

No.AC.2(S)/785/2019-20

**NOTIFICATION**

**Sub:** Revision of scheme of practical examinations for B.Sc. Chemistry from the Academic Year 2019-20.

**Ref:** 1. Decision of Board of Studies in Chemistry (UG) meeting held on 18.12.2018.  
2. Decision of the Faculty of Science & Technology Meeting held on 01.04.2019.  
3. Decision of Academic Council meeting held on 07.06.2019.

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The Board of Studies in Chemistry (UG) which met on 18-12-2018 has recommended to revise the scheme of practical examinations B.Sc. (I to VI semester) the syllabus of B.Sc. Chemistry from the Academic Year 2019-20.

The Faculty of Science and Technology and Academic Council meeting held on 01-04-2019 and 07.06.2019 respectively have approved the above said proposal and the same is hereby notified.

The revised scheme of examination / syllabus of B.Sc. Chemistry course is annexed. The contents may be downloaded from the University Website i.e., [www.uni-mysore.ac.in](http://www.uni-mysore.ac.in).

Draft approved by the Registrar

*Lingesha 15/7/19*  
Deputy Registrar (Academic),  
**Deputy Registrar (Academic)**  
**University of Mysore**  
**Mysore-570 005**  
*R*

To:

1. The Registrar (Evaluation), University of Mysore, Mysore.
2. The Dean, Faculty of Science & Technology, DOS in Zoology, MGM.
3. The Chairperson, BOS in Chemistry, DOS in Chemistry, Manasagangotri, Mysore.
4. The Chairman, DOS in Chemistry, Manasagangotri, Mysore.
5. The Director, College Development Council, Moulya Bhavan, Manasagangotri, Mysore.
6. The Deputy/Assistant Registrar/Superintendent, AB and EB, UOM, Mysore.
7. The P.A. to the Vice-Chancellor/Registrar/Registrar (Evaluation), UOM, Mysore.
8. Office file.

# UNIVERSITY OF MYSORE



## CHOICE BASED CREDIT SYSTEM (CBCS) SYLLABUS

Continuous Assessment and Grading Pattern (CAGP) UG Program, Faculty of  
Science and Technology 2018-19

**CHEMISTRY**

**FOR B.Sc. DEGREE**

**PROGRAMME**

**2018-19**

Semester	Course type	course	L	T	P	Total no Credits	Work hours per week
I	DSC-2A + Practicals	Inorganic Chemistry, Organic Chemistry, Physical Chemistry, General Chemistry	4	0	2	06	4+ 4
II	DSC-2A + Practicals	Inorganic Chemistry, Organic Chemistry, Physical Chemistry, General Chemistry	4	0	2	06	4+ 4
III	DSC-2A + Practicals	Inorganic Chemistry, Organic Chemistry, Physical Chemistry, General Chemistry	4	0	2	06	4+ 4
IV	DSC-2A + Practicals	Inorganic Chemistry, Organic Chemistry, Physical Chemistry, General Chemistry	4	0	2	06	4+ 4
V	DSE-2A + Practicals	Inorganic Chemistry, Organic Chemistry, Physical Chemistry	4	0	2	06	4+ 4
VI	DSE-2B + Practicals	Inorganic Chemistry, Organic Chemistry, Physical Chemistry	4	0	2	06	4+ 4
V	SEC-1	Basic Analytical Chemistry	2	0	0	02	2+ 0
V	SEC-2	Fuel Chemistry	2	0	0	02	2+ 0
VI	SEC-3	Polymer Chemistry	2	0	0	02	2+ 0
VI	SEC-4	Chemical Technology ,Pesticide Chemistry & Society	2	0	0	02	2+ 0

Total no. of Credits:  $36 + 2+2 = 40$

## GENERAL REQUIREMENTS

### Scheme of Instructions

- Title and Commencement:** As per the university guidelines (12 Ref. letter UA2/379/2016-17).
- Undergraduate programme offered:  
2.2 Faculty of Science  
I. Bachelor of Science (B.Sc. 6 Semesters)
- Semester and Programme Structure:**  
The credit pattern for the course is L:P

### Course structure in chemistry

Semester	Course opted	SEC Course (2 Credits each)	Credits
I	Core course-DSC-2A		4 (L) + 2 (P)=6
II	Core course- DSC-2B		4 (L) + 2 (P)=6
III	Core course- DSC-2C		4 (L) + 2 (P)=6
IV	Core course- DSC-2D		4 (L) + 2 (P)=6
V	Core course- DSE-2A	SEC- 1 and SEC-2	4 (L) + 2 (P)=6+SEC
VI	Core course- DSE-2B	SEC-3 and SEC-4	4 (L) + 2 (P)=6+SEC
<b>Total Credits</b>			<b>36 + Credits from SEC</b>

### 4. Definitions:

4.1. **DSC:** Discipline Specific Course:

**DSE:** Discipline Specific Elective

**SEC:** Skill Enhancement Course

5. **Subject Combinations:** As per the university guidelines(Ref. letter UA2/379/2016-17).

### 6. Eligibility for Admission.

For B.Sc program only those students who have completed PUC or its equivalent examination with Science subjects are eligible.

7. **Medium of Instruction:** The medium of instruction shall be English/Kannada.

8. **Scheme of the Program:** As per the university guidelines (Ref. letter UA2/379/2016-17).

9. **Course Registration:** As per the university guidelines (9.1 to 9.6 Ref. letter UA2/379/2016-17).

10. **Attendance:** As per the university guidelines (10.1 and 10.2 Ref. letter UA2/379/2016-17).

**11. Continuous Assessment:**

**11.1.** C1 marks should be considered by conducting a test in the respective topics. C2 marks can be considered by conducting test/Assignment/Seminar /Dissertation.

**11.2.** The first component, C1 of assessment is for 10% (includes Theory and Practicals). This should be completed during the eighth week of the semester

**11.3.** The second component, C2 of assessment is for 10% (includes Theory and Practicals). C2 will be completed during the fifteenth week of the semester.

**11.5.** As per the university guidelines (11.5 Ref. letter UA2/379/2016-17)

**11.6.** The scheme of evaluation for C1, C2 and C3 component of the theory and practicals are given in the table below.

**Scheme of Examination for DSC and DSE**

Credits L:P	Maximum marks in the C1, C2 and C3 components (I to VI)			Duration of examination
	C1 Marks	C2 Marks	C3 Marks	
4: 2	Theory: 10	Theory: 10	Theory: 80	Theory: 3 hours
	Practicals: 10	Practicals: 10	Practicals: 80	Practical: 4 hours
Average	10	10	80	

C3 is the final examination marks

**Scheme of Examination for SEC**

Credits L: P	Maximum marks in the examination/ Assessment			Duration of examination
	C1	C2	C3	
2:0				3 hours
	10	10	80	

C3 is the final examination marks.

## 12. Evaluation of C1 and C2

As per the university guidelines (12 Ref. letter UA2/379/2016-17).

## 13. Examination and Evaluation for C3

13.1. a) The question paper pattern for C3 component is given below

### Examination and Evaluation for C<sub>3</sub>

The question paper pattern for C<sub>3</sub> component is given below:

#### Question paper pattern for DSC (Semester I to IV)

<b>Duration:</b> 3 hours		<b>Max. Marks:</b> 80
<b>The question paper contains 5 parts</b>		
Part-A (Compulsory)	Eight questions carrying 1 mark each	8 X 1 = 08
Part-B (Inorganic Chemistry)	Answer any 2 out of 3 questions	2 x 9 = 18
Part-C (Organic Chemistry)	Answer any 2 out of 3 questions	2 x 9 = 18
Part-D (Physical Chemistry)	Answer any 2 out of 3 questions	2 x 9 = 18
Part-E (General Chemistry)	Answer any 2 out of 3 questions	2 x 9 = 18
<b>Pattern:</b> (3 + 3 + 3) / (4 + 3 + 3)		

#### Question paper pattern for DSE (Semester V to VI)

<b>Duration:</b> 3 hours		<b>Max. Marks:</b> 80
<b>The question paper contains 4 parts</b>		
Part-A (Compulsory)	Eight questions carrying 1 mark each	8 X 1 = 08
Part-B (Inorganic Chemistry)	Answer any 3 out of 4 questions	3 x 8 = 24
Part-C (Organic Chemistry)	Answer any 3 out of 4 questions	3 x 8 = 24
Part-D (Physical Chemistry)	Answer any 3 out of 4 questions	3 x 8 = 24
<b>Pattern:</b> (5 + 3)/(3 + 3 + 2)/(2 + 2 + 4)		

#### Question paper pattern for SEC (Semester V to VI)

<b>Duration:</b> 3 hours		<b>Max. Marks:</b> 80
<b>The question paper contains 2 parts</b>		
Part-A (Compulsory)	Eight questions carrying 1 mark each	8 X 1 = 08
Part-B (Inorganic Chemistry)	Answer any 9 out of 12 questions	9 x 8 = 72
<b>Pattern:</b> (4 + 2 + 2)/(4 + 4)/(3 + 3 + 2)		

b) As per the university guidelines (13 Ref. letter UA2/379/2016-17)

**12.2 Valuation:** As per the university guidelines (Ref. letter UA2/379/2016-17).

14. As per the university guidelines (14 Ref. letter UA2/379/2016-17).

## 15. Passing Criteria

**15.1.** A student is considered to have passed the course, only on securing a minimum of 40% from C1, C2 and C3 put together from Theory and Practical. **15.2.** A student can take C3 exam irrespective of the marks scored in C1 and C2 of a particular course

**15.3.** In case a student secures less than 30% in C3 or absent for C3, the student is said to have not completed the course. The student shall complete the course by reappearing only for C3 component of that course when university conducts. **15.4.** As per the university guidelines (15. Ref. letter UA2/379/2016-17)

16. Makeup examination: As per the university guidelines (16. Ref. letter UA2/379/2016-17).

17. **Percentage and Grading:** As per the university guidelines (17 Ref. letter UA2/379/2016-17).

