Bachelor of Sciences in Industrial Chemistry

SEMESTER V

DISCIPLINE SPECIFIC CORE COURSE – 13: (DSC-13) INDUSTRIAL CATALYSTS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Industrial Catalysts (DSC-13: Industrial Chemistry -V)	04	02	--	02	Physics, Chemistry, Mathematics, in Class XII	NIL

Learning Objectives:

The Learning Objectives of this course are as follows:

- To imparts basic knowledge of catalysis, properties of catalysts and mode of action of catalyst.
- To enrich students with the knowledge of various types of catalysts such as organometallic catalyst, biocatalyst, shape selective catalyst and photocatalysts.
- To impart the theoretical and practical knowledge of catalysts with the view of their industrial applications.

Learning Outcomes:

By the end of this course, students will be able to:

- Establish an appreciation of the role of catalyst in industrial applications.
- Gain sound knowledge of various types of catalyst.
- Get skilled in the scientific method of planning, developing, conducting, reviewing and reporting experiments.
- Get skilled concepts of industrial catalysis which will help them to explore new innovative areas of research.

Unit 1: Introduction of Catalyst — Hours: 8

General principles of catalysis, properties of catalysts, Mode of action of catalyst, Types of catalyst (homogeneous and heterogeneous catalysis), Deactivation and regeneration of catalysts, catalytic poison, Promoter, Turnover frequency, Turnover number, Specificity and selectivity

Unit 2: Catalysis by Organometallic Compounds — Hours: 6

Study of the following industrial processes, catalytic cycle and their mechanism:
Alkene hydrogenation (Wilkinson's Catalyst), Synthetic gasoline (Fischer Tropsch reaction), Polymerisation of ethene using Ziegler-Natta catalyst

Unit 3: Biocatalysis Hours: 5

Introduction, Kinetics of enzyme–catalysed reactions, Industrial process with biocatalyst, Aspartame through enzymatic peptide synthesis, 4-Hydroxyphenoxypropionic acid as herbicide intermediate

Unit 4: Shape selective catalysis: Zeolites Hours: 6

Composition and structure of Zeolites, Catalytic properties of Zeolites, Shape selectivity, Isomorphic substitution of Zeolites, Metal doped Zeolites, Applications of Zeolites

Unit 5: Photocatalysis Hours: 5

Basic principle, Photoreduction and oxidation of water, Water reduction, Water oxidation, Photocleavage of water

Practical

(Credits: 2, Laboratory periods: 60)

1. Catalytic bromination of benzene. Catalyst: $FeCl_3/AlCl_3$
2. Catalytic chlorination of benzene. Catalyst: $FeCl_3/AlCl_3$
3. Catalytic Removal of Bromates from polluted Water: Synthesis of catalyst one lab, Removal of Bromates one lab.
4. Phase-Transfer Catalytic Reactions
5. Catalytic oxidation of ammonia using chromium(III) oxide as a catalyst. Catalytic Friedal-craft reaction using $AlCl_3$ and Lewis acid catalyst. Synthesis of toluene.
6. Synthesis of "Zeolite A" catalyst.
7. Zeolite Hydrogen-Y or dil.HCl/dil.H_2SO_4 as a Catalyst for the Preparation of an Ester.
8. Synthesis of biaryl using palladium catalyst.
9. Catalytic Transfer Hydrogenation of Castor Oil
10. Reduction of Nitrobenzene

References (Theory):

1. Huheey, J. E.; Keiter, E.A.; Keiter; R. L.; Medhi, O.K. (2009), **Inorganic Chemistry-Principles of Structure and Reactivity**, Pearson Education.
2. Cotton, F.A.; Wilkinson, G. (1999), **Advanced Inorganic Chemistry,** Wiley-VCH.
3. Jens Hagen (2015) **Industrial Catalysis: A Practical Approach** Wiley-VCH Verlag GmbH & Co

References (Practical):

1. Cerrillo, J. L.; López-Hernández, I.; Palomares, A. E. **Catalytic Removal of Bromates from Water: A Hands-On Laboratory Experiment to Solve a Water Pollution Problem through Catalysis** J. Chem. Educ. 2021, 98, 1726−1731.
2. Shabestary, N.; Khazaeli, S.; Hickman, R.; **Phase-Transfer Catalytic Reactions Journal of Chemical Education**, 1998, 75, 1470-1472.
3. Volkovich, V. A.; Griffiths, T. R.; **Catalytic Oxidation of Ammonia: A Sparkling Experiment** J. Chem. Educ. 2000, 77, 2, 177.

