 1) moderate half life using the relation

$$\log N_t - \log N_0 = 0.4343 \cdot t$$

- 2) long half life using the relation, $\lambda = -\frac{dN/dt}{N}$

- 3) extremely long or short half life using radioactive equilibrium data and Geiger – Nuttall relation.

5.3 Nuclear transmutation and artificial radioactivity, alpha particles, protons, deuterons and neutrons as projectiles – typical examples like

(α, p) (α, n) (p, α) (p, n) (p, d) (d, p)

(d, n) (d, α) (n, p) (n, α)

5.4 Q value in nuclear reactions, threshold energy.

5.5 Nuclear fission, Liquid drop model.

Nuclear reactors – power, research and breeder reactors.

5.6 Nuclear fusion

6. Chemical Kinetics

4L

Effect of temperature on reaction rate. Arrhenius theory, molecular activation and energy of activation, Collision theory and Transition state theory of reaction rates (only qualitative aspects-derivation not expected).

SECTION II (6 UNITS ONLY)

50 Marks

60 Lectures

UNIT – V and VI 7. Basics of Quantum Chemistry

10L

7.1 Limitations of Classical Mechanics

7.2 Foundation of Quantum Mechanics:

7.3 The wave nature of electron, Heisenberg's Uncertainty Principle.

7.4 Progressive waves, standing waves.

7.5 Schrodinger's time-independent equation (derivation not expected),

7.6 Interpretation of wave function.

7.7 Concept of operators: definition, addition, subtraction and multiplication of operators, commutative and non-commutative operators, linear operator, Hamiltonian operator.

8. Introduction to Polymer Chemistry

10L

8.1 Basic concepts, classification of polymers, concept of chain polymerisation and step polymerisation,

8.2 Average molecular weights of polymers – number average, weight average and viscosity average molecular weight determination using the following techniques

8.3 Ultracentrifuge and viscosity measurements.

8.4 Introduction to biodegradable polymers.

9. Phase rule

10L

9.1 Gibb's phase rule, terms involved.

9.2 One component system – water and CO₂ systems.

9.3 Two component system – condensed systems.

Simple eutectic system – Pb-Ag system.

UNIT – VII 10. Electrochemistry – Applied Aspects

7L

10.1 Energy sources – alkaline battery, Ni-Cd cell, fuel cells – H₂-O₂, Solar cells.

10.2 Polarisation, Decomposition potential, Overvoltage.

Determination of decomposition potential and overvoltage. Tafel's theory and Tafel's equation, Simultaneous deposition of metals, Basic ideas of electroplating.



- 11.1 Nuclear Magnetic Resonance : nuclear spin, nuclear magnetic moment, nuclear 'g' factor, energy levels, Larmor frequency, chemical shift, spin-spin coupling, relaxation processes – spin-spin and spin-lattice.
- 11.2 Introduction to ESR – hyper structure with respect to hydrogen atom.

UNIT – VIII 12.Surface Chemistry and Catalysis

10L

- 12.1 Adsorption – general idea, Freundlich isotherm, Langmuir isotherm (derivation expected), BET equation, (no derivation), determination of surface area from BET equation.
- 12.2 Catalysis – Concept of catalysis, classification of catalysed reactions – (i) homogeneous and (ii) heterogeneous. Catalytic activity and selectivity, catalyst support, promoters, inhibitors, catalyst poisoning and deactivation.
- 12.3 Kinetics of catalysed reactions – (i) homogeneous – acid-base and enzyme and (ii) heterogeneous.

13.Colloidal State

5L

- 13.1 Origin of charge on colloidal particles, Concept of double layer, Helmholtz and Stern models, qualitative idea of electrokinetic phenomena – electrophoresis, electro-osmosis, streaming potential and Dorn effect.
- 13.2 Colloidal electrolytes, Donnan membrane equilibrium. Emulsions – o/w and w/o types, emulsifying agents. Surfactants – micelle formation, applications of surfactants in – detergents, pesticide formulations and food industry.

PHYSICAL CHEMISTRY PRACTICALS

For 6 Units

A) Non-Instrumental Experiments

- 1 To determine the energy of activation for the acid catalysed hydrolysis of methyl acetate.
- 2 To study the effect of addition of electrolyte (KCl) on the reaction between potassium persulphate and potassium iodide.
- 3 To study the distribution of iodine between water and carbon tetrachloride.
- 4 To Determine the molecular weight of polyvinyl alcohol from viscosity measurements.

B) Instrumental Experiments Potentiometry

- 1 To determine the amount of Fe(II) and the formal redox potential of Fe(II) - (III) by potentiometric titration of Fe(II) solution against ceric sulphate/potassium dichromate solution.
- 2 To determine the solubility and solubility product of AgCl using chemical cell.
- 3 To determine the standard potential of any one of the following electrodes
 $\text{Al} \mid \text{Al}^{3+}$, $\text{Zn} \mid \text{Zn}^{2+}$, $\text{Cu} \mid \text{Cu}^{2+}$ or $\text{Ag} \mid \text{Ag}^{+}$
- 4 To determine the free energy change ΔG° and equilibrium constant for the reaction,
$$\text{Cu} + 2\text{Ag}^{+} \longrightarrow \text{Cu}^{2+} + 2\text{Ag} \text{ potentiometrically}$$
- 5 Colorimetry
To test the validity of the Beer-Lambert's law (using methylene blue) and to determine
i) λ_{max} and ii) molar absorptivity
- 6 Conductometry
To study the kinetics of saponification of ethyl acetate conductometrically.

PHYSICAL CHEMISTRY PRACTICALS

FOR 3 UNITS

1. To determine the energy of activation for the acid catalysed hydrolysis of methyl acetate.
2. To study the distribution of iodine between water and carbon tetrachloride.
3. Potentiometry:
To determine the amount of Fe(II) and the formal redox potential of Fe(II) - Fe(II) by potentiometric titration of Fe(II) solution against ceric sulphate / potassium dichromate solution.
4. To determine the standard potential of any one of the following electrodes:
 Al/Al^{3+} , Zn/Zn^{2+} , Cu/Cu^{2+} , Ag/Ag^{+}
5. Colorimetry:
To test the validity of the Beer-Lambert's law (using methylene blue) and to determine
i) λ max and ii) molar absorptivity.

REFERENCE BOOKS

- 1) T.Y.B.Sc. : PHYSICAL CHEMISTRY
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6th ed., Tata McGraw Hill Publishing Co. Ltd., New Delhi.
- 2) Physical Chemistry : G. W. Castellan
3rd ed., Narosa Publishing House, New Delhi.
- 3) Physical Chemistry : G.K. Vemulapalli (1997)
Prentice Hall of India Pvt. Ltd., New Delhi
- 4) Physical Chemistry : K.J.Laidler and J.H. Meiser, 2nd ed.
(First Indian ed. 1999) CBS Publishers and Distributors, New Delhi.
- 2) Physical Chemistry : Ira N Levine (1995)
4th ed., McGraw Hill Inc.
- 3) The Elements of Physical Chemistry : P.W. Atkins (1996)
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John Wiley & Sons (Asia) Pvt. Ltd., (Singapore) 3rd ed. (2002).
- 8) Thermodynamics for Chemists – Samuel Glasstone
Affiliated East-West Press.
- 9) An introduction to Electrochemistry – Samuel Glasstone
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- 10) Electrochemistry – C.H.Hanman
John Wiley, 1998.
- 11) Fundamentals of Molecular Spectroscopy – C.N.Banwell, 5th ed.
- 12) Atomic Structure and Chemical bond including molecular spectroscopy – Manas Chanda, 3rd ed., Tata McGraw Hill Pub. Co. Ltd., New Delhi.
- 13) Source book of Atomic Energy – Samuel Glasstone,
Affiliated East-West Press.
- 14) Nuclear and Radiochemistry – Friedlander, Kennedy and Miller,
Wiley International.
- 15) Chemical Kinetics – K.J.Laidler
3rd ed., Elsevier Publishers.
- 16) Basic Chemical Kinetics – G. L.Agrawal (1990)
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- 17) Principles of the Solid State – H.V.Keer (1993)
New Age International (P) Ltd., Publishers, New Delhi.

- 18) Chemical Kinetics and Catalysis – R.I.Masel,
John Wiley (2001)
- 19) Quantum Chemistry – R.K.Prasad
2nd ed., New Age International Publ.
- 20) Quantum Chemistry including spectroscopy – B.K.Sen
Kalyani Publishers.
- 21) A textbook of Polymer Science – Fred W. Billmeyer
3rd ed., John Wiley & Sons.
- 22) Introduction to Polymer Science – Vasant R. Gowarikar
N.V.Viswanathan and J. Sreedhar (1996), NAI, New Delhi.
- 23) Introductory Polymer Chemistry – G.S.Misra (1993)
Wiley Eastern Ltd., New Delhi.
- 24) The Phase rule and its applications – Findlay Alexander,
Edited by Campbell and Smith, 9th ed. (Dower Publication Inc.)
- 25) Phase equilibria – Reisman Arnold
Edited by Ernest M. Loebe, New York and London Academic Press.
- 26) Phase Rule – F.D.Ferguson and P.K.Jones
(Butterworth Publishers).
- 27) Adsorption and Catalysis – D.K.Chakravarty
Oxford Publishers.
- 28) Introduction to Colloid and Interface Science
- D.J.Shaw, Butterworth & Co. (1981)
- 29) Fundamentals of Colloid Science – R.J.Hunter
Clarden Press (1987).
- 30) Schaum's Outline of Physical Chemistry – S.R.Metz
McGraw Hill
- 31) Solid State Chemistry – D.K.Chakravarty
New Age International Ltd., Publishers, New Delhi.
- 32) Surface Chemistry – J.J.Bickerman,
Academic Press.
- 33) Chemical and Electrochemistry Energy Systems -
R.Narayan and B. Viswanathan, Universities Press 1998).
- 34) A Basic Course in Crystallography – J.A.K.Tareen and T.R.N.Kutty,
Universities Press (2001).
- 35) 2000 Solved Problems in Physical Chemistry – S.R.Metz -
McGraw Hill Publishers, New Delhi.

UNIVERSITY OF MUMBAI

Revised Syllabus For

T. Y. B. Sc. Chemistry

(From the Academic Year 2004–2005)

Paper – II Inorganic Chemistry

Marks: 100

Lectures: 120

SECTION – I (3 and 6 units)

- Unit I**
- 1. Chemical Bonding:**
 - 1 Application of Molecular Orbital Theory (MOT) to:
 - (a) Simple polyatomic ions/molecules such as H_3^+ , H_2O , BeH_2 , CO_2 and CH_4 .
 - (b) Metallic bond. Explanation of electrical properties of conductors, insulators and semiconductors (n and p type) on the basis of MOT.
 - 1. Molecular Symmetry:**
 - 2 Introduction, importance of symmetry in chemistry, symmetry elements and symmetry operations. Point groups of simple molecules like H_2 , HCl , H_2O , dichloroethylene, NH_3 , BCl_3 , CH_4 , CH_3Cl , CH_2Cl_2 , CHCl_3 , CCl_4 and SF_6 with explanation. .
- Unit II**
- 2. Inner Transition Elements ('f' Block Elements):**
 - 2.1 Introduction: The two series of 'f' block elements, their position in the periodic table, electronic configuration and general comparison of properties.
 - 2.2 Lanthanide Series: (a) Chemistry of lanthanides with reference to:
 - (i) oxidation states, (ii) magnetic properties, (iii) colour and spectra, (iv) lanthanide contraction, and (v) complex formation.(b) Occurrence, extraction and separation of lanthanides by (i) ion exchange and (ii) by solvent extraction methods.
 - (c) Applications of lanthanides.
 - 2.3 Actinide Series:
Chemistry of uranium and plutonium with reference to occurrence, extraction (solvent extraction method), properties and applications.
- Unit III**
- 3.1 Structure of Solids:**

Importance of solid state chemistry. Explanation of terms like crystal lattice, lattice points, unit cells, lattice constants, closest packing of rigid spheres (hcp, ccp), packing density in simple cubic, bcc, fcc and hcp lattices (numerical problems expected), tetrahedral and octahedral interstitial voids in ccp lattice, tetrahedral holes and limiting radius ratio for 4 coordination number.