**18 to 22.** As per the university guidelines (Ref. letter UA2/379/2016-17)

## SCHEME OF VALUATION IN CHEMISTRY FOR THE PRACTICAL EXAMINATION 2018-19

### I Semester

#### Chemistry DSC-2A

C1 :10 Marks

C2 :10 Marks

C3 :80 Marks

Max. Marks :100 Marks

**Note:** Duly Certified practical record shall be submitted at the practical examination

**Practical Duration:** 4 hours

**Practical Proper Marks:** 80

#### **Part-A**

C1	Practical Test	:10 Marks
C2	Record	:10 Marks

#### **Part-B**

C3	Final Practical Examination: Volumetric Estimation	
	a) Procedure writing	:10 Marks
	b) Preparation of Standard solution and Calculation of Normality	:10 Marks
	c) Titre values of Standardization + Estimation	:40 Marks (20+20)
	d) Calculation	:10 Marks
	e) Viva	: 10 Marks

### II Semester

#### Chemistry DSC-2B

C1 :10 Marks

C2 :10 Marks

C3 :80 Marks

Max. Marks :100 Marks

**Note:** Duly Certified practical record shall be submitted at the practical examination

**Practical Duration:** 4 hours

**Practical Proper Marks:** 80

#### **Part-A**

C1	Practical Test	:10 Marks
C2	Record	:10 Marks

#### **Part-B**

C3	Final Practical Examination: Volumetric Estimation	
	a) Analysis of Organic Compounds	:40 Marks
	b) Preparation of Organic compound	:30 Marks
	c) Viva	:10 Marks

### III Semester

#### Chemistry DSC-2C

C1 :10 Marks

C2 :10 Marks

C3 :80 Marks

Max. Marks :100 Marks

**Note:** Duly Certified practical record shall be submitted at the practical examination

**Practical Duration:** 4 hours

**Practical Proper Marks:** 80

#### **Part-A**

C1	Practical Test	:10 Marks
C2	Record	:10 Marks

#### **Part-B**

C3	Final Practical Examination: Volumetric Estimation	
	a) Analysis of Inorganic salts mixture	:40 Marks
	b) Preparation of Inorganic complex	:30 Marks
	c) Viva	:10 Marks

### IV Semester

#### Chemistry DSC-2D

C1 :10 Marks

C2 :10 Marks

C3 :80 Marks

Max. Marks :100 Marks

**Note:** Duly Certified practical record shall be submitted at the practical examination

**Practical Duration:** 4 hours

**Practical Proper Marks:** 80

#### **Part-A**

C1	Practical Test	:10 Marks
C2	Record	:10 Marks

#### **Part-B**

C3	Final Practical Examination	
	a) Procedure writing for Organic estimation	:10 Marks
	b) Physical chemistry experiment	:30 Marks
	c) Organic estimation	:30 Marks
	d) Viva	:10 Marks

## V Semester

### Chemistry DSE-2A

C1 :10 Marks

C2 :10 Marks

C3 :80 Marks

Max. Marks :100 Marks

**Note:** Duly Certified practical record shall be submitted at the practical examination

**Practical Duration:** 4 hours

**Practical Proper Marks:** 80

#### Part-A

C1	Practical Test	:10 Marks
C2	Record	:10 Marks

#### Part-B

C3	Final Practical Examination	
	a) Procedure writing	:10 Marks
	b) Gravimetric estimation	:30 Marks
	c) Ore estimation	:30 Marks
	d) Viva	:10 Marks

## VI Semester

### Chemistry DSE-2B

C1 :10 Marks

C2 :10 Marks

C3 :80 Marks

Max. Marks :100 Marks

**Note:** Duly Certified practical record shall be submitted at the practical examination

**Practical Duration:** 4 hours

**Practical Proper Marks:** 80

#### Part-A

C1	Practical Test	:10 Marks
C2	Record	:10 Marks

#### Part-B

C3	Final Practical Examination	
	a) Procedure writing	:10 Marks
	b) Physical Chemistry Instrumental experiments( Part-I &Part-II)	:30+30 Marks
	c) Viva	:10 Marks

Chairman  
BOS in Chemistry

## I SEMESTER

### CHEMISTRY -I (DSC-2A)

CLASS DURATION – THEORY: 04 HOURS/WEEK

PRACTICALS: 04 HOURS/WEEK

Theory and Practicals: 60 Hours each-Total Credits-06 (Theory-04, Practicals-02)

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**Discipline Specific Course (DSC-2A Chemistry) is a core course for I semester, which should be compulsorily studied by a student as a core requirement of the programme.**

#### **UNIT-I: Inorganic Chemistry**

**Atomic Structure:** Review of Bohr's theory and its limitations, dual behaviour of matter and radiation, de Broglie's equation-derivation, Heisenberg's uncertainty principle. Hydrogen atomic spectra. Need of a new approach to Atomic structure. **[3 hours]**

Elements of Quantum chemistry- Schrodinger wave equation and meaning of various terms in it. Significance of  $\psi$  and  $\psi^2$ , Schrödinger equation for hydrogen atom. Radial and angular parts of the hydrogenic wave functions (atomic orbitals) and their variations for 1s, 2s, 2p, 3s, 3p and 3d orbitals (Only graphical representation). Radial and angular nodes and their significance. Quantum numbers and their Significance. Shapes of s, p and d atomic orbitals, nodal planes. Rules for filling up of electrons in various orbitals (Aufbau principle, Pauli's exclusion principle, Hund's rule of maximum multiplicity and n+l rule), Electronic configuration of the elements ( up to Z=30) and anomalous electronic configurations. Stability of half-filled and completely filled orbitals- concept of pairing and exchange energy. **[6 hours]**

**Periodic Table and Periodicity:** Classification of elements into s, p, d, and f-blocks, cause of periodicity.

**Atomic radius:** Covalent, ionic, van der Waal's and crystal radii. Additive nature of covalent radii. Determination of ionic radii by Lande's method. Variation of covalent radii in a group and in a period- explanation for the observed trends. Comparison of the size of

atoms with their corresponding anions and cations, variation of ionic radii in isoelectronic ions.

**Ionization enthalpy:** Successive ionization enthalpy, factors affecting ionization enthalpy, applications of ionization enthalpy. Variation in a group and in a period – explanation for the observed trends.

**Electron gain enthalpy:** Successive electron gain enthalpy, variation of electron gain enthalpy in a period and in a group- explanation for the observed trends.

**Electronegativity:** Variation of electronegativity in a group and in a period- explanation for the observed trends. Factors determining electro negativity (charge on the atom and hybridization). Pauling, Mulliken and Alfred-Rochow scale of electronegativity. Applications of electronegativity. **[6 hours]**

## **UNIT-II: Organic Chemistry**

**Basic Concepts in Organic Chemistry:** Bond cleavage, reactive intermediates, Generation, stability and reactions involving carbocations, carbanions, free radicals, nitrenes and carbenes. **[3 hours]**

**Types of organic reactions:** Definition with examples of addition, substitution, elimination, isomerisation, condensation and rearrangement reactions with examples. **[2 hours]**

**Electronic effects :** Electronic displacement effects: Inductive Effect, Electromeric Effect, Resonance, Hyperconjugation and their significance. **[3 hours]**

**Alkanes:** Preparation by Corey-House reaction, conversion of alkanes to aromatic compounds via alkenes and alkynes- aromatization and pyrolysis.

**Alkenes:** Preparation of alkenes by Wittig's reaction, Hoffmann's elimination, Stereoselectivity. Mechanism of electrophilic addition, oxymercuration, reduction, hydroboration – oxidation and epoxidation. Mechanism of oxidation with  $\text{KMnO}_4$  and  $\text{OsO}_4$ , ozonolysis. Industrial applications of ethene and propene.

**Dienes:** Types, relative stabilities of dienes, conjugated dienes – 1,3 butadiene-structure, 1,2 and 1,4-addition reactions with  $\text{H}_2$  and halogens, Diel's Alder reaction with an example.

**Alkynes:** Methods of preparation – Dehydrohalogenation, vicinal and gem dihalides, reactions of alkynes – Electrophilic additions with  $\text{HCN}$ ,  $\text{CH}_3\text{COOH}$  and  $\text{H}_2\text{O}$  polymerization. **[7 hours]**

### **UNIT-III: Physical Chemistry**

**Indicators:** Definition, types (acid-base, redox, adsorption indicators), examples for each type. Theory of indicators – Oswald's theory and Quinonoid theory – indicator constant – action of phenolphthalein and methyl orange in acid-base solutions – pH titration curves for strong acid vs strong base, weak acid vs strong base, weak base vs strong acid, choice of indicators in these types of titrations. Calculation of pH in mixture of acid and base.

[5 hours]

**Liquid mixtures:** Classification of binary mixtures – partially miscible, completely miscible and completely immiscible pairs of liquids (explanation with examples for each type).

**Partially miscible liquids:** Critical solution temperature (CST) – types – phenol-water system, triethylamine-water system, nicotine-water system (mutual solubility temperature (MST) vs composition curves to be drawn). Effect of addition of non-volatile solute on CST. Binary mixtures of completely miscible liquids.

Vapour pressure – definition, vapour pressure – composition diagrams and boiling point – composition diagrams. Classification into the types – obeying Raoult's law (type I), showing positive deviation from Raoult's Law (type II) and showing negative deviation from Raoult's Law (type III) – examples for each type.

**Principles of fractional distillation:** Fractional distillation of type I, type II and type III liquid mixtures (with examples). Azeotropic mixtures (definition). Binary mixtures of completely immiscible liquids (with examples), weight fraction of distillates (no derivation), principle of distillation, applications (numerical problem on weight fractions of components).

[6 hours]

**Distribution Law:** Nernst distribution law – statement, distribution coefficient, verification of distribution law taking distribution of  $I_2$  in  $H_2O$  and  $CCl_4$  – limitations of the law, conditions for the validity of distribution law, association of the solute in one of the solvents, dissociation of the solute in one of the solvents, application of distribution law with respect to solvent extraction process (numerical problems).

[4 hours]

### **UNIT-IV: General Chemistry**

**Purification of compounds:** Crystallisation, fractional crystallization, distillation, steam distillation, fractional distillation and distillation under reduced pressure, sublimation techniques with suitable examples.

[4 hours]

**Stoichiometry:** Mole concept, Concentration terms: normality, molarity, molality, molefraction and ppm(Problems to be worked). Calculation of equivalent mass (acids, bases, salts, oxidising and reducing agents) and oxidation number of element in a molecule. Applications of oxidation number, balancing of redox reactions by oxidation number method. Oxidation number and valency (comparison). **[8 hours]**

**Introduction to organic chemistry-** Definition and importance of organic compounds to life and applications in food, fuels, textiles, dyes, drugs and cosmetics with examples. Nomenclature(IUPAC) of bifunctional, aliphatic and aromatic compounds. **[3 hours]**

## I Semester Practicals

### CHEMISTRY-DSC 2A LAB

#### VOLUMETRIC ANALYSIS

Practical duration: 1 practical per week of 4 hrs

60 Hours (Credits: 02)

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#### Acidimetry/Alkalimetry Titrations:

1. Preparation of standard sodium carbonate solution and standardization of hydrochloric acid solution (methyl orange indicator). Estimation of sodium hydroxide present in the solution using phenolphthalein indicator.
2. Preparation of standard oxalic acid solution and standardization of sodium hydroxide solution. Estimation of sulphuric acid present in the solution.
3. Preparation of standard potassium biphthalate solution and standardization of sodium hydroxide solution. Estimation of oxalic acid present in the solution.
4. Estimation of NaOH and Na<sub>2</sub>CO<sub>3</sub> in a mixture (or caustic soda) by double indicator method using approximately 0.1N HCl.
5. Estimation of ammonium chloride using 0.05N sodium hydroxide and 0.1N hydrochloric acid solutions (back titration).