Classification of solids on the basis of bonding, structure of metallic solids, structure of zinc blende and failure of radius ratio rule (directional bonding), structure of wurtzite, structures of perovskites (BaTiO_3 , SrTiO_3). Qualitative description of $\text{YBa}_2\text{Cu}_3\text{O}_{7-8}$ (1-2-3) high T_c superconductors.
 - 3.2 Superconductivity:**

Superconductivity, Meissner effect, different superconducting materials such as conventional superconductors, organic superconductors, alkali metal fullerenes (A_3C_{60}) and high temperature superconductors. Brief applications of superconducting materials.

- Unit IV** **4.1 Acid-base Concepts:** 5L
 Introduction. Arrhenius and Bronsted-Lowry concepts, leveling and differentiating solvents, strengths of Bronsted acids and bases. Solvent system (auto-ionization) concept, Lewis concept, strengths of Lewis acids and bases, Pearson's classification, Hard and soft acid base (HSAB) concept, Usanovich concept. Applications and limitations of these concepts.
- 4.2 Non-aqueous Solvents:** 5L
 Introduction. Classification of solvents. Study of liquid ammonia with reference to the (i) acid-base, (ii) solvolysis (iii) redox, (iv) precipitation, and (v) complex formation reactions.
 Solutions of metals in liquid ammonia and their applications.
 Dinitrogen tetroxide as solvent, its properties, general reactions in dinitrogen tetroxide.
- 4.3 Corrosion and its Protection:** 5L
 Introduction, economics and importance of corrosion, corrosion types, electro chemical theory of corrosion, protection methods.

SECTION - II (6 Units only)

- Unit V** **5.1 Bonding in Coordination Compounds:** 15L
 (a) Crystal field theory (CFT) splitting of d-orbitals in octahedral, tetrahedral, distorted octahedral and square planar electrostatic fields. Splitting energy,
 crystal field parameter $10Dq$, for octahedral complexes and factors affecting its magnitude. Effects of crystal field splitting on magnetic and spectral properties of octahedral complexes. Thermodynamic and related effects: (i) ionic radii (ii) lattice energies, (iii) hydration energies, and (iv) stability constants. Experimental evidences for covalency in coordination compounds: ESR spectra, NMR spectra, intensities of d-d transitions, Nephelauxetic effect, and anti-ferromagnetic coupling. Theoretical failure of the CFT model.
 (b) Molecular orbital theory as applied to octahedral complexes of the ML_6 type like (i) $[Ti(H_2O)_6]^{3+}$, (ii) fluoro and cyano complexes of Fe^{2+} and Fe^{3+} , and (iii) fluoro and ammine complexes of Co^{3+} . Effects of π -bonding on ligand field splitting parameter; $M \rightarrow L$ and $L \rightarrow M$ π -interactions.
- Unit VI** **6.1 Stability of complexes:** 5L
 Thermodynamic stability and kinetic lability of complexes with examples. Stability constants. Factors affecting thermodynamic stability. Methods of determination of stability constants with details of potentiometric method.
- 6.2 Substitution Reaction in Octahedral Complexes:** 6L
 Introduction. Types of reactions of complexes. Ligand substitution reactions: basic mechanisms. Labile and inert complexes, electronic configuration and lability of complexes. Acid hydrolysis, base hydrolysis and anation reactions.
- 6.3 Electronic Spectra of Complexes:** 4L
 Origin of electronic spectra, types of electronic transitions (intra-ligand, charge transfer and d-d), the three selection rules, applications of electronic spectra in brief with special reference to determination of the geometry of the complexes.

Unit VII	7.1 Organometallic Compounds:	
	(a) Chemistry of iron carbonyls with reference to preparation, properties, structure and bonding. Differentiation of terminal and bridging carbonyl groups on the basis of infrared spectra.	
	(b) Metallocenes: Introduction. Synthesis, structures, reactions and applications of ferrocene. Bonding in ferrocene.	
	(c) δ -Bonding in Re and Mo halide complexes.	
	7.2 Catalysis and its Industrial Applications:	4I
	Homogeneous catalysis with reference to (i) hydrogenation of alkenes (Wilkinson catalyst), (ii) hydroformylation reaction (Rollen catalyst), and (iii) polymerization reaction (Ziegler Natta catalyst).	
	7.3 Inorganic Polymers:	4I
	Introduction. Various methods of classification with examples. Chemistry of borazine and silicones with reference to preparation, properties, structure, bonding and applications.	
Unit VIII	Some Selected Topics:	
	8.1 Environmental Pollution:	6L
	(a) Introduction, study of various pollutants such as oxides of nitrogen, carbon and sulphur, particulate matter and heavy metals, with respect to i) sources of emission, ii) reactions, iii) health hazards, and iv) control measures.	
	(b) Green house effect, ozone layer depletion and their consequences.	
	8.2 Bioinorganic Chemistry:	3L
	Role of sodium and potassium, mechanism of ion pump. Study of vitamin B ₁₂ .	
	8.3 Nano particles: Introduction. Their properties and applications.	3L
	8.4 Lasers : Introduction, types, properties and applications.	3L

PRACTICALS (INORGANIC CHEMISTRY)

(For Six Units)

1. **GRAVIMETRIC ANALYSIS:** 25 M
Estimation of following cations from the mixture of salts as mentioned:
(a) Ni^{2+} as nickel dimethyl glyoximate from a solution of copper chloride and nickel chloride.
(b) Ba^{2+} as barium chromate from a solution of barium chloride and ferric chloride.
(c) Zn^{2+} as zinc ammonium phosphate (ZnNH_4PO_4) from a solution zinc sulphate and copper sulphate.
2. **INORGANIC PREPARATIONS AND CHARACTERIZATION:** 25 M
Preparation of following compounds and determination of their metal content by complexometric titration after decomposition.
(a) Tris-(ethylenediamine) nickel(II) thiosulphate
(b) Copper acetylacetonate.
(c) Magnesium oxinate.
N. B.: In Inorganic preparation, the student is expected to weigh the chemicals, prepare solutions, carry out the reaction, isolate and report the crude product yield and purify the compound by recrystallization from appropriate solvent.
3. **TITRIMETRIC ANALYSIS:** 15 M
(a) Estimation of zinc using Eriochrome Black T indicator
(b) Estimation of cobalt using xylenol orange indicator.
(c) Analysis of talcum powder for magnesium content.
(d) Estimation of total hardness in well water.
(e) Analysis of boric acid for its percentage purity.
(Note: Students to prepare 0.02M Na_2EDTA solution for titration).

Practicals (Inorganic Chemistry)

(For Three Units)

1. **GRAVIMETRIC ANALYSIS:**
Estimation of following cations from the mixture of salts as mentioned:
(a) Ni^{2+} as nickel dimethyl glyoximate from a solution of copper chloride and nickel chloride.
(b) Ba^{2+} as barium chromate from a solution of barium chloride and ferric chloride.
(c) Zn^{2+} as zinc ammonium phosphate (ZnNH_4PO_4) from a solution zinc sulphate and copper sulphate.
2. **Titrimetric Analysis:-**
a) Estimation of zinc using Eriochrome Black T indicator
b) Estimation of cobalt using xylenol orange indicator.
c) Analysis of talcum powder for magnesium content.

References:

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- 8) **Concepts and Models of Inorganic Chemistry : B. Douglas, D. Mc. Daniel and J. Alexander, (1994), 3rd Edition, John Wiley and Sons Inc.**
- 9) **Vogel's Textbook of Quantitative Chemical Analysis : Revised by G. H. Jeffery, G. H. Bassett, Menham and R. C. Denney, 5th Edition, ELBS Publications, 1989**
- 10) **Chemistry of Elements :N. N. Greenwood and Earnshaw, Pergamon Press, UK. 1989.**
- 11) **Electrons and Chemical Bonding: Harry B. Gray, W. A. Benjamin Inc., New York.1964.**
- 12) **Concise Inorganic Chemistry: J. D. Lee (1996), 5th Edition, Oxford University Press.**
- 13) **Theoretical Principles of Inorganic Chemistry : G. S. Manku, (1990), Tata McGraw Hill Publishing Co. Ltd., New Delhi.**
- 14) **Satya Prakash's Modern Inorganic Chemistry: R. D. Madan, 1st Edition, S. Chand & Co. Ltd., New Delhi.**
- 15) **Advanced Inorganic Chemistry Vol. 2: Satyaprakash, Tuli, Basu and Madan etc. S. Chand & Co. Pvt. Ltd., New Delhi.**
- 16) **Introduction to Solids: Azroff LU., Tata Mc Grow Hills, New Delhi, 1977**
- 17) **Chemical Application of Group Theory: Cotton F. A. , Wiley Eastern, 2nd Edn., 1989.**
- 18) **Structural Inorganic Chemistry: A.F. Wells, 5th Edn., Clarendon Pres, Oxford, 1986**
- 19) **The Elements of Physical Chemistry: Atkins, 7th Edition.**
- 20) **Group Theory In Chemistry and Physics M.G. Arora: Anmol Publications**
- 21) **Symmetry and Spectroscopy of molecules: K. Reddy.**
- 22) **Symmetry in Molecules: J. M. Hollas, Chapman & Hall, 1972.**
- 23) **Principles of Lasers by O'Svelto.**
- 24) **An Introduction to Lasers and Masers: A. E. Siegmann**
- 25) **Lasers - Principles and Applications: J. Wilson and J. F. B. Hawkes, Prentice Hall, NY(1987).**
- 26) **Introduction to Lasers and their Applications: O. Svelto and D.C. Hanna, Plenum, Press, NY(1982).**

PAPER III - ORGANIC CHEMISTRY

Learning Objectives:

- 1) While learning different topics, the current state-of-art and new developments in Organic Chemistry should be kept in mind.
- 2) The topics should be learnt with the corresponding background knowledge gained during the previous two years.
- 3) Wherever applicable, emphasis should be given on the mechanisms of organic reactions being studied.
- 4) Wherever applicable, the importance of the topics with respect to the industrial practices should be highlighted. For this appropriate text may be referred.
- 5) On the background of the F.Y. and S.Y. syllabi, a unified and systematic picture of Organic Chemistry be developed.

Marks: 100

Lectures 120

SECTION I (3 and 6 units)

Unit I

1. IUPAC Nomenclature:

4L

IUPAC nomenclature of – Bicyclic (up to ten membered ring) saturated and unsaturated compounds, spirans, biphenyls, and cummulenes; monocyclic aromatic as well as nonaromatic heterocyclic compounds (five and six membered rings) containing up to two heteroatoms among N, O, S.