#### Permanganometry Titrations:

6. Preparation of standard oxalic acid solution and standardization of potassium permanganate solution. Estimation of ferrous ammonium sulphate present in the solution.
7. Preparation of standard oxalic acid solution and standardization of potassium permanganate solution. Estimation of hydrogen peroxide present in the solution.
8. Estimation of sulphuric acid and oxalic acid in a mixture using standard sodium hydroxide and standard potassium permanganate solutions.

#### Dichrometry Titrations:

9. Preparation of std. potassium dichromate solution and estimation of ferrous ammonium sulphate present in the solution using potassium ferrocyanide as an external indicator.

10. Estimation of ferrous and ferric iron in a given mixture using standard potassium dichromate solution.

11. Preparation of standard FAS and estimation of potassium dichromate solution using N-phenyl anthranilic acid as an indicator.

#### **Iodometry Titrations-**

12. Determination of BOD in sewage water.

13. Determination of dissolved oxygen in sewage water.

14. Estimation of copper in  $\text{CuSO}_4$  using potassium dichromate crystals and approximately 0.1N sodium thiosulphate solution.

#### **Complexometric Titration-**

15. Preparation of zinc sulphate solution and standardization of EDTA. Estimation of total hardness of water.

## II SEMESTER

### CHEMISTRY –II (DSC-2B)

CLASS DURATION – THEORY: 04 HOURS/WEEK

PRACTICALS: 04 HOURS/WEEK

Theory and Practicals: 60 Hours each-Total Credits-06 (Theory-04, Practicals-02)

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Discipline Specific Course (DSC-2B Chemistry) is a core course for II semester, which should be compulsorily studied by a student as a core requirement of the programme.

#### UNIT-I: Inorganic Chemistry

##### **Chemical Bonding and Molecular Structure**

**Ionic Bonding:** Definition and explanation with suitable examples. General characteristics of ionic bonding. Energy considerations in ionic bonding, lattice energy and solvation energy and their importance in the context of stability and solubility of ionic compounds. Born-Landé equation for calculation of lattice energy, Born-Haber cycle and its applications, polarizing power and polarizability. Fajan's rules, ionic character in covalent compounds, bond moment, dipole moment and percentage ionic character.

[4 hours]

**Covalent bonding:** Definition and explanation with suitable examples, factors favouring the formation of covalent bond. Valence bond approach -Shapes of some inorganic molecules and ions on the basis of VSEPR theory( $\text{NH}_3$ ,  $\text{H}_2\text{O}$ ,  $\text{SO}_4^{2-}$  &  $\text{ClO}_4^-$ ). Hybridization of linear, trigonal planar, square planar, tetrahedral, trigonal bipyramidal and octahedral arrangements( $\text{BeCl}_2$ ,  $\text{BF}_3$ ,  $[\text{Ni}(\text{CN})_4]^{2-}$ ,  $\text{SiCl}_4$ ,  $\text{PCl}_5$  and  $\text{SF}_6$  respectively).

[4 hours]

Concept of resonance and resonating structures in various inorganic compounds and ions ( $\text{CO}$ ,  $\text{CO}_2$ ,  $\text{N}_2\text{O}$ ,  $\text{SO}_3^{2-}$ ,  $\text{CO}_3^{2-}$ ).

[2 hours]

**MO approach:** Rules for the LCAO method, bonding and antibonding MOs and their characteristics for s-s, s-p and p-p combinations of atomic orbitals, nonbonding

combination of orbitals, MO treatment of homonuclear diatomic molecules of 1st and 2nd periods ( $H_2$ ,  $He_2$ ,  $He_2^+$ ,  $N_2$ ,  $O_2$  and  $F_2$ ) (including idea of *s-p* mixing) and heteronuclear diatomic molecules such as CO, NO and  $NO^+$ . Comparison of VB and MO approaches.

[5 hours]

## **UNIT-II: Organic Chemistry**

**Cycloalkanes:** Sacke-Mohr theory. Conformation of cyclopentane and cyclohexane, mono and disubstituted cyclohexane. Conformational analysis of butane and ethylene glycol with energy profile diagram.

[4 hours]

**Aromatic hydrocarbons:** Nomenclature of benzene derivatives, Huckel's rule with respect to benzenoids, (benzene, naphthalene, anthracene and phenanthracene) and non-benzenoid compounds (cyclopentadienyl anion, cycloheptadienyl cation) anti-aromaticity. Annulenes (14 to 18 carbon atoms)

Aromatic electrophilic substitution – General mechanism, electronic interpretation of orientating influence of electron donating groups ( $-CH_3$ ,  $-Cl$ ,  $-NH_2$  and  $-OH$  groups) and electron withdrawing groups ( $-NO_2$ ,  $-CHO$ ,  $-COOH$  and  $-SO_3H$  groups) on electrophilic substitution reactions.

[4 hours]

**Hydrogenation of aromatic compounds:** Birch reduction, side chain oxidation of toluene to benzaldehyde and benzoic acid. Resonating structures of benzene, naphthalene and anthracene. Diel's Alder reactions of anthracene with maleic anhydride.

**Biphenyls:** Preparation – Ullmann reaction.

**Alkenyl Benzenes:** Preparation of stilbene (one method), Cis-trans isomers of stilbene

[3 hours]

**Organic halides:** Alkyl halides: isomerism and classification, elimination reaction: dehydrohalogenation. Saytzeff rule, Nucleophilic substitution reaction.  $S_N^1$  and  $S_N^2$  with energy profile diagram. Effect of nature of alkyl groups, nature of leaving groups, nucleophiles and solvents.

[4 hours]

## **UNIT-III: Physical chemistry**

**Chemical Kinetics:** Introduction – differential and integrated rate equations for second order kinetics, derivation of second order rate equation when  $a=b$  and  $a \neq b$ , unit of rate constant, half-life period, problems. Experimental verification of second order reactions – study of kinetics of saponification of an ester, determination of the order of reaction –

differential, time for half-change method and isolation method. Effect of temperature on rate of a reaction, Arrhenius equation, concept of activation energy, problems. Theories of reaction rates-simple collision theory and transition state theory, comparison of two theories. Experimental methods of chemical kinetics, conductometric – example - saponification of esters and spectrophotometric – example – colorimetric study of kinetics of oxidation of Indigocarmine by chloramine-T. **[9 hours]**

**Ionic equilibria:** Debye-Huckel theory of strong electrolytes (relaxation time effect, electrophoretic effect and viscous effect). Debye-Huckel-Onsagar equation (no derivation), Debye-Huckel Limiting equation for activity coefficients (no derivation). Hydrolysis of salts – (four types) derivation - degree of hydrolysis and its relationship with  $K_h$ , effect of temperature and dilution on degree of hydrolysis. Relationship between  $K_h$ ,  $K_w$ ,  $K_a$  and  $K_b$ . pH of salt solutions and problems. **[6 hours]**

#### **UNIT-IV: General Chemistry**

Preparation and synthetic applications of organic reagents – acetyl chloride, acetic anhydride, benzoyl chloride, Raney Nickel, Dimethyl sulphate, Lithium aluminium hydride.

**[2 hours] Polymers:** Introduction, monomer, repeating units, types (linear, branches and network) with examples, degree of polymerization, classification (arrangement and shape) with examples, polymerization reaction (addition and condensation), molar masses of polymers – types (number average and mass average), determination of molar mass (viscosity and osmotic pressure method) (Numerical problems). **[5 hours]**

**Organic reagents in inorganic analysis-** Advantages of organic precipitants over inorganic precipitants, DMG, 8-hydroxy quinoline (Oxine), 1,10-phenanthroline and EDTA. Structure of  $Ni^{2+}$ -DMG and  $Mg^{2+}$ -oxine complexes. **[3 hours]**

**Soaps, detergents and waxes :** definition and types of soaps, manufacture of soap by hot process, cleansing action of soap. Detergents, types with examples. Differences between soaps and detergents. Waxes – Definition, types with examples. **[5 hours]**

## II Semester Practicals

### CHEMISTRY-DSC 2B LAB

Practical duration: 1 practical per week of 4 hrs

60 Hours (Credits: 02)

#### SYSTEMATIC ANALYSIS OF ORGANIC COMPOUNDS AND ORGANIC PREPARATION

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**Part 1:** Systematic qualitative organic analysis of the following compounds (Minimum 10 compounds).

1. Acids
2. Alcohols
3. Aldehydes
4. Amides
5. Amines
6. Halogenated hydrocarbons
7. Hydrocarbons
8. Ketones
9. Nitro compounds
10. Phenols

**Part 2:** Organic preparations: Recrystallisation and determination of melting point and its importance may be mentioned

1. Acetylation : Preparation of acetanilide from aniline.
2. Oxidation: Preparation of benzoic acid from benzaldehyde.
3. Nitration : Preparation of m-dinitrobenzene from benzene.
4. Hydrolysis : preparation of benzoic acid from ethyl benzoate.
5. Bromination : Preparation of 2,4,6-tribromophenol.
6. Glucosazones : extraction of glucose from cane sugar.
7. Diazotization : preparation of methyl orange.

**Note:** Preparation-equation, recrystallisation, theoretical and practical yield.

### III SEMESTER

#### CHEMISTRY -III (DSC-2C)

CLASS DURATION – THEORY: 04 HOURS/WEEK

PRACTICALS: 04 HOURS/WEEK

Theory and Practicals: 60 Hours each-Total Credits-06 (Theory-04, Practicals-02)

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**Discipline Specific Course (DSC-2C Chemistry) is a core course for III semester, which should be compulsorily studied by a student as a core requirement of the programme.**

#### UNIT-I: Inorganic Chemistry

**Chemistry of transition elements:** Position in the periodic table, electronic configuration, general characteristics- atomic and ionic radii, ionization energy, variable oxidation states, spectral properties, redox potentials, colour and magnetic properties, catalytic activity, complex formation and interstitial compounds formation (3d, 4d and 5d series).

**Chemistry of inner transition elements:** Electronic configuration and position in the periodic table, oxidation states, spectral properties, colour and magnetic properties, complex formation and ionic radii, lanthanide contraction – cause and its consequences. General survey of actinides–comparison with lanthanides, transuranic elements.

[10 hours]

#### **Organometallic Compounds**

Definition and Classification with appropriate examples based on nature of metal-carbon bond (ionic, s, p and multicentre bonds). Structures of methyl lithium, Zeiss salt and ferrocene. EAN rule as applied to carbonyls. Preparation, structure, bonding and properties of mononuclear and polynuclear carbonyls of 3d metals. p-acceptor behaviour of carbon monoxide.

[5 hours]

#### UNIT-II: Organic Chemistry

**Alcohols:** Definition and classification.

**Monohydric alcohols:** Preparation of alcohols by Hydroboration-oxidation method. Hydration of alkenes. Distinction tests between 1°, 2°, and 3° alcohols by Victor Meyer and

oxidation method. Conversion of 1° to 2°, 2° to 3° and 1° to 3° alcohols. Dehydration of 1°, 2°, 3° alcohols and comparison of their rates.

**Dihydric alcohols:** Glycol – preparation from vicinal dihalides and uses. Pinacoles – synthesis, mechanism of pinacol-pinacolone rearrangement

**Trihydric alcohols:** Glycerol, synthesis from propene, reactions with HNO<sub>3</sub>, H<sub>2</sub>SO<sub>4</sub>, oxalic acid and HI. Uses of glycerol. **[4 Hours]** **Phenols:** Definition, classification with examples, acidity of phenols, effect of substituents on acidity of phenols. Mechanism of Reimer-Tiemann reaction and Kolbe reaction. Fries and Claisen rearrangement with examples. conversion of phenol to phenolphthalein and fluorescein. **[4 Hours]**

**Ethers:** Nomenclature, Williamson ether synthesis, reactions – cleavage and auto oxidation- Ziesel's method.

**Epoxides:** Synthesis by Darzen's method. Acid and base catalyzed opening of epoxides.

**Crown ethers:** Introduction with examples. **[3 Hours]**

**Carbonyl Compounds:** Distinction between aldehydes and ketones – oxidation and reduction method. Addition of alcohols- formation of hemiacetal and acetal. Condensation with NH<sub>2</sub>OH and 2,4-DNP. Mechanism of aldol condensation, Perkins reaction, Cannizzaro reaction, Claisen condensation, Knoevenagel reaction. **[4 Hours]**

### **UNIT-III: Physical Chemistry**

**Second law of thermodynamics:** Limitations of First Law of Thermodynamics – need for II Law of thermodynamics, spontaneous, non-spontaneous and equilibrium processes (definitions and examples for each), different ways of stating II Law, concept of entropy – definition and physical significances of entropy – criteria of spontaneity in terms of entropy change, statements of II law in terms of entropy.

**Free energy:** Helmholtz and Gibb's free energy – their definitions and their relationship, Gibb's – Helmholtz equation at constant pressure and volume (derivations), thermodynamic criteria of equilibrium and spontaneity, variation of free energy with temperature and pressure, Clausius – Clappeyron equation (differential form to be derived), integrated form of Clausius – Clappeyron equation (to be assumed) and its applications (enthalpy of vapourization, boiling point and freezing point at different temperatures), (numerical problems on these applications). Calculation of bond energy, bond dissociation energy and resonance energy from thermochemical data. **[6 Hours]**

**Crystallography:** Amorphous and Crystalline solids, differences. Crystal systems and their characteristics, Elements of symmetry – plane, axis and centre, elements of symmetry in

cubic crystals, law of rational indices – Weiss and Miller indices, Crystal systems and their characteristics, Crystal lattice and unit cell, types of Lattice – Bravais lattices, X-Ray diffraction and Bragg's Law (to be derived), determination of crystal structure of rock salt by rotating crystal method using Bragg's spectrometer, Structure of NaCl, KCl & CsCl (only qualitative), application of X-ray studies – distance between lattice planes, density of crystals, determination of Avogadro Number (numerical problems on applications), Qualitative treatment of Nernst heat theorem and III law of thermodynamics-statement only.

**Liquid Crystals:** Definition, classification of thermotropic liquid crystals into smectic, nematic and cholesteric with examples-molecular arrangement of these and their uses.

[9 Hours]

#### **UNIT-IV: General Chemistry**

**Chromatography:** Paper: introduction to ascending, descending and circular,  $R_f$  value and its applications

**TLC:** Introduction and applications

**Column Chromatography:** Introduction, principle and experimental details and applications

**Gas Chromatography:** Introduction, apparatus, programmed temperature gas chromatography, quantitative analysis of GLC

**HPLC:** Introduction, schematic diagram of instrumentation and application. [5 Hours]

**Energy sources-**Dry cell, lead storage battery, solar cell and fuel cell. [3 Hours]

**Nanotechnology:** Definition, uses and nature of nanotechnology, **Nanomaterials-** definition, properties and applications, **Carbon nanotubes-** definition, types, methods of preparation (mention), properties and industrial applications of carbon nanotubes, **Nanowires-** definition, types, production of crystalline nanowires by vapour-liquid-solid synthesis method, applications of nanowires. [4 Hours]

**Amino acids and proteins:** Structure, classification with examples, peptide bond, N-protecting & C-protecting groups, peptide synthesis (Gly-Gly, Gly-Ala) Proteins-types-based on functional properties. Denaturation, colour reaction (Biuret, Ninhydrin and Millon's test) [3 Hours]

### III Semester Practicals

#### CHEMISTRY-DSC 2C LAB

Practical duration: 1 practical per week of 4 hrs

60 Hours (Credits: 02)

#### QUALITATIVE ANALYSIS OF INORGANIC SALT MIXTURE AND INORGANIC PREPARATION

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**Part 1: Systematic semi-micro Qualitative Analysis of Inorganic Salt Mixture containing two cations and two anions (Minimum 10 mixtures to be analysed).**

The constituent ions in the mixture to be restricted to the following:

**Anions:**  $\text{HCO}_3^-$ ,  $\text{CO}_3^{2-}$ ,  $\text{SO}_4^{2-}$ ,  $\text{Cl}^-$ ,  $\text{Br}^-$ ,  $\text{NO}_3^-$ ,  $\text{BO}_3^{3-}$ ,  $\text{SO}_4^{2-}$  and  $\text{PO}_4^{3-}$

**Cations:**  $\text{Pb}^{2+}$ ,  $\text{Bi}^{3+}$ ,  $\text{Cd}^{2+}$ ,  $\text{Al}^{3+}$ ,  $\text{Fe}^{3+}$ ,  $\text{Fe}^{2+}$ ,  $\text{Mn}^{2+}$ ,  $\text{Zn}^{2+}$ ,  $\text{Ba}^{2+}$ ,  $\text{Sr}^{2+}$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{K}^+$ ,  $\text{Na}^+$  and  $\text{NH}_4^+$

**Note:**

1. Mixtures requiring elimination of phosphate and borate should not be given.
2. Combination like  $\text{Cl}^-$  and  $\text{Br}^-$ ,  $\text{NO}_3^-$  and  $\text{Br}^-$  shall be avoided.
3. Salts that yield double decomposition shall be avoided (like  $\text{CaSO}_4$ ,  $\text{BaSO}_4$ ,  $\text{PbSO}_4$ ,  $\text{FeSO}_4$ ).
4. The combination of two cations in the mixture should belong to different groups. However combinations like  $\text{Mg}^{2+}$  and  $\text{NH}_4^+$  and  $\text{Na}^+$  and  $\text{NH}_4^+$  can be given.

**Part 2: Inorganic preparations**

1. Preparation of Chloropentaminocobalt(III)chloride.
2. Preparation of Cuprammoniumsulphate
3. Preparation of Ferric alum
4. Preparation of ferrous oxalate.
5. Preparation of Prussian blue (ferri ferrocyanide).

## IV SEMESTER

### CHEMISTRY -IV (DSC-2D)

CLASS DURATION – THEORY: 04 HOURS/WEEK

PRACTICALS: 04 HOURS/WEEK

**Theory and Practicals: 60 Hours each-Total Credits-06 (Theory-04, Practicals-02)**

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**Discipline Specific Course (DSC-2D Chemistry) is a core course for IV semester, which should be compulsorily studied by a student as a core requirement of the programme.**

#### **UNIT I: Inorganic Chemistry**

**Coordination Chemistry:** Ligands, classification of ligands and chelation, nomenclature of co-ordination compounds, physical methods in the study of complexes – change in conductance, colour and pH. Stability of complexes – stability constant, a brief outline of thermodynamic stability of metal complexes, factors affecting the stability of complexes. Polynuclear complexes, inner metallic complexes.

**Applications of complexes:** Cis platin in cancer therapy, Na<sub>2</sub>CaEDTA in treatment of heavy metals (Pb & Hg) poisoning.

**Isomerism in co-ordination complexes:** Stereo-isomerism – Geometrical and optical isomerism exhibited by co-ordination compounds of co-ordination number 4 and 6.

**[6 hours]**

**Valence bond theory:** Salient features, formation of octahedral complexes on the basis of VBT, outer and inner orbital octahedral complexes- [Fe(CN)<sub>6</sub>]<sup>4-</sup>, [Fe(CN)<sub>6</sub>]<sup>3-</sup>, [Co(CN)<sub>6</sub>]<sup>3-</sup>, [CoF<sub>6</sub>]<sup>3-</sup>[Cr(H<sub>2</sub>O)<sub>6</sub>]<sup>3+</sup> and [Fe(H<sub>2</sub>O)<sub>6</sub>]<sup>2+</sup>. Formation of tetrahedral and square planar complexes on the basis of VBT – [Ni(CN)<sub>4</sub>]<sup>2-</sup>, [Cu(NH<sub>3</sub>)]<sup>2+</sup>, [Zn(NH<sub>3</sub>)<sub>4</sub>]<sup>2+</sup>and [Ni(CO)<sub>4</sub>], limitations of VBT.

**[4 hours]**

**Crystal field theory:** Important features of crystal field theory, crystal field splitting of d-orbitals in tetrahedral, octahedral and square planar complexes, crystal field stabilization energy (CFSE), factors affecting the magnitude of Δ<sub>o</sub>, (nature of ligand, oxidation state of the metal ion, size of the orbitals, geometry of the complex), high spin (HS) and low spin (LS) complexes, magnetic properties of metal complexes based on crystal field theory- [Co(NH<sub>3</sub>)<sub>6</sub>]<sup>3+</sup>, [CoF<sub>6</sub>]<sup>3-</sup>, [Fe(CN)<sub>6</sub>]<sup>4-</sup>, [Fe(CN)<sub>6</sub>]<sup>3-</sup> and [Ni(CN)<sub>4</sub>]<sup>2-</sup>. Magnetic

susceptibility, measurement of magnetic moment by Gouy's method. Limitations of CFT.

**Ligand field theory:** Evidences for metal ligand covalent bonding in complex. [5 hours]

## **UNIT II: Organic Chemistry**

**Stereochemistry:** Introduction, definition, elements of symmetry (plane, centre, simple axes and alternative axes), asymmetry and dissymmetry, Chirality, designation of configuration (D-L and R-S). Optical activity – explanation – cause of optical activity (non-super impossibility). Enantiomers and diastereomers optical isomerism in tartaric acid and biphenyl compounds, racemisation, resolution, methods of resolution (Chemical and biochemical methods) Walden inversion, asymmetric synthesis (partial and absolute).

**Geometrical isomerism:** Definition with example, designation of cis-trans and E-Z notations with examples. Characteristics of geometrical isomers, Identification of geometrical isomers. Geometrical isomerism in aldoximes and ketoximes, Beckmann rearrangement with mechanism. [8 Hours]

**Carbohydrates:** Definition and importance, classification based on composition with examples-reducing and non-reducing sugars.