2. Mechanisms with stereochemistry of the following reactions:

11L

2.1. Elimination reaction: E_1 and E_2 mechanisms-Hoffmann and Saytzeff rules

2.2. Mechanism of reactions of carbonyl compounds with nucleophiles: Tetrahedral mechanism: Addition of nitrogen nucleophiles to aldehydes/ketones, formation of acetals/ ketals from aldehydes/ ketones, acids catalyzed esterification of carboxylic acids with alcohols and acid and base catalyzed hydrolysis of esters ($B_{AC}2$ and $A_{AC}2$ mechanisms only).

2.3. Rearrangements:

2.3.1. Electron deficient carbon: Wagner-Meerwein, Pinacol- Pinacolone, Fries.

2.3.2. Electron deficient nitrogen: Hoffmann, Beckmann, Lossen, Schmidt.

Unit II

3. Stereochemistry:

15L

3.1. Structure of cycloalkanes (up to C_6): Structure; strains in cycloalkanes- Angle, van der Waal, Torsional. Structure of cyclohexane in detail. Configurations and conformations of mono- and di-substituted cyclohexanes.

3.2. Molecular Chirality and Elements of symmetry: Stereochemistry of biphenyl, spirans and cummulenes.

3.3. Regioselectivity: Concept with the following examples – (i) Addition of bromine and HX to 1,3-butadiene (ii) Dehydration of alcohols e.g. 2-methylcyclohexanol and 2-methyl-2-butanol

3.4. Stereoselectivity and Stereospecificity: Idea of enantiomeric and distereomeric selectivities, *de* and *ee*. Topicity – Enantiotopic and diastereotopic atoms, groups and faces. The mechanism and stereochemical outcome of the following reactions: (i) S_N1 and S_N2 reactions, Walden inversion (ii) Catalytic hydrogenation of alkenes (iii) Addition of bromine to alkenes: only ionic *trans* addition.



(iv) Epoxidation of alkenes, acid catalysed ring opening of epoxides. (v) Reactions of OsO_4 and KMnO_4 with olefins.

Unit III

4. Heterocyclic chemistry:

8L

4.1. Introduction, electronic structures, aromaticity, reactivity and general methods of synthesis of - pyrroles, furans, thiophenes and pyridines.

4.2. Reactions: Furans: Halogenation, Nitration, Sulphonation, Ring opening, Vilsmeier reaction, Diels-Alder reaction.

Thiophenes: Halogenation, Nitration, Sulphonation, Vilsmeier reaction, Friedel-Crafts reaction

Pyrroles: Basicity/acidity, halogenation, Nitration, Sulphonation, Acid catalyzed polymerization, Vilsmeier reaction, Friedel-Crafts reaction

Pyridines: Basicity, Quaternization, reduction, Oxidation of alkyl pyridines, Preparation and important reactions of pyridine-N-oxide.

5. Organic Chemistry in Industry:

7L

5.1. Synthesis and commercial importance of the following compounds, with special emphasis on the key steps/aspects involved in each synthesis, which highlight specific principles of organic synthesis: Trimethoprim, Ciprofloxacin, Nephedipin, Diclophenac sodium, tramadol, 2-Hydroxy-3-amino-5-nitrobenzene sulphonic acid from chlorobenzene, H-acid, 1-Amino-4-bromoanthraquinone-2-sulphonic acid (bromanine acid)

5.2. Green Chemistry: 12 principles of green chemistry with explanation and applications of each. E-factor, Atom economy/selectivity- concepts and numerical examples of these.

Unit IV

6. Polymers:

11L

6.1. Introduction: General idea of structure. Naming, Types of polymers, Tacticity, polymerization processes with examples, radical and ionic mechanisms of polymerizations. Characteristic properties of polymers. General ideas of resins, plastics, rubber. Idea of plasticizers, stabilizers, fillers.

6.2. Structure, preparation and applications of PE (types and Ziegler-Natta process), PP, teflon, PVC, PS, Polyacrylates, PAN, Neoprene, Terylene, Nylons, Phenol/Melamine/Urea- Formaldehyde Resins, polyurethane, polycarbonate, epoxy resins (structures of the monomers and those of the polymers are expected)

7. Oxidation and reduction:

4L

The following reagents are to be studied with respect to selectivity in the respective conversions, no mechanisms are expected.

7.1 Oxidations using - H_2O_2 , mCPBA, KMnO_4 , MnO_2 , $\text{K}_2\text{Cr}_2\text{O}_7$, CrO_3 , Oppenaur oxidation, SeO_2 .
Reductions using - LAH, NaBH_4 , Diborane, catalytic hydrogenations using catalysts -

7.2 Pd-C, Pd-BaSO₄ (Lindlar), PtO₂ (Adams catalyst), MPV reduction, hydrazine (Wolff-Kishner reduction)

SECTION II (6 units only)

Unit V

8. Introduction to spectroscopy of Organic compounds:

15L

8.1. Introduction: Idea of electromagnetic spectrum. Absorption of radiation- Quantisation principle, different units of expressing wavelength.

8.2. UV-Visible spectroscopy- Basic theory (instrumentation not expected), Analysis of the spectrum, Chromophore-Chromophore and Chromophore-Auxochrome interactions, General applications with particular emphasis on chromophore detection. UV-Vis spectra of conjugated dienes, conjugated enones and aromatic compounds.

8.3. IR Spectroscopy: Basic theory (instrumentation not expected), Selection rule, Vibrational coupling, General applications with emphasis on qualitative identification of functional groups. Intensity and position of IR bands, Fingerprint region.

8.4. NMR Spectroscopy: proton magnetic resonance spectroscopy: Basic theory (instrumentation not expected), chemical Shift, standard, solvent, spin-spin coupling, magnetic anisotropy of C=C, C=O, C $\cdot$ C and aromatic ring, importance of D₂O exchange

With respect to above types of spectroscopy the spectral characteristics of the following classes of simple organic compounds, including benzene and monosubstituted benzenes, are to be discussed:

(i) Alkanes (ii) Alkenes (iii) Alkynes (iv) Haloalkanes (v) Alcohols (vi) Aldehydes-Ketones (vii) Carboxylic acids and their esters and amides (viii) ethers

(Exact peak positions are not expected, however, broad regions characteristic of different groups are expected)

8.5. Mass Spectroscopy: Basic theory (Instrumentation not expected), Importance of molecular ion peak, M⁺ peak, isotopic peaks. Major fragmentations modes of simple molecules belonging to alkanes, alkenes, aldehydes/ketones and alcohols.

Problems pertaining to structure elucidation of simple organic compounds using the above spectroscopic techniques are expected.

Unit VI

9. Chemistry of Natural Products:

11L

General idea, including classification, structures and commercial importance of terpenes, alkaloids, vitamins, hormones, steroids.

9.1. Structure determination of - α -pinene, atropine

9.2. (a) The following commercial synthesis : α pinene to camphor, α pinene to methol, isopentene to citral, citral to beta-ionone, pNA to thyroxine (b) Total synthesis (including part synthesis) of - α -terpeneol, atropine.

10. Photochemistry:

4L

Principles of photochemistry, Singlet and Triplet states, Photosensitization, Isomerization and rearrangements of olefins, Photoreduction- benzophenone to benzpinacol, Norrish Type-I and Norrish Type- II reactions.

Units VII – VIII

11. Carbohydrates:

10L

11.1. Introduction: Classification based on chemical constitution with suitable examples, sources, nomenclature, glycosides.

11.2. Structure of Carbohydrates: Open chain and Ring structure of carbohydrates - Furanose and Pyranose structures of pentoses and hexoses (interconversion open-Haworth-chair form); determination of the configurations of glucose and fructose (with ring size) assuming their open chain structures; Mutarotation. Chain lengthening and shortening reactions

11.3. Reactions of glucose and fructose: Osazone formation, acetylation, methylation, reduction-catalytic and using NaBH₄, oxidation-periodic acid, conversion of glucose to fructose.

11.4. Disaccharides: Structure of sucrose, maltose, lactose. (structure determination not expected)

11.5. Commercial importance of carbohydrates.

(The structures of all carbohydrates must be presented in the corresponding cyclic forms).

12. Chemistry of some Important Biomolecules:

10L

12.1. Amino acids and proteins: General structure, including stereochemistry, of α -amino acids, essential amino acids, isoelectric point, synthesis of α -amino acids - amination of haloacids, azalactone synthesis, Curtius method, Gabriel method. Synthesis of polypeptides: Bergmann method, Fischer method and solid phase synthesis. Secondary and tertiary structures of proteins.

12.2 Nucleic acid: Structures of important purines and pyrimidines bases and carbohydrates residues present in nucleic acids, structure of nucleosides, structure of nucleotides. Structure of DNA and RNA-Base, pairing in. Importance of nucleic acids in- (i) Self duplication (ii) protein synthesis.

13. Organometallics:

9L

Nature of carbon-metal bond, nomenclature.

13.1. Organolithium compounds: Methods of preparation of alkyl/aryl lithium, their use as bases, synthesis of alcohols and carboxylic acids using them. Lithium dialkyl cuprates: Preparation and use in the synthesis of higher alkanes

13.2. Organozinc compounds: Preparation of iodomethyl zinc iodide and its use in the synthesis of cyclopropanes (Simmons-Smith reaction) (with stereochemistry). Reformatsky reaction (with mechanism).

13.3. Oxymercuration-demercuration and solvomercuration of alkenes: Mechanism and regioselection.

(Synthetic problems involving these organometallics are expected)

PRACTICAL ORGANIC CHEMISTRY (6 units)

[1] Separation of Organic Mixtures.

25M

Quantitative separation of a binary organic mixture, based on the differences in the physical and chemical properties of the two components. Both the components should be purified by crystallization or distillation with the entire separated quantities, and the yields should be noted. One of the component should be identified. The following types of mixtures may be given: (i) water soluble + water insoluble (ii) two liquids differing significantly in b.p. (iii) a volatile liquid with a high melting solid. (iv) two compounds (both solid) differing in nature (acid /phenol/base/neutral). Emphasis must be given on effectiveness of separation and purification (around 2g of each solid and 6-8 mL of each liquid may be given for separation).

The weights of the separated crystallized products should be recorded. The quality of the products should be adjudged on the basis of m.p. /b.p

[2] Organic synthesis

15M

The following one step synthesis be done and the products be purified and the percent yields reported (About 2g of the starting compound may be given)

- (i) N-Acylation of an aromatic primary amine (N-acetylation/propionylation of aniline /4-methylaniline /4-nitroaniline)
- (ii) Condensation of benzaldehyde with acetophenone, Condensation of an aromatic aldehyde with a primary amine (e. g. benzaldehyde with aniline/ 4-methylaniline/ benzylamine)
- (iii) O-Methylation of a phenol using dimethyl sulphate (O-methylation of phenol/ α - or β -naphthol/ cresol)
- (iv) Oxidation of benzaldehyde to benzoic acid, Oxidation of 4-nitrobenzaldehyde to 4-nitrobenzoic acid
- (v) Reduction of benzophenone to benzhydrol (using either NaBH_4 or Zn-HOAc)
- (vi) Azo coupling reaction (coupling of diazotized 4-nitroaniline with α -naphthol/ salicylic acid).
- (vii) Halogenation: Acetanilide to 4-bromoacetanilide.
- (viii) Nitration of an aromatic compound (nitration of nitrobenzene, salicylic acid)
- (ix) Oximation: Oximation of cyclohexanone, acetophenone

At least one preparation from each of the above types should be done.

Laboratory Safety aspects: The use of hand gloves, while handling especially hazardous chemicals, and the use of safety goggles and safety shoes in general, are recommended.

[3] Viva

6M

Questions related to laboratory safety, chemical hazards, etc., besides those based on the practical exercises, should be asked in the viva.

[4] Journal

4M

PRACTICAL ORGANIC CHEMISTRY (3 units)

[1] Organic synthesis

The following one step synthesis be done and the products be purified and the percent yields reported (About 2g of the starting compound may be given)

- i) N-Acylation of an aromatic primary amine (N-acetylation/propionylation of aniline /4-methylaniline /4-nitroaniline)
- ii) Condensation of benzaldehyde with acetophenone, Condensation of an aromatic aldehyde with a primary amine (e. g. benzaldehyde with aniline/ 4-methylaniline/ benzylamine)
- iii) O-Methylation of a phenol using dimethyl sulphate (O-methylation of phenol/ α - or β -naphthol/ cresol)
- iv) Oxidation of benzaldehyde to benzoic acid, Oxidation of 4-nitrobenzaldehyde to 4-nitrobenzoic acid
- v) Reduction of benzophenone to benzhydrol (using either NaBH_4 or Zn-HOAc)
- vi) Azo coupling reaction (coupling of diazotized 4-nitroaniline with α -naphthol/ salicylic acid).
- vii) Halogenation: Acetanilide to 4-bromoacetanilide.
- viii) Nitration of an aromatic compound (nitration of nitrobenzene, salicylic acid)
- ix) Oximation: Oximation of cyclohexanone, acetophenone

At least one preparation from each of the above types should be done.

[3] Viva

Questions related to laboratory safety, chemical hazards, etc., besides those based on the practical exercises, should be asked in the viva.

[4] Journal

Suggested Books:

1. Organic Chemistry, J. Clayden, N. Greeves, S. Warren, P. Wothers, Oxford University Press, Oxford, 2001
2. Organic Chemistry by F. A. Carey 3rd Edition, Tata McGraw-Hill Companies, Inc., 1996.
3. Organic Chemistry, J. McMurry, 5th Edition, Brooks/Cole, 1999.
4. Organic Chemistry, T. W. G. Solomons, C. B. Fryhle, 7th Edition, John Wiley and Sons Inc, 2000.
5. Organic Chemistry, G. Marc Loudon, 4th Edition, Oxford university Press, 2002 (Indian Reprints)
6. Organic Chemistry, L. G. Wade Jr., 5th Edition, Pearson Education, 2003 (Indian Reprint 2004).

7. Organic Chemistry – Structure and Function, 4th Edition, K. P. C. Vollhardt and N. E. Schore, W. H. Freeman and Co., New York, 2003.
8. Organic Chemistry by S. H. Pine, J. B. Hedrickson, D. J. Cram and G. S. Hammond, McGraw-Hill Kogakusha, 1980.
9. Spectroscopic method in Organic Chemistry, by D. H. Williams and I. Fleming, Tata McGraw-Hill Company Ltd.
10. Organic Spectroscopy by W. Kemp, MacMillan Publishers
11. Organic Spectroscopy by V. R. Dani, Tata McGraw-Hill Company Ltd.
12. Stereochemistry of Carbon Compounds by E. L. Eliel, McGraw-Hill, 2003
13. Stereochemistry: Conformations and mechanism, P. S. Kalsi, Wiley Eastern Ltd.
14. Stereochemistry and mechanism through solved problems, P. S. Kalsi 3rd Edition New age International Pvt Ltd.
15. Chemistry of Organic Natural Products – Vol. I and II by O. P. Agarwal, Goel Publishing House, 2002.
16. Organometallic Chemistry by R. C. Mehrotra, Anirudh Singh, New age International Pvt Ltd, 2002.
17. Carbohydrate Chemistry by A. J. Fairbanks and B. G. Davis, Oxford University Press, 2002.
18. Organic Chemistry, S. N. Ege, D. C. Heath and Co. 1984.
19. Polymer Science, V. R. Gowarikar, N. V. Vishwanathan, J. Sreedhar, New Age International, 1986.
20. Molecular Reactions and Photochemistry, C. H. DePuy and O. S. Chapman, Prentice - hall of India, New Delhi, 1988.
21. The organic chemistry lab survival manual,, J.W. Zubrick, John Wiley & Sons, 2004.
22. Laboratory manual in Organic Chemistry, R.K.Bansal, New Age International.
23. Elementary Organic Chemistry, Parts I,II,III, A.I.Vogel, ELBS Longmans Group Ltd.
24. Microscale Organic Laboratory, D. W. Mayo, R. M. Pike and P. K. Trumper, 3rd Edition, John Wiley and Sons.

Section I (3 and 6 units)

Unit-I: 1. Treatment of Analytical Data and Sampling:

1.1. Treatment and presentation of analytical data - 1: Determinate and indeterminate errors, precision and accuracy, mean, median, range, standard deviation, variance, significant figures. (Numerical problems expected.) (7 L)

1.2. Sampling: Definition and purpose of sampling, Types of sampling; Sampling of gases: ambient and stack sampling; Sampling of liquids: homogeneous and heterogeneous liquids, static and flowing liquids; Sampling of solids: sample size, size reduction, Different sampling equipments and methods of sampling (8 L)

Unit-II: 2. Volumetric analysis:

2.1. Theoretical aspects of titration methods, titration curves, and end point evaluation and choice of indicators in (i) Complexometric titrations: Cu^{2+} /EDTA and Ca^{2+} /EDTA, (ii) Redox titrations: $\text{Fe}^{2+}/\text{Ce}^{4+}$, $\text{Fe}^{2+} / \text{Cr}_2\text{O}_7^{2-}$ and $\text{Fe}^{2+}/\text{MnO}_4^{1-}$ and (iii) Precipitation titrations: Mohr and Volhard methods (12 L)

2.2. Non aqueous titrations- basic principles and applications. (3 L)

Unit-III: 3. Methods of separation - I:

3.1. Solvent Extraction: Nernst distribution law, Partition coefficient, distribution ratio, extraction efficiency, solvent properties; batch and continuous extraction (numerical problems expected.) (8 L)

3.2. Chromatography: classification of chromatographic methods, Principles, technique and applications of (i) paper chromatography and (ii) thin layer chromatography. (7 L)

Unit-IV: 4. Optical methods - I:

UV and Visible Spectroscopy:

Beer -Lambert's law and its limitations, double beam photo colorimeters, single beam and double beam spectrophotometers - block diagrams and components of the instruments with their functions, analytical applications; Photometric titrations and their applications. (numerical problems expected)

(15 L)

Section II (6 units only)

Unit-V: 5. Treatment of Analytical Data and Chromatography:

5.1 Treatment and presentation of analytical data - II: Distribution of random errors - Gaussian curve, Student's t , confidence limits, confidence interval, criteria for rejection of results - 2.5d and 4d rules and Q-test, graphical presentation of results, null hypothesis, testing of significance - F test, calibration curve method, method of averages and least squares method; Basic concepts of uncertainty measurement. (numerical problems expected)

Use of computers in chemical analysis: Enhancement of instrument capabilities, control of instruments, data acquisition, processing and storage. (7 L)

5.2. Methods of separation - II: Chromatographic Methods:

(i) Principles, Instrumentation and applications of Gas Chromatography and HPLC (ii) Basic principles and applications of Ion exchange chromatography. (8 L)

Unit-VI: 6. Electroanalytical Methods:

6.1 Introduction to Ion Selective Electrodes: hydrogen and fluoride (3 L)

6.2 Potentiometric titrations: acid base and redox titrations, variation of electrode potential and cell emf during titrations. (4L)

6.3 D.C. Polarography: Basic principles, polarizable and non-polarizable electrodes, dropping mercury electrode, supporting electrolyte, residual current, diffusion current, limiting current, half wave potential, derivation of polarographic wave equation for a reversible reaction, Ilkovic equation, oxygen interference, Polarographic maxima and its suppression, polarographic cell, circuit - diagram, qualitative and quantitative analysis; calibration curve and standard addition methods; applications. (numerical problems expected) (8 L)

Unit-VII: 7. Optical methods - II:

7.1 Atomic spectroscopy: sources of atomic spectra, energy level diagrams, atomic emission and absorption spectra. (3 L)

(i) Flame photometry: Components of flame photometer, atomizers, types of burners, filters and detection devices. (3 L)

(ii) Atomic absorption spectrophotometry: hollow cathode lamp, flame and electro-thermal atomizers, detectors. (3 L)

(iii) Methods of quantification and applications: Calibration curve, standard addition and internal standard methods as used in A.A.S. and flame photometry and applications. (2 L)

7.2 Molecular fluorescence and phosphorescence spectroscopy: theory, instrumentation and applications. (4 L)

Unit-VIII: 8. Optical and Miscellaneous Methods:

8.1 Turbidimetry and Nephelometry: Scattering of light, effect of concentration, particle size and wavelength on scattering; instrumentation and applications. (4 L)

8.2 Introduction to Mass spectrometry: Basic principles, instrumentation (magnetic sector analyzer) and applications. (4 L)

8.3 Introduction to Radio-analytical Methods: Basic concepts and applications of neutron activation analysis. (4 L)

8.4 Introduction to Thermo-analytical Methods: Theory, instrumentation and applications of thermogravimetry. (3 L)

List of reference books:

1. D. A. Skoog, D. M. West, and F. J. Holler, *Fundamentals of Analytical Chemistry*, 7th ed., Philadelphia: Saunders College Publishing, 1996.
2. G. D. Christian, *Analytical Chemistry*, 6th ed., John Wiley and Sons, New York, 2003.
3. D. A. Skoog, F. J. Holler, and T. A. Nieman, *Principles of Instrumental Analysis*, 5th ed., Philadelphia: Saunders College Publishing, 1996.
4. J. G. Dick, *Analytical Chemistry*, International Students Edition, McGraw Hill, Kogakusha Ltd., New Delhi, 1973.

5. R. A. Day, Jr. and A. L. Underwood, *Quantitative Analysis*, 6th ed., Prentice Hall of India Pvt. Ltd., New Delhi, 1993.
6. G. H. Jeffery, J. Bassett, J. Mendham and R. C. Denney, *Vogel's Textbook of Quantitative Chemical Analysis*, 5th ed., ELBS, Longman Scientific & Technical, England, 1991.

PRACTICALS

Section I (3 and 6 units)

1. pH titration of sodium carbonate against HCl to demonstrate the selection of indicators for two inflections.
2. Titration of a mixture of strong acid and weak acid vs. strong base by conductometry
3. Calibration of a spectrophotometer (in the visible range) using KMnO_4 solution.
4. Determination of Mn by periodate method colorimetrically using least squares method.
5. Separation of metal ions viz. Ni, Co, Mn, Zn (any two) by ascending paper chromatography.
6. Estimation of sodium using a cation exchanger.
7. Determination of saponification value of an oil or fat.