**Monosaccharides:** Glucose: reactions of glucose (with  $\text{H}_2\text{N-OH}$ ,  $\text{HCN}$ ,  $\text{C}_6\text{H}_5\text{NHNH}_2$ ,  $\text{Br}_2$  water, Conc.  $\text{HNO}_3$ , reductions with  $\text{HI/red P}$ , methanol/dry  $\text{HCl}$ , acetic anhydride and reduction reactions.

**Structural elucidation of glucose:** Open chain structure, configuration, drawbacks of open chain structure, ring structure – Fisher and Haworth structure. Determination of ring size by methylation method.

**Structural elucidation of fructose:** Reactions of fructose, Fischer and Haworth structures, Fischer and Haworth structures of galactose and mannose.

**Conversion reactions:** 1. Ascending (Kiliani's synthesis) 2. Descending (Wohl's degradation) 3. Aldose to ketose 4. Ketose to Aldose 5. Epimerisation

**Disaccharides:** Structural elucidation of sucrose, structural formulae of maltose and lactose (Haworth structure).

**Polysaccharides:** Partial structural formulae of starch, cellulose, glycogen and their uses.

[7 Hours]

## **UNIT III: Physical Chemistry**

**Elementary Quantum Mechanics:** black body radiation – Planck's Law, Photoelectric effect, Compton effect, Schrodinger's wave equation (no derivation) and its importance,

Eigen function and Eigen values, significance of  $\Psi$  and  $\Psi^2$ , particle in one dimensional box (derivation), operators-linear,  $\Delta$  and  $\Delta^2$  and Hamiltonian operator. **[5 Hours]**

**Electrochemistry-I:** Introduction, conductance – specific conductance, equivalent conductance and molar conductance – their definitions and SI units. Conductivity cell and cell constant. Determination of equivalent conductance by meter – bridge method, ionic mobility, ionic conductance, Kohlrausch's law and its significance – determination of equivalent conductance at infinite dilution for weak electrolyte.

**Transport number:** Definition and explanation, anomalous transport number – explanation with examples – relationship between ionic conductance and transport number (to be derived), determination of transport number by moving boundary method – transport number of  $H^+$  using  $CdCl_2$  as supporting electrolyte (numerical problems on equivalent conductance, transport numbers and Kohlrausch's law). **[6 Hours]**

**Application of conductance measurements** – (a) solubility and solubility product of sparingly soluble salt, (b) ionic product of water, (c) degree of ionization of weak electrolyte. Numerical problems.

**Conductometric titration:** strong acid vs strong base, weak acid vs strong base, strong acid vs weak base, weak acid vs weak base, with suitable examples for each. **[4 Hours]**

#### **UNIT IV: General Chemistry**

**HSAB:** Classification of acids and bases as Hard and Soft. Pearson's HSAB concept, acid-base strength, hardness and softness, symbiosis. **[3 Hours]**

**Gravimetry:** Introduction to gravimetric analysis – precipitation methods (various steps involved to be discussed), advantages of gravimetric analysis, purity of the precipitates, coprecipitation and post-precipitation, conditions of precipitation, precipitation from homogeneous solution (hydroxides and sulphates), washing and ignition of precipitate (general discussion only). Electro-gravimetric analysis-estimation of copper. **[4 Hours]**

**Dyes:** Colour and constitution, chromophore - Auxochrome theory, classification of dyes based on chromophore present and applications with examples, synthesis of indigo, malachite green, congo red, structural elucidation of alizarin and its synthesis. **[3 Hours]**

**Physical Properties and chemical constitution:** Additive and constitutive properties, properties of liquids – viscosity, definition of coefficient of viscosity, factors affecting viscosity – temperature, size and weight of molecules, intermolecular forces, determination of viscosity of liquids by Ostwald's method.

**Surface tension:** Definition, effect of temperature and solute on surface tension, determination of surface tension of liquids using stalagmometer.

**Parachor:** Definition – Sugden equation, calculation of parachor and its application with respect to structural elucidation of benzene and quinone, numerical problems based on surface tension, viscosity and parachor applications. **[5 Hours]**

## IV Semester Practicals

### CHEMISTRY-DSC 2D LAB

Practical duration: 1 practical per week of 4 hrs

60 Hours (Credits: 02)

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#### Part 1:

1. Determination of the density using specific gravity bottle and viscosity of a liquid using Ostwald's viscometer.
2. Determination of the density using specific gravity bottle and surface tension of a liquid using stalagmometer.
3. Determination of molecular mass of a non-volatile solute by Walker-Lumsden method.
4. Determination of rate constant of the decomposition of hydrogen peroxide catalyzed by  $\text{FeCl}_3$ .
5. Determination of transition temperature of the salt hydrates ( $\text{Na}_2\text{S}_2\text{O}_3$ ,  $\text{SrCl}_2$ ,  $\text{CH}_3\text{COONa}$ ).
6. Determination of percentage composition of sodium chloride solution by determining the miscibility temperature of phenol - water system.
7. Estimation of the given strong acid using strong base by thermometric titration method [ $\text{HCl X NaOH}$ ].
8. Study of kinetics of reaction between  $\text{K}_2\text{S}_2\text{O}_8$  and  $\text{KI}$ , 2<sup>nd</sup> order, determination of rate constant.

#### Part 2: Organic Estimations:

1. Estimation of glucose by Fehling solution method.
2. Estimation of ascorbic acid by iodometric method.
3. Determination of Iodine value of oils by chloramine-T.
4. Isolation of Caffeine from tea powder.
5. Estimation of neutral amino acids by titrametric method.
6. Estimation of carboxylic acid by titrametric method.
7. Determination of saponification value of oils.

## V SEMESTER

### CHEMISTRY -V (DSE-2A)

CLASS DURATION – THEORY: 04 HOURS/WEEK

PRACTICALS: 04 HOURS/WEEK

**Theory and Practicals: 60 Hours each-Total Credits-06 (Theory-04, Practicals-02)**

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**Discipline Specific Elective (DSE-2A Chemistry) is a course for V semester offered under the main Disciple/Subject of study or a Project/Dissertation, which should be compulsorily studied by a student as a core requirement of the programme**

#### **UNIT I: Inorganic Chemistry:**

#### **INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE**

##### **Silicate Industries**

**Glass:** Raw materials, glassy state and its properties, classification (silicate and non-silicate glasses). Manufacture and processing of glass. Composition and properties of the following types of glasses: Soda lime glass, lead glass, armoured glass, safety glass, borosilicate glass, fluorosilicate, coloured glass, photosensitive glass.

**Ceramics:** Important clays and feldspar, ceramic, their types and manufacture. High technology ceramics and their applications, superconducting and semiconducting oxides, fullerenes carbon nanotubes and carbon fibre.

**Cement:** Classification of cement, ingredients and their role, Manufacture of cement and the setting process, quick setting cement. **[8 hours]**

##### **Fertilizers:**

Different types of fertilizers. Manufacture of the following fertilizers: Urea, ammonium nitrate, calcium ammonium nitrate, ammonium phosphates; polyphosphate, superphosphate, compound and mixed fertilizers, potassium chloride, potassium sulphate.

**[5 hours]**

##### **Surface Coatings:**

Objectives of coatings surfaces, preliminary treatment of surface, classification of surface coatings. Paints and pigments-formulation, composition and related properties. Oil paint, Vehicle, modified oils, Pigments, toners and lakes pigments, Fillers, Thinners, Enamels,

emulsifying agents. Special paints (Heat retardant, Fire retardant, Eco-friendly paint, Plastic paint), Dyes, Wax polishing, Water and Oil paints, additives, Metallic coatings (electrolytic and electroless), metal spraying and anodizing. **[7 Hours]**

## **UNIT II: Organic Chemistry**

**Terpenes:** Definition, isoprene rule, classification, isolation (solvent extraction and steam distillation) structural elucidation of citral and its synthesis, structural formulae of  $\alpha$ -terpeniol, camphor and menthol. **[3 Hours]**

**Heterocyclic Compounds:** Definition, classification with examples, synthesis of furan, thiophene, pyrrole, pyridine, indole (Fischer method) quinoline (Skrup's synthesis with mechanism), isoquinoline, pyrimidine (one method each), aromaticity and basicity of pyrrole and pyridine. Electrophilic substitution reactions of pyrrole and pyridine.

**Uric acid:** Elucidation of structure and synthesis by Fischer's method, conversion of uric acid to purine and caffeine

**Alkaloids:** Definition, classification based on heterocyclic rings-isolation, synthesis and structural elucidation of nicotine and morphine, physiological importance of alkaloids.

**[8 Hours]**

**Vitamins:** Definition, classification, structural elucidation and synthesis of Vit-A, Synthesis of Vit-C, structural formulae of Vit B<sub>1</sub>, B<sub>2</sub>, B<sub>6</sub>, calciferol, E and K and their importance.

**Hormones:** Definition, classification, synthesis of adrenaline, thyroxine, structural formulae of estradiol, progesterone and testosterone and their importance.

**Drugs:** Chemotherapy and chemotherapeutic agents, definition of drugs, types of drugs, antipyretics, analgesics, anesthetics, sedatives, narcotics, antiseptics, antibacterials, antibiotics, antimalarials and sulpha drugs with examples. Synthesis of paracetamol, sulphanilamide, sulphaguanidine. **[9 Hours]**

## **UNIT III: Physical Chemistry**

**Spectrophotometry and photochemistry:** Lambert – Beer's law – statement and mathematical form (to be derived). Molar extinction coefficient – definition – spectrophotometer – construction and working, its application.

Laws of photochemistry – Grotthus-Draper law of photochemical activation and Einstein's law of photochemical equivalence, quantum efficiency, reasons for low quantum yield (HBr formation as example) and high quantum yield (HCl formation as example), actinometry – Uranyl oxalate actinometer.

**Photophysical processes:** Definition with examples – photosensitization (eg. photosynthesis in plants), photo inhibition, fluorescence, phosphorescence, chemiluminescence and bioluminescence with examples. Determination of absorbed intensity – schematic diagram of apparatus used. Detectors – thermopile, photoelectric cell.

**[7 Hours]**

**Radiation Chemistry:** Definition, primary and secondary stages in radiochemical reactions, ionic yield, energy yield, comparison with photochemistry, units of radiation – rad, gray and roentgen, Dosimeter – Fricke dosimeter, theories of radiolysis – Lind's and EHT theories. Radiolysis of water vapour, benzene and acetic acid.

**[3 Hours]**

**Molecular Spectroscopy:** Regions of spectra, types of spectra, microwave spectra – rotational spectra of diatomic molecules, moment of inertia (expression to be derived). Expression for rotational energy, selection rule and transition equal spacing between rotational spectral lines (to be discussed), effect of isotopic substitution taking example of  $^{12}\text{C}^{16}\text{O}$  and  $^{13}\text{C}^{16}\text{O}$ , calculation of bond length.