Section II (6 units only)

8. Identification of an acid (Maleic, Malonic and Phosphoric acids) by acid-base titration pHmetrically.
9. Determination of the stability constant of Fe^{3+} - salicylic acid system by spectrophotometric method.
10. Separation of Zinc and Magnesium on an anion exchanger.
11. Determination of Vitamin C by titration with Ce^{4+} using ferroin indicator.
12. Determination of amino acid eg. glycine by non-aqueous titration in glacial acetic acid using crystal violet indicator.
13. Estimation of an ester / amide by hydrolysis.
14. Estimation of nitro group by SnCl_2 reduction.

UNIVERSITY OF MUMBAI
DRAFT SYLLABUS FOR THE SUBJECT OF DRUGS AND DYES PRESCRIBED
UNDER THE APPLIED COMPONENT GROUP FOR THE T.Y.B.Sc. (CHEMISTRY)
UNDER THE REVISED PATTERN---2004---2005

PAPER-I: DRUGS

Marks – 60

Lectures-60

Unit - I

1. General Introduction to drugs

3L

- 1.1 Definition of a drug- Requirements of an ideal drug, Classification of drugs (based on therapeutic action)
- 1.2 Nomenclature of drugs - generic name, branded name, systematic name
- 1.3 Historical development including contributions of different scientists (only landmarks of the 20th century to be covered)
- 1.4 An overview of the present scenario in the Indian Pharmaceutical Industry

2. Important terms in medicinal chemistry

3L

Pharmakon, Pharmacophore, Receptors, Drug-receptor interaction, Prodrug, Drug potency, Half-life efficiency, LD50, ED50, Therapeutic index, Bioavailability, Drug toxicity, Drug addiction, Spurious drugs, Misbranded drugs, Adulterated drugs.

3. Routes of drug administration and dosage forms

2L

- 3.1 Oral and parenteral routes, with advantages and disadvantages.
- 3.2 Different dosage forms - emphasis on sustained release formulations

4. Pharmacodynamic agents

4.1 Central Nervous System (C.N.S.) Drugs:

6

L

(i) Sedatives, Hypnotics and Anticonvulsants

Concept of sedation and hypnosis. Types of epilepsy

Barbiturates - Classification based on duration of action with examples and structures

Synthesis of Phenobarbitone

Hydantoin derivatives:--e.g. Phenytoin (str)

Oxazolidinediones:--eg -Alaxidone, Trimethadione(strs)

Synthesis of Trimethadione

(ii) Tranquilizers: (only antipsychotics to be covered with structures)

Phenothiazines-Chlorpromazine, Trifluorpromazine.

Butyrophenone ders.- Haldol

Benzodiazepines - Diazepam

(Structure -activity relationship in Benzodiazepines to be discussed)

Synthesis of Chlorpromazine

(iii) Stimulants:--Classification: cerebral, respiratory and psychomotor stimulants, with structures of the following classes

Nicotinic acid derivatives - Coramine

Purines - Xanthine bases

Phenylethylamine derivatives - Amphetamine and related compounds

Tricyclic compds - Chlorprothixene

(Mode of action to be discussed)
Synthesis of Amphetamine, Coramine.

4.2 Analgesics and Antipyretics

2L

Narcotic analgesics - Morphine and Codeine (structures)
Non-narcotic analgesics (with structures)
Pyrazolones and pyrazolidones - Antipyrine and Novalgin
Salicylic acid derivatives - Aspirin (various dosage forms)
p-Aminophenol derivatives - Paracetamol, Phenacetin
Synthesis of Novalgin

4.3 Anti-inflammatory drugs

2L

Mechanism of inflammation and various inflammatory conditions.
Non steroidal anti-inflammatory drugs (with structures)
Aryl acetic acid derivatives - Ibuprofen, Diclofenac

N-aryl anthranilic acid derivatives - Mefenamic acid

Pyrazolones - Oxyphenbutazone
Synthesis of Diclofenac

4.4 Antihistaminic drugs

3L

Mechanism of histamine release and action
Following drugs with structures to be discussed
Ethanolamine derivatives - Benadryl
Ethylenediamine derivatives - Antergan
Phenothiazine derivatives - Promethazine hydrochloride
Miscellaneous - Chlorpheniramine maleate

Synthesis of Benadryl

H₂ antagonists (antisecretory drugs)
Cimetidine, Ranitidine (structures)
Synthesis of Ranitidine

4.5 Antihypertensive drugs

2L

Concept of blood pressure and its irregularities
General idea of the following types of drugs with structures.
Vasodilators:-Hydralazine hydrochloride, Isosorbide
Beta blockers:-propranolol, atenolol
Calcium channel blockers:-Nifedipine Amlodipine
Synthesis of Nifedipine
(Mechanism of action of beta blockers to be discussed)

4.6 Diuretics

2L

Osmotic diuretics:-Mannitol, Ammonium chloride urea (general idea)
Thiazides:-Chlorothiazide (structures)
Sulphonamides:-Acetazolamide (structures)
Sulphamyl benzoic acid der;-Furesomide (structures)
Synthesis of Furesomide

4.7 Antidiabetics

2L

General idea of types of Diabetes.

Insulin therapy, oral hypoglycaemic agents (structures)

Tolbutamide, Glipizide, Glibenclamide

Synthesis of Tolbutamide

4.8 Antiparkinsonism drugs

1L

Idea of Parkinsons disease, str of the foll. Drugs:-

Piperidine analogues:-Cycrimine hydrochloride

Pyrrolidine analogues:-Procyclidine hydrochloride

Phenothiazine der:-Ethopropazine hydrochloride

4.9 Drugs for respiratory system

2L

General idea of the foll. Types of drugs (with structures .)

Expectorants:-Bromhexine hydrochloride, Guaiphenesin

Bronchodilators:-Salbutamol, Epinephrine.

Decongestants:-Ephedrine, Oxymetazoline.

Synthesis of Salbutamol

Unit II

5. Drug metabolism

2L

Different types of chemical transformations of drugs with specific examples

6. Chirality in drugs

2L

Effect of chirality on drug action - different examples. Resolution techniques for (+)-Ethambutol and D(-)-Threo chloramphenicol. Chiral synthesis of Ibuprofen

7. Chemotherapeutic agents

5L

7.1 Antibiotics

Definition, characteristics, classification (diff. Methods), properties and therapeutic uses of the foll. Classes of antibiotics (with structural features)

Beta lactum antibiotics:-Cloxacillin, Ampicillin, Amoxicillin.

Cephalosporins:-Cephalosporin N, Cephalosporin C, Cephalexin.

Tetracyclines:-Tetracycline, Doxycycline

Quinolones:-Nalidixic acid, Ciprofloxacin

Structure activity relationship in Penicillins to be discussed

Synthesis of Ciprofloxacin

7.2 Antimalarials

2L

Types of parasites, symptoms (life history of malarial parasite---not to be discussed)

Foll. Classes with str:-

4-Aminoquinolines:- Chloroquin

8-Aminoquinolines:- Primaquin

Acridines:-Quinacrine

Biguanides:-Paludrine

Diamino pyrimidines:-Pyrimethamine

Synthesis of Pyrimethamine, Paludrine.

7.3 Antitubercular drugs

2L

Types of tuberculosis, following classes of drugs with structures.

Antibiotics:-Streptomycin, Rifampin.

Amino salicylates:-PAS.

Hydrazides:-Isoniazide

Pyrazine der:-Pyrazinamide

Aliphatic diamines:-Ethambutol

(combination chemotherapy to be discussed)

synthesis of PAS, Ethambutol.

7.4 Antileprotic drugs

1L

Types of leprosy, foll.drugs with str.

Dapsone, Acedapsone, Clofazimine.Synthesis of Acedapsone

7.5 Antiamoebic drugs

2L

Classification of Amoebicides,

Hydroxy quinolines:-Vioform, Diodoquin

Imidazoles:-Metronidazole, Tinidazole.

Antibiotics:-Bacitracin

Furan der;-Diloxanide Furoate

Mechanism of action of Imidazoles

Synthesis of Metronidazole

7.6 Anthelmintics

2L

Drugs effective in the treatment of Nematode and Cestode infestations only.

Piperazine der:-Piperazine ,Diethylcarbamazine

Benzimidazoles:-Mebendazole

Amides:-Niclosamide

Nitro derivatives:-Netobimin

Synthesis of Mebendazole

7.7 Antiseptics and Disinfectants

2L

General idea,

Phenols:-hexyl resorcinol, thymol.

Halogen containing compds:-chloroxylonol, hexachlorophane

Dyes:-Mercurochrome, genetian violet

Nitrofurans der:-nitrofurazone

Synthesis of Mercurochrome

7.8 Antineoplastic Drugs (cancer chemotherapy)

2L

Idea of malignancy, causes of cancer.

Nitrogen mustards:-Chlorambucil

Antimetabolites:-Fluorouracil, Methotrexate

Steroid hormones:-Estrogens, Prednisolone.

Microtubule inhibitors:-vincristine, vinblastine

Synthesis of chlorambucil

7.9 Antiretroviral Drugs

1L

Idea of HIV pathogenicity, symptoms of AIDS. Suggested treatment,

AZT, DDI, CD-4 Glycoproteins.

8. Inorganic pharmaceuticals

2L

Only the general idea of the following:

8.1 Iron compounds as antianaemic drugs:- Ferrous sulphate, Ferrous fumarate, Ferrous gluconate

8.2 Antacids:-Sodium bicarbonate, Aluminium hydroxide, Magnesium hydroxide.

8.3 Saline cathartics:-Sodium phosphate, Potassium sodium tartrate, Magnesium sulphate.

8.4 Tincture iodine as a topical antimicrobial agent.

9. General idea of Radiopharmaceuticals

2L

NaI-131 in the diagnosis and treatment of hyperthyroidism

10. Recent advances in medicinal chemistry

2L

10.1 Peptide drugs.

10.2 Computer aided drug design.

11. Introduction to Pharmacopoea (IP,BP and USP.)

1L

Unit –I

1. Introduction to Dyestuff Chemistry

6L

1.1 A brief history of the development of colourants.

1.1.1 Natural colouring matters and their limitations (Indigo, Tyrian purple, Madder, Cochineal, Curcumin, Annato).

1.1.2 Synthetic Dyes- Important milestones- (Perkin's Mauveine, Diazotisation and Congo Red, Synthesis of Indigo and Indanthrene, Phthalocyanines, Fluorescent dyes and brighteners, Disperse dyes, Reactive dyes. Mention of recent applications of dyes-dyes for lasers, bio-medical applications).

(Note: For the above topics, dye structures may be shown for explanation purpose but are not expected for examination).

1.2 Definition of a dye (Distinction between dyes and pigments)

Properties of dyes: Colour (hue, depth); Fastness (Light, Washing, Perspiration, Heat,

Rubbing, Bleaching)

Substantivity to substrate; Solubility; Economic viability.

1.3 Explanation of nomenclature of commercial dyes with one example; suffixes- G, O, R, B, 6B, K, L, S; mention of Colour Index and Colour Index number.

1.4 Brief idea of the development of the dye industry in India.

2. Classification of Dyes based on constitution

8L

(Examples as mentioned below with structures)

- a) Nitro dyes - Naphthol Yellow S
- b) Nitroso dyes- Gambine Y
- c) Azo dyes - Monoazo-Orange-II; Disazo-Chrysophenine G, Trisazo-Direct Brown V
- d) Diphenylmethane dyes- Auramine-O
- e) Triphenylmethane dyes- Diamines- Malachite Green; Triamines- Crystal Violet; Phenols- Phenolphthalein
- f) Following classes of heterocyclic dyes- Xanthene dyes- Eosine;
 - Acridine dyes- Acridine Orange NO;
 - Azine dyes- Safranin-T;
 - Oxazine dyes- Meldola's blue;
 - Thiazine dyes- Methylene Blue;
 - Quinoline dyes-Quinoline Yellow.
- g) Anthraquinone dyes- Alizarin; Alizarine Cyanine Green G; Indanthrone
- h) Indigoid dyes- Indigo, Indigosol-O
- i) Phthalocyanines - Monastral Fast Blue BS

3. Classes of Dyes based on application

3L

Explanation of the following classes; main fastness properties where applicable, major substrates; examples specified with structures.

- a) Acid dyes: Orange-II, Alizarine Cyanine Green G.
- b) Basic dyes : Crystal Violet, Rhodamine B.

- c) Mordant dyes : Eriochrome Black T, Alizarin.
- d) Direct dyes : Chrysophenine G.
- e) Azoic dyes : Coupling components - Naphtol AS, Naphtol AS-G; Bases: Fast Red B Base, Fast Blue B Base.
- f) Vat dyes : Indigo, Flavanthrone.
- g) Disperse dyes : Celliton Scarlet B, Dispersol Blue FFR.
- h) Reactive dyes : Procion Brilliant Red M- 2BS, Remazol Brilliant Blue R(Reactive Blue 19).
- i) Sulphur dyes : Sulphur Black T (no structure).
- j) Fluorescent dyes and brighteners : Rhodamine B, Tinopal BV.

4. Colour and Chemical constitution of Dyes and Pigments 6L

4.1 Introduction to the following: Absorption of visible light, colour of wavelength absorbed and complementary colour, chromogen, chromophore, auxochrome, bathochromic and hypsochromic shifts.

4.2 Relation of colour to resonance in the following classes of dyes: Azo, Triphenylmethane, Anthraquinone.

5. Non-textile uses of dyes 3L

8.1 Uses of dyes for dyeing leather, paper, foodstuffs, cosmetics (Structural features of the substrate, fastness and other property requirements and main classes of dyes used to be mentioned as applicable.) (Two examples only with structures for each of the above substrates)

8.2 A brief idea of dyes used in photography.
(Two examples only with structures)

6. Optical brighteners and Organic Pigments 4L

6.1 Optical brighteners: General idea and important characteristics of optical brighteners; one example each with structure of the stilbene and coumarin classes of optical brighteners.

6.2 Organic pigments: General idea and important characteristics of organic pigments; Toners and Lakes; Uses of pigments, Structure of following pigments: Hansa Yellow-G, Flavanthrone, Copper phthalocyanine.

Unit -II

7. Intermediates 12L

7.1 A brief idea of unit processes

7.1.1 Introduction to terms: primary, intermediate, unit process.

7.1.2 Importance of unit processes in the dyestuff industry .

7.1.3 Some aspects of the following unit processes: Nitration (Generation of NO_2^+ , role of H_2SO_4 , importance of nitration, examples). Sulphonation (Sulphonating agents, sulphonation of benzene-naphthalene-anthracene mixture, importance of sulphonation including sulphonation of naphthalene and anthraquinone). Halogenation (nuclear and side chain halogenation of toluene). Diazotisation (Direct, reverse and nitrosyl sulphuric acid methods). Reduction of nitro group - Catalytic hydrogenation, Bechamp reduction, Sulphide reduction (advantages).

(Note: Pollution caused to be mentioned where applicable. Mechanism of unit processes not required).

7.2 Preparation of the following intermediates

7.2.1 Benzene derivatives : Benzene sulphonic acid, 1,3- Benzene disulphonic acid, Resorcinol, Sulphanilic acid, o, m, p- Phenylenediamine, Chlorobenzene, o,m,p,- Chloronitrobenzenes 4,4'-diamino benzenesulphanilide, Naphtol AS-G.

7.2.2 Naphthalene derivatives : • / • -Naphthols, Schaeffer acid , G acid, R acid, N-W acid
Naphthionic acid, , H- acid, Tobias acid, BON acid, Naphtol A S

7.2.3 Anthraquinone derivatives : 1-Nitroanthraquinone, 1-Aminoanthraquinone, Anthraquinone -1- sulphonic acid, Anthraquinone-2- sulphonic acid, 1-Chloroanthraquinone, 2- Chloroanthraquinone, 2- Methyl anthraquinone, Benzanthrone.

8. Synthesis of specific Dyes and their uses

11L

- 1) Orange IV from sulphanilic acid.
- 2) Tartrazine from ethyl acetate and diethyl oxalate.
- 3) Eriochrome Black T from β -Naphthol.
- 4) Eriochrome Black A from β -Naphthol.
- 5) Eriochrome Red B from ethyl acetoacetate and 1-amino-2-naphthol-4-sulphonic acid.
- 6) Celliton Scarlet B from p-nitroaniline and aniline.
- 10) Congo Red from nitrobenzene.
- 11) Malachite green from benzaldehyde and N, N-dimethylaniline.
- 12) Methylene Blue from 4-amino-N, N-dimethylaniline and N; N-dimethylaniline.
- 13) Safranin T from o-toluidine and aniline.
- 14) Acid Magenta (Ink Blue) from p-toluidine and aniline.
- 15) Alizarine Cyanine Green G from phthalic anhydride and p-chlorophenol.
- 16) Alizarin from anthraquinone.
- 17) Indanthrone from anthraquinone.
- 18) 3-Methoxybenzanthrone from benzanthrone.
- 19) Dispersol Blue FFR from from phthalic anhydride and p-chlorophenol.
- 20) Indigo from anthranilic acid.
- 21) Rhodamine B from m-N, N-diethylaminophenol and phthalic anhydride.

9. General information about application of dyes to fibres (a brief idea)

6L

7.1 Introduction to the following types of fibres: cotton, wool, silk and polyester.

7.2 Names of the main classes of dyes applicable to above fibres: cotton (direct dyes, mordant dyes, vat dyes, ingrain dyes, reactive dyes), wool (acid dyes, acid-mordant dyes, basic dyes, reactive dyes), silk (acid dyes, mordant dyes, basic dyes), polyester (disperse dyes).

7.3 Forces binding dyes to fibres: Ionic forces, H-bonds, Van der Waal's forces and Covalent linkages.

7.4 Basic operations involved in a dyeing process: preparing of fibre for dyeing, preparation of the dye bath, application of the dye and finishing.

10. Ecology and toxicity of dyes

1L

Brief idea of environmental pollution and health effects due to dyes.

I. PREPARATION (30 MARKS): (Any one preparation)

(1) PREPARATION OF DRUGS INTERMEDIATES:-

- (1.1) Aspirin
- (1.2) p-nitroacetanilide
- (1.3) p-nitroaniline
- (1.4) o-chlorobenzoic acid

(2) PREPARATION OF DYES INTERMEDIATES:-

- (2.1) Orange II
- (2.2) Fluorescein
- (2.3) Anthraquinone
- (2.4) m-dinitrobenzene

ESTIMATION (25 MARKS): (Any one estimation)

(3) ESTIMATION OF DRUGS:-

- (3.1) Aspirin (by IP method)
- (3.2) Vitamin C (by iodine oxidation method)
- (3.3) Tincture iodine
- (3.4) Ibuprofen
- (3.5) Vitamin B-12 (by colorimetry)

(4) ESTIMATION OF DYES:-

- (4.1) Aromatic primary amino gp. (aniline or p-toluidine---by diazotisation)
- (4.2) Methyl orange (by colorimetry)

(5) EXPERIMENTS FOR DEMONSTRATION (to be entered in the journal)

- (5.1) Separation of Methylene Blue and Methyl Orange (by column chromatography)
- (5.2) Separation of food colours (by paper chromatography)
- (5.3) Separation of drug mixture from a tablet (by TLC)

(6) PROJECT WORK (to be recorded in the journal) (5 marks)

- (6.1) Dyeing of a fabric (wool)
- (6.2) Preparation of monograph (for a selected drug)

Journal – 5 marks

Oral (pertaining to the experiments prescribed in the syllabus and the project work)- 15 marks

Practical Examination for one day with 7.5 hrs duration.

Reference Books:

Drugs:

- (1) Medicinal chemistry by Alfred Burger (Wiley Interscience)
- (2) Pharmacology and Pharmacotherapeutics by Satoskar and Bhandarkar (Popular Prakashan Mumbai), volumes I and II
- (3) A Text book of Medicinal Chemistry (synthesis and biochemical approach) volume I and II by Surendra Pandeya, SG publisher Varanasi
- (4) Medicinal Chemistry by Ashutosh Kar
- (5) Inorganic Medicinal and Pharmaceutical Chemistry by Block, Roche, Soine, Wilson, Varghese publishing house, Mumbai
- (6) Medicinal Chemistry for the 21st century by Wermoth

Dyes:

- 1) The chemistry of synthetic dyes and pigments - H.A. Lubs (Robert Krieger)
- 2) Chemistry of synthetic dyes - Vol. I-VI, Venkatraman.
- 3) The colour science of dyes and pigments - K. McLaren (Adam Hilger Ltd.)
- 4) Colour Chemistry - H. Zollinger (VCH).
- 5) Colour Chemistry - R.L.M Allen (Nelson).
- 6) Chemistry of Dyes and Principles of Dyeing - V.A.Shenai (Sevak).
- 7) Unit Processes by Goggins
- 8) Practical Organic Chemistry- Vogel (Orient Longman).

UNIVERSITY OF MUMBAI
DRAFT SYLLABUS FOR THE SUBJECT OF PETROCHEMICALS PRESCRIBED
UNDER THE APPLIED COMPONENT GROUP FOR THE T.Y.B.Sc. (CHEMISTRY)
UNDER THE REVISED PATTERN---2004---2005

PAPER I (Marks – 60)

Lectures - 60

UNIT – I

1. RAW MATERIALS : (6L)

- 1.1 Crude oil and natural gas :- Formation, production.
- 1.2 Exploration methods – geological and drilling (only brief reference-details not expected)

2. REFINERY PROCESSES AND PRODUCTS : (15L)

- 2.1 Chemical composition
- 2.2 Meaning of terms such as flash point, ignition point, octane number, 'doctor solution', smoke print, calorific value.
- 2.3 Distillation – separation based on relative volatilities –fractions obtained, with flow sheet diagrams.
- 2.4 Petroleum products - LPG Napthol, Gasoline, Kerosene
- 2.5 Conditions of conversion processes (catalyst, temperature, pressure etc.) mentioned below -
 - Pyrolysis, catalytic cracking and hydrocracking
 - Isomerisation
 - Alkylation Reforming

3. INORGANIC CHEMICALS FROM PETROLEUM : (9L)

- 3.1 Sulphur byproducts
- 3.2 Hydrogen
- 3.3 Petroleum coke
- 3.4 Nitrogen compounds

UNIT – II

4. SOURCES OF THE FOLLOWING SECONDARY MATERIALS FROM PETROCHEMICALS (16L)

Methane, ethylene, acetylene, propylene, C₄ hydrocarbons, higher olfins and aromatic hydrocarbons with flow sheet diagrams.