**IR Spectra** – vibrational spectra of diatomic molecules – force constant (no derivation), expression for vibrational energy, zero point energy, selection rule and transitions. Vibrational modes of polyatomic molecules taking  $\text{H}_2\text{O}$  and  $\text{CO}_2$  molecules as example. Applications of IR spectroscopy (mention).

**Raman Spectra:** Concept of polarizability, pure rotation, vibration (qualitative study) stoke's and antistoke's lines, selection rule, applications (mention)

**Electronic Spectra:** Potential energy curves for bonding and antibonding molecular orbitals, band theory, electronic transitions, qualitative description of non-bonding orbitals and transition between them. Selection rule and Franck Condon principle.

**[10 Hours]**

## V Semester Practicals

### CHEMISTRY-DSE-2A LAB

Practical duration: 1 practical per week of 4 hrs

60 Hours (Credits: 02)

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#### Gravimetric Estimations:

1. Gravimetric estimation of barium as barium sulphate.
2. Gravimetric estimation of iron as iron (III) oxide.
3. Gravimetric estimation of copper as copper (I) thiocyanate.
4. Gravimetric estimation of nickel as nickel dimethylglyoximate.
5. Gravimetric estimation of magnesium as magnesium -8-hydroxy oxinate.
6. Gravimetric estimation of sulphate as barium sulphate.
7. Gravimetric estimation of aluminum as aluminum oxide.
8. Gravimetric estimation of zinc as zinc oxide.

#### Ore analysis:

9. Preparation of standard potassium dichromate solution and estimation of iron in the given sample of hematite by dichromate method.
10. Estimation of percentage of calcium in limestone by oxalate method.
11. Estimation of manganese in the given sample of pyrolusite.
12. Estimation of magnesium in the given sample of dolomite by EDTA method.

#### Alloy Estimations:

13. Estimation of copper in bronze by iodometric method.
14. Estimation of tin in solder using EDTA.
15. Estimation of aluminium in Duralumin.

## VI SEMESTER

### CHEMISTRY -VI (DSE-2B)

CLASS DURATION – THEORY: 04 HOURS/WEEK

PRACTICALS: 04 HOURS/WEEK

**Theory and Practicals: 60 Hours each-Total Credits-06 (Theory-04, Practicals-02)**

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**Discipline Specific Elective (DSE-2B Chemistry) is a course for VI semester offered under the main Discipline/Subject of study or a Project/Dissertation, which should be compulsorily studied by a student as a core requirement of the programme**

#### **UNIT I: Inorganic Chemistry**

**Metallurgy:** Chief modes of occurrence of metals based on standard electrode potentials. Ellingham diagrams for reduction of metal oxides using carbon as reducing agent.

**Pyrometallurgy:** Extraction of Nickel from sulphide ore – general metallurgy followed by Mond's process (purification), manganese from oxide ores – reduction by the Aluminothermite process – refining by electrolytic process.

**Hydrometallurgy:** Extraction of gold from native ore by cyanide process and refining by quartation process.

**Electrometallurgy:** Extraction of lithium by fusion method followed by electrolysis of lithium chloride.

**Powder metallurgy:** Importance, and applications, production of tungsten powder. Principles of electroplating. **[10 Hours]**

#### **Alloys:**

Classification of alloys, ferrous and non-ferrous alloys, Specific properties of elements in alloys. Manufacture of Steel (removal of silicon decarbonization, demanganization, desulphurization dephosphorisation) and surface treatment (argon treatment, heat treatment, nitriding, ). Composition and properties of different types of steels. Production of ferro alloys; ferro chrome, ferro manganese. **[5 hours]**

#### **Bio-Inorganic Chemistry**

A brief introduction to bio-inorganic chemistry. Essential and trace elements in biological process. Role of metal ions present in biological systems with special reference to Na<sup>+</sup>, K<sup>+</sup> and

Ca<sup>2+</sup>, Mg<sup>2+</sup> ions: Na/K pump; Role of Mg<sup>2+</sup> ions in energy production and chlorophyll. Role of Ca<sup>2+</sup> ions in blood clotting. Enzymatic role of iron in haemoglobin and myoglobin, Mg in chlorophyll and cobalt in vitamin-B12. stabilization of protein structures and structural role (bones). Biological functions and toxicity of Cr, Mn, Co, Ni and I, Hg, Mo and Se.

[5 hours]

## **UNIT II : Organic Chemistry**

### **Special techniques in organic synthesis:**

- Polymer supported reagents – introduction, properties of polymer support- advantages of polymer support reagents, choice of polymers, types and applications.
- Phase transfer catalysis – introduction, definition, types, preparation, mechanism and advantages.
- Microwave induced organic synthesis – introduction, reaction vessel, reaction medium, advantages, limitations, precaution and applications.
- Sonochemistry – use of ultra sound in organic synthesis, introduction, instrumentation, physical aspects, types and applications.

[6 Hours]

**Natural Pigments:** Introduction to anthocyanines, structural formulae and their importance of anthocyanins,  $\beta$ -carotene and haemoglobin.

[2 Hours]

**Diazonium Compounds:** preparation, mechanism of preparation and synthetic applications of benzene diazonium chloride. Conversion to phenol, halobenzene, phenyl hydrazine and coupling reaction.

[2 Hours]

**Hydroxy acids:** Synthesis of lactic, citric and tartaric acids. One method each and their importance. Effect of heat on  $\alpha$ ,  $\beta$ ,  $\gamma$ -hydroxy acids.

[3 Hours]

**Nucleic acids:** Types, components, formation of nucleic acids, structure of DNA and RNA, importance of these in biological system.

[2 Hours]

**Identification of organic compounds by spectroscopic technique: UV-visible spectroscopy:** Introduction, chromophores and auxochrome, blue shift and red shift, graphical representation of spectra of 1,3-butadiene, benzene and lycopene. Influence of conjugation on UV absorption-comparison of UV spectra of acetone and methylvinyl ketone  
**IR-Spectroscopy:** Introduction, stretching frequency of –OH (free and H-bonded), alkyl –C-H, C=C, C=C, C-C, C=O and C-O groups (by taking suitable examples). Graphical representation of IR spectra of benzoic acid and methyl benzoate.

**NMR Spectroscopy:** Basic principles of proton magnetic resonance, nuclear magnetic spin quantum number  $l$ , influence of the magnetic field on the spin of nuclei, spin population, saturation using radio frequency, nuclear magnetic resonance-chemical shift ( $\delta$  value),

uses of TMS reference, nuclear shielding effects, equivalent and non-equivalent protons, spin-spin splitting and coupling.

Applications of NMR spectroscopy to simple organic molecules (like ethyl alcohol, ethane, propane, ethylene, methylamine, aniline, benzene, toluene, acetone, acetophenone, methyl cyanide and other simple molecules. **[5 Hours]**

### **UNIT III: Physical Chemistry**

#### **Electrochemistry**

Electrolytic and electrochemical cells, electrode reaction of Daniel cell, single electrode potential, sign of electrode potential-convention (reduction potential to be adopted), convention of representing a cell, EMF and standard EMF of a cell, cell reaction, reversible and irreversible cells, Nernst equation (to be derived) and calculation of electrode potential, standard hydrogen gas electrode, reference electrodes-calomel and Ag-AgCl electrode-construction and working, electrochemical series and its significance, equilibrium constant and free energy of cell reaction, spontaneity of a cell reaction, concentration cells.

**EMF of concentration cells:** Definition with explanation – with transference and without transference, concentration cells – with examples. Liquid junction potential and salt bridge. (Numerical problems on Nernst equation and EMF calculations).

**Application of EMF measurements:** (a) Determination of pH of a solution using quinhydrone electrode and glass electrode (using dip type Calomel electrode) – Explanation with principle and procedure. (b) Potentiometric titration – principle, location of end points in - (1) Neutralization reactions [NaOH Vs HCl] (2) Oxidation-reduction reactions [K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> Vs FAS] (3) Precipitation reaction [KCl Vs AgNO<sub>3</sub>] and (4) Complexometric reactions (ZnSO<sub>4</sub> Vs K<sub>3</sub>[Fe(CN)<sub>6</sub>]) **[8 Hours]**

**Phase equilibria:** Gibb's phase rule – definition of the terms with examples, application to one component system (water and sulphur system), reduced phase rule – statement, reduced systems, two component system – simple eutectic type KI-water system, freezing mixtures, Pb-Ag system (desilverization of argentiferrous lead). **[5 Hours]**

**Adsorption:** Adsorption of gases on solids – factors which influence. Adsorption isotherms (definition) –Freundlich's and Langmuir's adsorption isotherms and BET equation (to be derived). Applications of adsorption. **[3 Hours]**

**Kinetics of fast reactions and techniques:** Introduction, examples of fast reactions. Techniques – principle and procedure involved in - stopped flow method, flash photolysis, temperature jump method and pressure jump method. **[4 Hours]**

## VI Semester Practicals

### CHEMISTRY-DSE-2B LAB

Practical duration: 1 practical per week of 4 hrs

60 Hours (Credits: 02)

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Determination of solubility of sparingly soluble salt (like  $\text{BaSO}_4$ ) by conductometric method.

1. Determination of  $K_a$  (dissociation constant of a weak acid) using digital conductometer.
2. Determination of rate constant of saponification of ethyl acetate by conductivity measurements.
3. Conductometric titration of strong acid x strong base and weak acid x strong base.
4. Determination of percentage composition of a given mixture containing two miscible liquids by Abbe's refractometer.
5. Potentiometric titration of ferrous ammonium sulphate against potassium dichromate.
6. pH titration of strong acid against strong base ( by observing change in pH).
7. Potentiometric titration of mixture of HCl and  $\text{CH}_3\text{COOH}$  using NaOH solution.
8. Colorimetric estimation of  $\text{Fe}^{3+}$  ion using ammonium thiocyanate as complexing agent.
9. Colorimetric estimation of  $\text{Cu}^{2+}$  ion using  $\text{NH}_4\text{OH}$  as complexing agent.
10. Colorimetric study of kinetics of oxidation of indigocarmine by chloramine-T.
11. Determination of pH of aerated drinks, fruit juices, shampoos and soaps.

#### Chromatography:

12. Paper chromatographic separation of  $\text{Fe}^{3+}$  and  $\text{Ni}^{2+}$  ions.
13. Paper chromatographic separation of  $\text{Na}^+$  and  $\text{K}^+$  ions.