5. GENERAL STUDY OF THE FOLLOWING REACTIONS USED IN PETROCHEMICAL INDUSTRY : (14L)

- 5.1 Oxidation
- 5.2 Ammoxidation

- 5.3 Hydroformylation (oxoreactions)
- 5.4 Hydration of Olefins
- 5.5 Chlorination
- 5.6 Polymerisation (free radical and ionic)

PAPER II

Marks 60

Lectures - 60

UNIT – I

1. PREPARATION OF IMPORANT CHEMICALS :

- 1.1 From methane and carbon monoxide : (6L)
Methanol, chlorinated methanes, carbon disulphide, hydrogen cyanide and carbon black.
- 1.2 From ethylene and propylene : (12L)
Ethyl chloride, ethylene oxide, ethylene glycol, ethanolamines, ethanol, acetaldehyde, acetic acid, styrene, vinyl acetate, isopropanol cumene, glycerine and acrylonitrile.
- 1.3 From acetylene : (4L)
Vinyl chloride, chloroprene, acrylonitrile, and acetaldehyde.
- 1.4 From C₄ – hydrocarbons : (3L)
butadiene, isobutene and butana
- 1.5 From aromatic hydrocarbons : (5L)

Aniline, chlorobenzene, D.D.T. xylenes, Phthalic Anhydride, Terephthalic Acid and Phenol.

UNIT – II

2. INDUSTRIAL CHEMICALS (General idea only) (12L)

- 2.1 Plastics – polyethylene, polyvinyl chloride, polystyrene.
- 2.2 Synthetic elastomers – styrene, butadiene, rubber, polychloropropene, nitrile rubber.
- 2.3 Synthetic fibres – polyester, polyamide, acrylics.

3. SYNTHETIC DETERGENTS : (12L)

- 3.1 Surface activity – Anionic, cationic, nonionic and amphoteric surface active agents.
- 3.2 Wetting agents detergents, emulsifying agents, dispersing agents.

4. POLLUTION CONTROL IN PETROLEUM INDUSTRY : (6L)

- 4.1 Air pollution
- 4.2 Water pollution

SYLLABUS FOR PRACTICALS IN THE SUBJECT OF PETROCHEMICALS

(Applied Component) Paper I & II

Marks : 80

I. ANALYSIS OF SOLID AND LIQUID HYDROCARBONS FROM PETROLEUM:

1. Hard paraffin :

- i) Solubility tests
- ii) Acidity or alkalinity
- iii) Solidifying point
- iv) Sulphated ash

2. Liquid Paraffin :

- i) Solubility
- ii) Acidity alkalinity
- iii) Density
- iv) Viscosity
- v) Solid paraffins
- vi) Readily carbonisable substances

3. WHITE SOFT PARAFFIN (White Petroleum Jelly) :

- i) Solubility
- ii) Acidity / alkalinity
- iii) Sulphated ash

II. ANALYSIS OF IMPORTANT SOLVENTS, PETROCHEMICALS :

Acetone :

- i) Solubility
- ii) Identification by colour tests
- iii) Acidity / Alkalinity
- iv) Clarity of solution
- v) Weight per ml.
- vi) Non volatile matter

Phenol :

- i) Solubility
- ii) Identification by colour / precipitation tests.
- iii) Acidity
- iv) Nonvolatile matter

Toluene :

- i) Weight per ml.
- ii) Sulphur compounds
- iii) Thiophene related substances

Chloroform :

- i) Solubility
- ii) Identification
- iii) Distillation range
- iv) Weight per ml.
- v) Acidity / Alkalinity
- vi) Test for chloride
- vii) Test for free chlorine
- viii) Test for aldehyde
- ix) Non volatile matter

III. ESTIMATION OF ACETONE, ANILINE/PHENOL :

IV. CLOUD POINT, POUR POINT AND ANILINE POINT FOR A FUEL :

(Demonstration)

V. ESTIMATION OF WATER AND SEDIMENTS IN FUEL OIL BY CENTRIFUGATION (any one fuel)

VI. COPPER STRIP CORROSION TEST FOR PETROLEUM PRODUCTS,

VII. DEMONSTRATION EXPERIMENTS :

1. Absorbance of 0.05% w/v solution of white soft/yellow soft paraffin in 2, 2, 4 – trimethyl pentane (uv spectrophotometry)
2. GLC analysis of LP6, naphtha, hydrocarbon mixture etc.
3. Flash / Fire point.
4. Calorific value of a fuel.

VII. VISITS / FEED BACK REPORT :

Two or three visits to factories manufacturing any chemicals listed in the syllabus.

Students should prepare and submit reports on their visits.

Books recommended for Applied Component (Petrochemicals)

Note : Latest Editions should be used when available.

1. G.D. Hobson and W. Pohl "Modern Petroleum Technology" (1978)

2. E.R. Reigel "Industrial Chemistry". (1960)
3. P.H. Groggins "Unit Processes In Organic Synthesis" (1952)
4. G.B. Crump "Petroanalysis TI" (1982)
5. R.N. Shreve "Chemical Process Industries" (1977)
6. P.H. Spitz "Chemical Process Industries" (1977)
7. B.P. Tissot and D.H. Welte "Petroleum formation and Occurrence" (1984)
8. P.W. Sherwood "Petrochemical Profits for tomorrow" (1966)
9. R.D. Patel "Petroleum and Petrochemicals" (1971)
10. Institute of Petroleum "Modern Petroleum Technology"
11. W.L. Faith, D.B. Keyes and R.L. Clark "Industrial Chemicals" (1965)
12. M.J. Antle "The Chemistry of Petrochemicals" (1956)
13. L. Hatch and S. Maker "From hydrocarbons to Petrochemicals"
14. T. Dumas and W. Bulani "Oxidation of Petrochemicals" (1979)
15. Dr. Ramprasad, "Petroleum Refining Technology", Khanna Publications (2000)
16. B.K. Bhaskar Rao, "Modern Petroleum Refining Processes", Oxford & IBH Publishing Company Pvt. Ltd., Calcutta.
17. Fundamental concepts of Environmental Chemistry by G.S. Sothi, Narora Publication House.
18. Advance Inorganic Chemistry II (including Environmental Chemistry by Gurdeep Raj, Goyal Publication.)

UNIVERSITY OF MUMBAI
**DRAFT SYLLABUS FOR THE SUBJECT OF NON CONVENTIONAL SOURCES
OF ENERGY AND WASTE RECYCLING/MANAGEMENT PRESCRIBED
UNDER THE APPLIED COMPONENT GROUP FOR THE T.Y.B.Sc. (CHEMISTRY)
UNDER THE REVISED PATTERN---2004—2005**

Paper I: Non conventional Sources Of Energy. (60Lectures)

Unit I

1 Perspectives on Energy Sources and Utilization: (12L)

- 1.1 Definition, units and concepts.
- 1.2 Energy needs for the domestic, industrial, and agricultural and transport sector, energy utilization and sustainable development, patterns of energy use in different parts of the world.
- 1.3 Various forms of energy sources, conventional/non conventional, renewable/nonrenewable, scope and limitations of conventional, nonrenewable energy sources, fossil fuels such as coal, oil, natural gas; thermal. Hydroelectric and nuclear.
- 1.4 Environmental implications of the energy use; energy storage and conservation, Role of government and nongovernmental organizations, socio-economic aspects.

2 Study of the following non conventional energy sources with respect to scope, present scenario, applications, limitations and future prospects:

2.1 Solar energy: (10L)

- 2.1.1 Solar spectrum and its relevance as the energy source, solar radiation, conversion of solar energy into heat in solar collectors, Fresnel lenses, parabolic reflectors.
- 2.1.2 Photovoltaic effect, semi-conductors as solar energy converters, different materials used, effect of different parameters on the photovoltaic efficiency, effect of temperature, solar cells.
- 2.1.3 Solar energy conversion by photo electrochemical process, applications of solar energy for different purposes.

2.2 Wind energy: (3L)

- 2.2.1 Wind velocity and generation of wind energy
- 2.2.2 Description of wind mills and its working, rotor with blades, gear generator, vertical and horizontal axis of rotation.

2.3 Tidal Energy: (2L)

- 2.3.1 Tide height and its potential for power generation.
- 2.3.2 Construction of dam across sea basin. Installation of the turbine, specification of the basin.

2.4 Geothermal Energy: (3L)

- 2.4.1 Origin of geothermal heat, temperature gradient, geothermal steam and hot springs, geysers.
- 2.4.2 Power production from geysers, mantle as source.

Unit II

3 Study of the following non conventional energy sources with respect to scope, present scenario, applications, limitations and future prospects:

3.1 Ocean Thermal Energy conversion: (3L)

3.1.1 Surface and deep water temperature of oceans, temperature difference as a driving source for power generation.

3.1.2 Requirements for a practical OTEC plant, different working fluids.

3.2 Biomass: (10L)

3.2.1 Solar energy flow and its contribution to biomass production, energy from plants.

3.2.2 Feasible biomass conversion technologies, thermo chemical combustion, pyrolysis, gasification.

3.2.3 Alcohol from fermentation of sugars, enzyme reactor for continuous production of alcohol.

4 Energy from Waste: (4L)

4.1 Fuels from farm and animal waste: fermentation and production of methane in the biogas plant, domestic and industrial use of bio gas.

4.2 Municipal and industrial solid waste, as heat source.

5 Fuel Cells: (10L)

5.1 Electrochemical energy conversion, basic principle of fuel cells, distinction between fuel cell and battery.

5.2 Thermodynamic and kinetic effects of the fuel cell.

5.3 Hydrogen- oxygen fuel cell, organic oxygen fuel cell.

5.4 Applications of fuel cells

6 Hydrogen as a potential fuel.

6.1 Advantages

6.2 Economically viable production of hydrogen, photolysis of water. (3L)

PaperII Waste Recycling/Management (60L)

Unit-I

1 Introduction to Waste Management: (12L)

1.1 Definition of waste, concept of waste management, end of the pipe treatment, in plant treatment, introduction to green chemistry.

1.2 Recovery, reuse, recycle and disposal of waste, economic viability of each of the above, waste audit .

1.3 Types of waste, domestic, industrial, agricultural and commercial waste. Gaseous, solid and liquid waste.

2 Solid Waste Management: (14L)

2.1 Sources and generation of solid waste, their characterization, chemical composition and classification.

2.2 Waste generation per capita, industrial, commercial, agricultural, mining and power plant discharges.

2.3 Recycling of metal, paper, plastic, rubber, and textiles.

2.4 Methods of disposal of solid waste, dumping of garbage, sanitary landfills, composting, soil conditioning, incineration etc.

2.5 Hazardous waste, definition, classification, methods of minimization,

- disaster management and risk analysis.
- 2.6 Miscellaneous waste, types, characterization, hospital waste, disposal and preventive measures.
- 2.7 Radioactive waste, sources, effects on plants, animal and man, level of activity and management, minimization and treatment. (4L)
- 3 Particulate matter and its management
- 3.1 Particulate matter, sources, characterization, effects.
- 3.2 Disposal methods, cyclone separator, wet scrubber, electrostatic precipitator, fabric filter.

Unit-II

4 Liquid Waste Management: (24L)

- 4.1 Sources and generation of liquid waste, their characterization,
- 4.2 Physical parameters; colour, odour, turbidity, TSS, TDS, TS.
- 4.3 Chemical parameters; pH, acidity, alkalinity, hardness, DO, COD, TOC, THOD, and BOD. Chemical composition, classification.
- 4.4 Recycling of wastewater in the industry.
- 4.5 Liquid Waste Treatment:
- 4.5.1 Characterization of the waste through COD, BOD and TOC.
- 4.5.2 Pre-primary treatment; neutralization, equalization.
- 4.5.3 Primary treatment; screening, sedimentation, coagulation, filtration.
- 4.5.4 Secondary treatment; principles of the biological treatment of liquid waste. Various processes used, aerobic and anaerobic process.
- 4.5.5 Aerobic process, oxidation ponds, oxidation ditch, lagoons, activated sludge process and trickling filter process
- 4.5.6 Anaerobic processes; anaerobic contact process,
- 4.5.7 Tertiary treatment; reverse osmosis, ultra filtration, electrodialysis, ion exchange, ozone treatment, Fenton's reagent.
- 4.6 Characteristics of effluent from (i) pharmaceutical (ii) food and beverage (iii) Fertilizer industry.

5 Management of gaseous waste: (6L)

- 5.1 Sources, types and effects.
- 5.2 Minimization methods, economic viability of reuse.
- 5.3 Treatment methods, adsorption, absorption, catalytic conversion, condensation, combustion.

LIST OF PRACTICALS & GROUP ASSESSEMENT:

(a) Practicals to be carried out by each student (55Marks)

- 1 Estimation of settling tendency of suspensions using different electrolytes, jar Test
- 2 Determination of pH, conductance, TSS, TDS and TS of wastewater.
- 3 Determination of dissolved oxygen in the wastewater sample.
- 4 Determination of total hardness and anions responsible for it.
- 5 Determination of COD of the wastewater sample.
- 6 Removal of ion-exchange resins- break through curves.
- 7 Removal of hardness by chemical addition-optimization studies.
- 8 Removal of colouration of waste water by adsorption using colour comparison method using methylene blue.
- 9 Determination of chlorine demand of wastewater sample by iodometry.
- 10 Determination of the BOD of the wastewater sample.

- 11 To study the current voltage characteristics of a silicon solar cell.
- 12 To determine the efficiency of a silicon solar cell using a standard.
- 13 Estimation of chlorophyll from plant leaves from industrial area by colourimetry.
- 14 To determine the heat of combustion of ethanol and methanol.
- 15 To determine the relative fuel value of two fuels.

**(b) EXPERIMENTS TO BE CONDUCTED BY A GROUP OF STUDENTS
(PROJECT WORK) (15marks)**

- 1 Visit to any of the sites or units where non-conventional sources of energy are being harnessed. Write a detailed report of the visit and the any studies undertaken.
- 2 Given characteristics of waste water released from an industry, prescribe suitable methods for its treatment. Describe various steps required to optimize the process. Submit as the project report.
- 3 The candidate shall submit the project work report to the laboratory supervisor, on the day of inspection, who in turn will make it available to the Examiners.

(c) Journal (5Marks)

(d) Viva-voce examination (5 Marks)

Reference Books:

- 1 Solar energy: principles of thermal collection and storage
S.P.Sukhatme, Tata McGraw Hill, New Delhi, 1990
- 2 Fuel Cells: Will Mitchell, Academic Press, 1963.
- 3 Photo electrochemical Cells: Studies in Physical and theoretical Chemistry, Vol. 50
K.V.S. Santham & M. Sharma, Elsevier Publishing Company, Amsterdam, 1988.
- 4 Wastewater Treatment and pollution control: S.A. Arsewala, Tata McGraw Hill, New Delhi, 1989.
- 5 Pollution Control in Process Industries: S.P. Mahajan, Tata McGraw Hill, New Delhi, 1990.
- 6 Waste Water Treatment: M.N. Rao and A.K. Datta,
Oxford and IBH Publishing 1978
- 7 Nonconventional energy sources; G.D. Rai; 4th edition, Khanna Publishers, New Delhi, 1996.
- 8 Waste Recycling and Pollution control Handbook, A.V. Bridge Water & Mumford,
- 9 Basic Photovoltaic Principles & Methods, Solar Energy Research Institute.
- 10 Industrial Water Pollution control, Eckenfelder, 2nd edition, McGraw Hill Book company, 1989.
- 11 Nonconventional Energy Systems, Principles, Progress and Processes, K.M. Mittal
1st edition, Wheeler Publishers, New Delhi.
- 12 Solar Energy Utilization, G.D. Rai, 5th edition, Khanna Publishers, New Delhi, 1989.

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UNIVERSITY OF MUMBAI
**DRAFT SYLLABUS FOR THE SUBJECT OF HEAVY (BULK) AND FINE
 (SPECIALITY) CHEMICALS PRESCRIBED**
 UNDER THE APPLIED COMPONENT GROUP FOR THE T.Y.B.Sc. (CHEMISTRY)
 UNDER THE REVISED PATTERN---2004—2005

Learning Objectives:

1. Learning of industrial aspects of chemical manufacturing processes.
2. The learning should be supplementary to the knowledge of various branches of chemistry at F.Y., S.Y., and T.Y. level.
3. If possible the students should be given an opportunity to observe industrial processes by organising industrial visits.

PAPER – I

Marks: 60

Lectures: 60

UNIT – I

1. **Introduction to Chemical Industry.** Explanation of the terms Heavy (Bulk) and Fine (speciality) Chemicals. 2L
2. **Different Sources of Energy –**
 - a) Generation, Treatment of boiler feed water, Properties of steam, steam tables. 6L
 - b) Other heating media : Discussion about Dowtherm heating system and other thermic fluids. 4L
3. **Refrigeration:** System, media used for cold transfer (i.e. brine and other) 4L
4. **Pumps for chemical work**
 - a) Pumping equipment for liquids – piston pump, diaphragm pump, gear pump, centrifugal pumps, and submersible pumps. 12L
 - b) Vacuum systems – oil sealed pumps, ejectors. 6L
5. **Silicates:** Glass – raw material, manufacture, types and applications. 6L

UNIT – II

4. **Manufacture and applications of the following: -**
 - 6.1 a) Hydrogen fluoride b) Nitric acid 4L
 - 6.2 Phosphorous oxychloride. 3L
 - 6.3 a) Sodium dichromate b) Chromium trioxide 5L
 - 6.4 a) Urea b) Ammonium nitrate and c) Ammonium Sulphate 4L
 - 6.5 Sodium hydroxide 3L
 - 6.6 Alumina from bauxite ore by Hall's process and Serpeck process 4L
5. **Paints and Pigments:**
 - a) Brief idea about pigments and their applications, different constituents of pigments, solvents, binders, driers and plasticizers. 5L
 - b) Brief idea about paints, emulsion paints, distemper, dry distemper fire : tar ant paints, lacquers, varnishes and methods of application. 2L

UNIT - I

1. Brief idea about economic aspects of chemical manufacturing process – Location, Raw material, energy, capital, manpower, technology, ecological aspects. 4L
2. Catalysts: Preparation of catalysts and their applications. Palladium, Platinum, Vanadium pentoxide, Raney Nickel and brief idea of supports, promoters and catalyst poisons. 8L
Phase transfer catalysts – Introduction, mechanism of action, advantages and two examples.
3. Brief account of: -
 - a) Perfumes – Introduction, classification (ethers, esters and essential oils) Composition, formation, blending and applications. Synthesis of α and β -ionones from citral. 4L
 - b) Flavours – Introduction, Classification (natural and synthetic), applications - Vanillin, coumarin (structures). Synthesis of vanillin. 3L
 - c) Sweeteners – Introduction, classification with examples and structures of carbohydrates – Glucose, sucrose, sorbitol. Sulphonamide – Saccharin. Peptide – Aspartame. Synthesis of aspartame. 3L
4. Agrochemicals: Classification with examples, Insect attractants and repellents, plant growth regulators. 8L

UNIT - II

5. Surfactants: Introduction, classification and applications. General information about PEG AND Anionic Surfactants. 4L
6. Manufacture of: - Acetic acid, ethyl acetate 3L
7. Industrial gases: - Storage, Handling, Colour code. Hydrogen, Oxygen, Nitrogen and Chlorine. 4L
8. Fluoroaromatics: - Introduction, importance, reagents used for fluorination. Preparation of ortho-fluorotoluene and 3-chloro, 4-fluoro anilines. 5L
9. Industrial solvents:- Brief idea of green solvents. Uses of the following as solvents in industrial processes –
 - a) Acetone b) Ethylacetate c) Isopropanol d) Toluene e) Dimethyl formamide 5L
10. A) Synthesis and uses of the following drugs:
 - 1) Dichlophenac sodium 2) Atenolol 3) Metronidazole 4) Ethambutol 5) Thiamine 6) Diazepam 5L
 - B) Synthesis and uses of the following dyes:-
 - 1) Indigo 2) Congo red 3) Alizarine 4) Tartrazine 5) Rhodamine. 4L

PRACTICALS

PAPER – I

- Preparation of: i) Ferrous sulphate ii) Copper sulphate.
- Determination of percentage purity of gypsum.
- Determination of thiosulphate content of a commercial hypo solution.
- Determination of the amount of ferrous and ferric ions in the given mixture of ferrous and ferric ammonium sulphate.
- Determination of the amount of magnesium hydroxide in a commercial sample of milk of magnesia.
- Determination of the amount of phosphoric acid in a given sample. (Students to prepare succinic acid solution for standardization).

PRACTICALS

PAPER – II

- Preparation of: i) Aspirin ii) Cinnamic acid iii) Nerolin.
- Estimation of ibuprofen in the given sample.
- Estimation of ascorbic acid in cola.
- Estimation of aspirin by iodometry.
- Estimation of acetic acid in a sample of vinegar.
- DEMONSTRATION EXPERIMENTS :- The students should be demonstrated i) Steam distillation ii) Fractional distillation iii) Thin layer chromatography. (To be entered in the journal. Questions may be asked on these experiments in the viva-voce).

HEAVY (BULK) AND FINE (SPECIALITY) CHEMICALS

RECOMMENDED BOOKS

- C.E.Dryden: Outlines of chemical technology, Affiliated East West Press, New Delhi.
- Faith, Keyes and Clerk's Industrial Chemicals, 4th Edn. Wiley Inter-science 1975.
- Foust A.S. et-al: Principles of unit operations, John Wiley and sons.
- P.H. Groggins : Unit processes in organic synthesis, Mc Graw Hill.
- Kirk and Othmer: Encyclopedia of chemical Technology, John Wiley and sons.
- Industrial Organic Chemistry – K. Welssermel, H.J.Arpe, VCH publishers, New York.
- Industrial Inorganic Chemistry – Buchner, Schliebs, Winer translated by D.R.Tennell, VCH Publishers, New York.
- B. Pearson – Speciality chemical Innovations in industrial synthesis.
- Textbook of organic medicinal and pharmaceutical chemistry – Wilson and Giswold.
- Text book of pharmacology – Satoskar and Bhandarkar
- The Chemistry of synthetic dyes - Edited by K. Venkatraman Academic Press Inc. London.
- Organic Synthesis – Special techniques – V.K.Ahluwalia and Renu Aggarwal – Narosa Publishing House.
- A.I.Vogel : Textbook of Quantitative analysis including instrumental analysis.
- A.I.Vogel : Textbook of Quantitative organic analysis.