#### Solvent extraction:

14. Separation of a mixture of  $\text{Fe}^{2+}$  and  $\text{Ni}^{2+}$  by complexation with DMG.

## V SEMESTER

### CHEMISTRY (SEC-1)

**BASIC ANALYTICAL CHEMISTRY CLASS DURATION – THEORY: 02 HOURS/WEEK**

**Theory: 30 Hours (Credits-02)**

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**Skill Enhancement Course (Chemistry SEC-1) is a course for V semester course which may be chosen from a pool of the courses.**

#### **SEC:1 BASIC ANALYTICAL CHEMISTRY**

**Introduction:** Introduction to Analytical Chemistry and its interdisciplinary nature. Concept of sampling. Importance of accuracy, precision and sources of error in analytical measurements. Presentation of experimental data and results, from the point of view of significant figures.

**Analysis of soil:** Composition of soil, Concept of pH and pH measurement, Complexometric titrations, Chelation, Chelating agents, use of indicators.

a. Determination of pH of soil samples.

b. Estimation of Calcium and Magnesium ions as Calcium carbonate by complexometric titration. **[10 hours]**

**Analysis of water:** Definition of pure water, sources responsible for contaminating water, water sampling methods, water purification methods.

a. Determination of pH, acidity and alkalinity of a water sample.

b. Determination of dissolved oxygen (DO) of a water sample.

**Analysis of food products:** Nutritional value of foods, idea about food processing and food preservations and adulteration.

a. Identification of adulterants in some common food items like coffee powder, asafoetida, chilli powder, turmeric powder, coriander powder and pulses, etc.

b. Analysis of preservatives and colouring matter. **[10 hours]**

**Chromatography:** Definition, general introduction on principles of chromatography, paper chromatography, TLC etc.

a. Paper chromatographic separation of mixture of metal ion ( $\text{Fe}^{3+}$  and  $\text{Al}^{3+}$ ).

b. To compare paint samples by TLC method.

**Ion-exchange:** Column, ion-exchange chromatography etc.

Determination of ion exchange capacity of anion / cation exchange resin (using batch procedure if use of column is not feasible). [10 hours]

**Reference Books:**

1. Willard, H.H., Merritt, L.L., Dean, J. & Settoe, F.A. *Instrumental Methods of Analysis*. 7th Ed. Wadsworth Publishing Co. Ltd., Belmont, California, USA, 1988. □□ Skoog, D.A. Holler F.J. & Nieman, T.A. *Principles of Instrumental Analysis*, Cengage Learning India Ed.
2. Skoog, D.A.; West, D.M. & Holler, F.J. *Fundamentals of Analytical Chemistry 6<sup>th</sup> Ed.*, Saunders College Publishing, Fort Worth (1992).
3. Harris, D. C. *Quantitative Chemical Analysis*, W. H. Freeman.
4. Dean, J. A. *Analytical Chemistry Notebook*, McGraw Hill.
5. Day, R. A. & Underwood, A. L. *Quantitative Analysis*, Prentice Hall of India.
6. Freifelder, D. *Physical Biochemistry 2nd Ed.*, W.H. Freeman and Co., N.Y. USA (1982).
7. Cooper, T.G. *The Tools of Biochemistry*, John Wiley and Sons, N.Y. USA. 16 (1977).
8. Vogel, A. I. *Vogel's Qualitative Inorganic Analysis 7th Ed.*, Prentice Hall.
9. Vogel, A. I. *Vogel's Quantitative Chemical Analysis 6th Ed.*, Prentice Hall.
10. Robinson, J.W. *Undergraduate Instrumental Analysis 5th Ed.*, Marcel Dekker, Inc., New York (1995).

## V SEMESTER

### CHEMISTRY (SEC-2)

#### FUEL CHEMISTRY

CLASS DURATION – THEORY: 02 HOURS/WEEK

Theory: 30 Hours (Credits-02)

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**Skill Enhancement Course (Chemistry SEC-2) is a course for V semester course which may be chosen from a pool of the courses.**

#### **SEC:2 FUEL CHEMISTRY**

Review of energy sources (renewable and non-renewable). Classification of fuels and their calorific value.

**Coal:** Uses of coal (fuel and nonfuel) in various industries, its composition, carbonization of coal. Coal gas, producer gas and water gas—composition and uses. Fractionation of coal tar, uses of coal tar bases chemicals, requisites of a good metallurgical coke, Coal gasification (Hydro gasification and Catalytic gasification), Coal liquefaction and Solvent Refining. **[10 hours]**

**Petroleum and Petrochemical Industry:** Composition of crude petroleum, Refining and different types of petroleum products and their applications. Fractional Distillation (Principle and process), Cracking (Thermal and catalytic cracking), Reforming Petroleum and non-petroleum fuels (LPG, CNG, LNG, bio-gas, fuels derived from biomass), fuel from waste, synthetic fuels (gaseous and liquids), clean fuels. Petrochemicals: Vinyl acetate, Propylene oxide, Isoprene, Butadiene, Toluene and its derivatives Xylene. **[15 hours]**

**Lubricants:** Classification of lubricants, lubricating oils (conducting and non-conducting) Solid and semisolid lubricants, synthetic lubricants. Properties of lubricants (viscosity index, cloud point, pore point) and their determination. **[05 hours]**

#### **Reference Books:**

1. Stocchi, E. *Industrial Chemistry*, Vol-I, Ellis Horwood Ltd. UK (1990).
2. Jain, P.C. & Jain, M. *Engineering Chemistry* Dhanpat Rai & Sons, Delhi.
3. Sharma, B.K. & Gaur, H. *Industrial Chemistry*, Goel Publishing House, Meerut(1996).

## VI SEMESTER

### CHEMISTRY (SEC-3)

#### POLYMER CHEMISTRY

CLASS DURATION – THEORY: 02 HOURS/WEEK

Theory: 30 Hours (Credits-02)

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**Skill Enhancement Course (Chemistry SEC-3) is a course for VI semester course which may be chosen from a pool of the courses.**

#### **SEC:3 POLYMER CHEMISTRY**

##### **Kinetics of Polymerization:**

Mechanism and kinetics of step growth, radical chain growth, ionic chain (both cationic and anionic) and coordination polymerizations, Mechanism and kinetics of copolymerization, polymerization techniques. **[5 hours]**

##### **Crystallization and crystallinity:**

Determination of crystalline melting point and degree of crystallinity, Morphology of crystalline polymers, Factors affecting crystalline melting point. **[5 hours]**

**Polymer Solution** – Criteria for polymer solubility, Solubility parameter, Thermodynamics of polymer solutions, entropy, enthalpy, and free energy change of mixing of polymers solutions, Flory- Huggins theory, Lower and Upper critical solution temperatures.

**[10 hours]**

##### **Properties of Polymers** (Physical, thermal, Flow & Mechanical Properties).

Brief introduction to preparation, structure, properties and application of the following polymers: polyolefins, polystyrene and styrene copolymers, poly(vinyl chloride) and related polymers, poly(vinyl acetate) and related polymers, acrylic polymers, fluoro polymers, polyamides and related polymers. Phenol formaldehyde resins (Bakelite, Novalac), polyurethanes, silicone polymers, polydienes, Polycarbonates, Conducting Polymers, [polyacetylene, polyaniline, poly (p-phenylene sulphide polypyrrole, polythiophene)]. **[10 hours]**

##### **Reference Books:**

1. Seymour, R.B. & Carraher, C.E. *Polymer Chemistry: An Introduction*, Marcel Dekker, Inc. New York, 1981.
2. Odian, G. *Principles of Polymerization*, 4th Ed. Wiley, 2004.
3. Billmeyer, F.W. *Textbook of Polymer Science*, 2nd Ed. Wiley Interscience, 1971.
4. Ghosh, P. *Polymer Science & Technology*, Tata McGraw-Hill Education, 1991.
5. Lenz, R.W. *Organic Chemistry of Synthetic High Polymers*. Interscience Publishers, New York, 1967.

## VI SEMESTER

### CHEMISTRY (SEC-4)

#### CHEMICAL TECHNOLOGY, PESTICIDE CHEMISTRY & SOCIETY

CLASS DURATION - THEORY: 02 HOURS/WEEK

Theory: 30 Hours (Credits-02)

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**Skill Enhancement Course (Chemistry SEC-4) is a course for VI semester course which may be chosen from a pool of the courses.**

#### CHEMICAL TECHNOLOGY, PESTICIDE CHEMISTRY & SOCIETY

##### **Chemical Technology**

Basic principles of distillation, solvent extraction, solid-liquid leaching and liquid-liquid extraction, separation by absorption and adsorption. An introduction into the scope of different types of equipment needed in chemical technology, including reactors, distillation columns, extruders, pumps, mills, emulgators. Scaling up operations in chemical industry. Introduction to clean technology. **[10 hours]**

##### **Pesticide Chemistry**

General introduction to pesticides (natural and synthetic), benefits and adverse effects, changing concepts of pesticides, structure activity relationship, synthesis and technical manufacture and uses of representative pesticides in the following classes: Organochlorines (DDT, Gammexene,); Organophosphates (Malathion, Parathion ); Carbamates (Carbofuran and carbaryl); Quinones (Chloranil), Anilides (Alachlor and Butachlor). **[10 hours]**

##### **Society**

Exploration of societal and technological issues from a chemical perspective. Chemical and scientific literacy as a means to better understand topics like air and water (and the trace materials found in them that are referred to as pollutants); energy from natural sources (i.e. solar and renewable forms), from fossil fuels and from nuclear fission; materials like plastics and polymers and their natural analogues, proteins and nucleic acids, and molecular reactivity and interconversions from simple examples like combustion to complex instances like genetic engineering and the manufacture of drugs. **[10 hours]**

**References:**

1. Reference Book: Cremlyn, R. Pesticides. Preparation and Modes of Action, John Wiley & Sons, New York, 1978.
2. Harris, D. C. *Quantitative Chemical Analysis*, W. H. Freeman.
3. Dean, J. A. *Analytical Chemistry Notebook*, McGraw Hill.
4. Day, R. A. & Underwood, A. L. *Quantitative Analysis*, Prentice Hall of India.
5. Freifelder, D. *Physical Biochemistry 2nd Ed.*, W.H. Freeman and Co., N.Y. USA (1982).
6. Cooper, T.G. *The Tools of Biochemistry*, John Wiley and Sons, N.Y. USA. 16 (1977).
7. John W. Hill, Terry W. McCreary & Doris K. Kolb, *Chemistry for changing times* 13th Ed.

## Reference Books:

1. Lee, J.D. *Concise Inorganic Chemistry* ELBS, 1991.
2. Cotton, F.A., Wilkinson, G. & Gaus, P.L. *Basic Inorganic Chemistry*, 3rd ed., Wiley.
3. Douglas, B.E., McDaniel, D.H. & Alexander, J.J. *Concepts and Models in Inorganic Chemistry*, John Wiley & Sons.
4. Huheey, J.E., Keiter, E.A., Keiter, R.L. & Medhi, O.K. *Inorganic Chemistry: Principles of structure and Reactivity*, Pearson Education India, 2006.
5. Graham Solomon, T.W., Fryhle, C.B. & Snyder, S.A. *Organic Chemistry*, John Wiley & Sons (2014).
6. McMurry, J.E. *Fundamentals of Organic Chemistry*, 7th Ed. Cengage Learning India Edition, 2013.
7. Sykes, P. *A Guidebook to Mechanism in Organic Chemistry*, Orient Longman, New Delhi (1988).
8. Eliel, E.L. *Stereochemistry of Carbon Compounds*, Tata McGraw Hill education, 2000.
9. Finar, I.L. *Organic Chemistry* (Vol. I & II), E.L.B.S.
10. Morrison, R.T. & Boyd, R.N. *Organic Chemistry*, Pearson, 2010.
11. Bahl, A. & Bahl, B.S. *Advanced Organic Chemistry*, S. Chand, 2010.
12. Barrow, G.M. *Physical Chemistry* Tata McGraw-Hill (2007).
13. Castellan, G.W. *Physical Chemistry* 4th Ed. Narosa (2004).
14. Kotz, J.C., Treichel, P.M. & Townsend, J.R. *General Chemistry* Cengage Learning India Pvt. Ltd., New Delhi (2009).
15. Mahan, B.H. *University Chemistry* 3rd Ed. Narosa (1998).
16. Petrucci, R.H. *General Chemistry* 5th Ed. Macmillan Publishing Co.: New York(1985).
17. Nelson, D. L. & Cox, M. M. Lehninger's *Principles of Biochemistry*, 7th Ed., W. H. Freeman.
18. Berg, J.M., Tymoczko, J.L. & Stryer, L. *Biochemistry*, W.H. Freeman, 2002.
19. Shriver, D.F. & Atkins, P.W. *Inorganic Chemistry*, Oxford University Press.
20. Wulfsberg, G. *Inorganic Chemistry*, Viva Books Pvt. Ltd.
21. Rodgers, G.E. *Inorganic & Solid State Chemistry*, Cengage Learning India Ltd., 2008.
22. Mark Weller and Fraser Armstrong, 5th Edition, Oxford University Press (2011-2012)
23. Adam, D.M. *Inorganic Solids: An introduction to concepts in solid-state structural chemistry*. John Wiley & Sons, 1974.
24. Poole, C.P. & Owens, F.J. *Introduction to Nanotechnology* John Wiley & Sons, 2003.
25. E. Stocchi: *Industrial Chemistry*, Vol-I, Ellis Horwood Ltd. UK.

26. R.M. Felder, R.W. Rousseau: *Elementary Principles of Chemical Processes*, Wiley Publishers, New Delhi.
27. J. A. Kent: *Riegel's Handbook of Industrial Chemistry*, CBS Publishers, New Delhi.
28. S. S. Dara: *A Textbook of Engineering Chemistry*, S. Chand & Company Ltd. New Delhi.
29. K. De, *Environmental Chemistry*: New Age International Pvt., Ltd, New Delhi.
30. S. M. Khopkar, *Environmental Pollution Analysis*: Wiley Eastern Ltd, New Delhi
31. S.E. Manahan, *Environmental Chemistry*, CRC Press (2005).
32. G.T. Miller, *Environmental Science* 11th edition. Brooks/ Cole (2006).
33. Mishra, *Environmental Studies*. Selective and Scientific Books, New Delhi (2005).
34. E. Stocchi: *Industrial Chemistry*, Vol-I, Ellis Horwood Ltd. UK.
35. W. D. Kingery, H. K. Bowen, D. R. Uhlmann: *Introduction to Ceramics*, Wiley Publishers, New Delhi.
36. P. C. Jain & M. Jain: *Engineering Chemistry*, Dhanpat Rai & Sons, Delhi.
37. R. Gopalan, D. Venkappayya, S. Nagarajan: *Engineering Chemistry*, Vikas Publications, New Delhi.
38. K. Sharma: *Engineering Chemistry*, Goel Publishing House, Meerut Reference books:
39. Skoog, D.A. Holler F.J. & Nieman, T.A. *Principles of Instrumental Analysis*, Cengage Learning India Ed.
40. Willard, H.H., Merritt, L.L., Dean, J. & Settoe, F.A. *Instrumental Methods of Analysis*, 7th Ed. Wadsworth Publishing Company Ltd., Belmont, California, USA, 1988.
41. P.W. Atkins: *Physical Chemistry*.
42. G.W. Castellan: *Physical Chemistry*.
43. Brian Smith: *Infrared Spectral Interpretations: A Systematic Approach*.
44. W.J. Moore: *Physical Chemistry*.
45. Banwell, C. N. & McCash, E. M. *Fundamentals of Molecular Spectroscopy* 4th Ed. Tata McGraw-Hill: New Delhi (2006).
46. Chandra, A. K. *Introductory Quantum Chemistry* Tata McGraw-Hill (2001).
47. House, J. E. *Fundamentals of Quantum Chemistry* 2nd Ed. Elsevier: USA (2004).
48. Lowe, J. P. & Peterson, K. *Quantum Chemistry*, Academic Press (2005).
49. Kakkar, R. *Atomic & Molecular Spectroscopy: Concepts & Applications*, Cambridge University Press (2015).
50. K J Laidler. *Chemical kinetics*.
51. J Rajaram and J C Kuriacose. *Kinetics and mechanism of chemical transformation*.
52. Frost and Pearson. *Chemical kinetics*.

53. Svehla, G. *Vogel's Qualitative Inorganic Analysis*, Pearson Education, 2012.
54. Mendham, J. *Vogel's Quantitative Chemical Analysis*, Pearson, 2009.
55. Vogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G., *Textbook of Practical Organic Chemistry*, Prentice-Hall, 5th edition, 1996.
56. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry* Orient-Longman, 1960.
57. Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry*, R.
58. Chand & Co.: New Delhi (2011).
59. Ahluwalia, V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry*, Universities Press.
60. Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. *Experiments in Physical Chemistry 8th Ed.*; McGraw-Hill: New York (2003).
61. Halpern, A. M. & McBane, G. C. *Experimental Physical Chemistry 3rd Ed.*; W.H. Freeman & Co.: New York (2003).
62. A.I. Vogel: *Qualitative Inorganic Analysis*, Prentice Hall, 7th Edn.
63. A.I. Vogel: *Quantitative Chemical Analysis*, Prentice Hall, 6th Edn.
64. P. L. Soni. *A Text book of Inorganic Chemistry*, Sultan Chand & Sons.
65. B. R. Puri & L. Sharma. *A Text book of Inorganic Chemistry*, Shobhanlal Nagin Chand Co.
66. Puri, Sharma & Kalia. *Principles of Inorganic Chemistry*, Shobhanlal Nagin Chand Co.
67. Gurudeep Raj. *A Text book of Inorganic Chemistry*.
68. Madan, Malik, Tuli. *Selected Topics in Inorganic Chemistry*, S. Chand & Company.
69. A. K. De. *A Text book of Inorganic Chemistry*, New Age International.
70. O. P. Agarwal. *Comprehensive Inorganic Chemistry*.
71. Kapoor & Chopra. *Inorganic Chemistry*.
72. B. K. Sharma. *Engineering Chemistry*.
73. B. K. Sharma. *Industrial Chemistry*.
74. Jain and Jain. *Engineering Chemistry*.
75. R. Gopalan. *Elements of Nuclear Chemistry*.
76. B. N. Chakarbathy. *Industrial Chemistry*. Oxford & IBH Publishers.
77. Gurdeep R. Chatwal & Sham Anand. *Instrumental methods of Chemical analysis*, Himalaya Publishing House.
78. C. R. Chatwal. *Inorganic Polymers*, Himalaya Publishing House.
79. Manku. *Theoretical Principles of Inorganic Chemistry*, Tata McGraw Hills.
80. Gurudeep Raj. *Advanced Practical Inorganic Chemistry*, Goel Publishing House.
81. C. N. R. Rao. *University Chemistry*, Mac Millan Company.

82. Robinson & Heslop. A Text book of Inorganic Chemistry, New Age Publications.
83. Willard, Meritind & Dean, *Analytical Chemistry*, New Age Publications.
84. Chattopadhyay. *Introduction to nanoscience & nanotechnology*.
85. Dr. Shuthosh Sharma & Dr. Bellari. *Advances in nanoscience & nanotechnology*.
86. M. K. Jain. *A Text book of Organic Chemistry*, S. Chand & Company
87. Bhal & Bhal. *A Text book of Organic Chemistry*, Chand & Company
88. P. L. Soni. *A Text book of Organic Chemistry*, S. Chand & Company
89. Raj K. Bansal. *Laboratory Manual of Organic Chemistry*, New Age Publications
90. Jayaraman.S. *Laboratory Manual of Organic Chemistry*, Chand & Company.
91. Aggarwal. *Chemistry of Natural products*, Goel Publishing House Meerut.
92. K. K. Sharma. *Organic Chemistry*, Shobhanlal & Nagan Company.
93. Puri & Sharma. *Organic Chemistry*, Shobhanlal & Nagan Company.
94. Ashuthosh Kar. *Medicinal Chemistry*, Tata Mcgraw Hill Publications.
95. Handrickson. *Organic Chemistry*, Tata Mcgraw Hill Publications
96. V. K. Ahluwalia & Renu Aggarwal. *Organic Synthesis special techniques*, Narosa publishing House.
97. Eliel. *Stereo Chemistry*, John Wiley Eastern Publications
98. Raj K. Bansal. *Heterocyclic Chemistry*, Tata Mcgraw Hill Publications
99. V. Kumar. *An introduction Green Chemistry*.
100. R. P. Verma. *Physical Chemistry*, Pradeep Publication
101. S. K. Jain. *Kinetics of Chemical Reactions*, Vishal publications, Jalandhar, New Delhi.
102. M. Kundan & S. K. Jain. *Physical Chemistry*. S. Chand & Company
103. K. K. Sharma & C. K. Sharma. *Text book of Physical Chemistry*, Vani Educational Books.
104. Upadhyaya & Upadhyaya. *Biophysical Chemistry*, Himalaya Publishing Homes.
105. Puri, Sharma & Pathania. *Principles of physical chemistry*.
106. B. S. Bahl, Arun Bahl & G. D. Tuli. *Essentials of physical chemistry*.
107. V. R. Gowriker. N. V. Vishwanathan & J. Sreedhar, *Polymer Science*.
108. A.K. Chandra. *Quantum Chemistry* (2<sup>nd</sup> edition).
109. R.K. Prasad. *Quantum Chemistry*.
110. R. L. Madan & G. D. Tuli. *Physical Chemistry*, S. Chand & Company.
111. Gurudeep Raj. *Text book of advanced Physical Chemistry*, Goel Prakashan. Meerut.
112. Jain & Jain. *Engineering Chemistry*, Dhanpal & Sons, New Delhi.
113. W. Bansal. *Text book of Photochemistry*, S. Chand & Company
114. Pathania & Sharma. *Physical Chemistry*, Vishal Publications Jalandhar & Delhi.