4. Williams, D. J.; Huck, B. E.; Wilkinson, A. P. **First-Year Undergraduate Laboratory Experiments with Zeolites Chem. Educator** 2002, 7, 33–36.
5. Coker, E. N.; Davis, P. J.; **Experiments with Zeolites at the Secondary-School Level: Experience from The Netherlands** Journal of Chemical Education 1999, 76, 10, 1417.
6. Hanson RW. **Catalytic transfer hydogenation reactions for undergraduate practical programs.** J Chem Educ. 2009, 74, 430.
7. Alwaseem H, Donahue CJ, Marincean S. **Catalytic transfer hydrogenation of castor oil.** J Chem Educ. 2014; 91, 575–8.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE –DSC 14: COORDINATION CHEMISTRY AND ORGANOMETALLICS

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Coordination Chemistry and Organometallics DSC-13: Chemistry- V	**04**	**02**	**-**	**02**	**Class 12th with Physics, Chemistry, Mathematics**	

Learning Objectives

The Learning Objectives of this course are as follows:

- To develop basic understanding of coordination chemistry and organometallics which are of immense importance to biological systems, qualitative quantitative analysis, catalysis, medicines, paints and pigments etc.
- The students learn nomenclature, isomerism and bonding in coordination compounds with special emphasis on important coordination compounds in the biological system.
- To understand classification of organometallic compounds, the concept of hapticity and the 18-electron rule governing the stability of a wide variety of organometallic species with special emphasis on metal carbonyls.

Learning outcomes

By studying this course, students will be able to:

- Understand terms: ligand, denticity of ligands, chelate, coordination number.
- Systematically name coordination compounds.

- Discuss the various types of isomerism possible in Octahedral and Tetrahedral coordination compounds.
- Use Valence Bond Theory to predict the structure and magnetic behaviour of metal complexes and understand the terms inner and outer orbital complexes.
- Explain the meaning of the terms Δo., Δt, pairing energy, CFSE, high spin and low spin and how CFSE affects thermodynamic properties like lattice enthalpy and hydration enthalpy.
- Explain magnetic properties and colour of complexes on basis of Crystal Field Theory
- Apply 18-electron rule to rationalize the stability of metal carbonyls and related species.
- Learn how IR data can be used to understand extent of back bonding in metal carbonyls.

Syllabus

Unit 1: Introduction to Coordination compounds (Hours: 6)

Brief discussion with examples of types of ligands, denticity and concept of chelate. IUPAC system of nomenclature of coordination compounds (mononuclear and binuclear) involving simple monodentate and bidentate ligands. Structural and stereoisomerism in complexes with coordination numbers 4 and 6.

Unit 2: Bonding in Coordination Compounds (Hours: 14)

Valence Bond Theory (VBT): Salient features of theory, concept of inner and outer orbital complexes, Drawbacks of VBT.

Crystal Field Theory: Splitting of d orbitals in octahedral symmetry. Crystal field effects for weak and strong fields, Crystal field stabilization energy (CFSE), concept of pairing energy, Factors affecting the magnitude of Δ, Spectrochemical series, Splitting of d orbitals in tetrahedral symmetry, Comparison of CFSE for octahedral and tetrahedral fields, tetragonal distortion of octahedral geometry, Jahn-Teller distortion

Unit 3: Organometallic Chemistry (Hours: 10)

Definition and classification with appropriate examples based on nature of metal-carbon bond (ionic, sigma, pi and multicentre bonds), Structure and bonding of methyl lithium and Zeise's salt, Structure and bonding of ferrocene, mononuclear and polynuclear carbonyls of 3d metals, 18-electron rule as applied to carbonyls, π-acceptor behaviour of carbon monoxide (MO diagram of CO to be discussed), synergic effect and use of IR data to explain extent of back bonding.

Practical Component Credits:02

(Laboratory periods:60)

8. Estimation of Mg^{2+} by direct complexometric titrations using EDTA.
9. Estimation of Zn^{2+} by direct complexometric titrations using EDTA.
10. Estimation of Ca^{2+} by direct complexometric titrations using EDTA.
11. Estimation of total hardness of a given sample of water by complexometric titration.
12. Determination of the composition of the Fe^{3+} - salicylic acid complex / Fe^{2+}-1, 10- phenanthroline complex in solution by Job's method.
13. Determination of the composition of the Fe^{3+} - salicylic acid complex / Fe^{2+}-1,10-phenanthroline complex in solution by mole ratio method
14. Preparation of the following inorganic compounds:
    a). Tetraamminecopper(II) sulphate
    b). Potassium trioxalatoferrate(III) trihydrate
    c). Chrome alum
    d). *Cis*- and *trans*-Potassium diaquadioxalatochromate(III)

8\. Any suitable experiment (other than the listed ones) based upon complexation reactions.

References:

Theory:

17. Huheey, J.E.; Keiter, E.A., Keiter; R. L.; Medhi, O.K. (2009), **Inorganic Chemistry-Principles of Structure and Reactivity***,* Pearson Education.
18. Shriver, D.D.; Atkins, P.; Langford, C.H. (1994), **Inorganic Chemistry** 2nd Ed., Oxford University Press.
19. Atkins, P.W.; Overton, T.L.; Rourke, J.P.; Weller, M.T.; Armstrong, F.A. (2010), **Inorganic *Chemistry***, 5th Edition, W. H. Freeman and Company.
20. Cotton, F.A.; Wilkinson, G.; Gaus, P.L. **Basic Inorganic Chemistry**, 3rd Edition, Wiley India.
21. Douglas, B.E.; McDaniel, D.H.; Alexander, J.J. (1994), **Concepts and Models of Inorganic Chemistry**, John Wiley & Sons.
22. Greenwood, N.N.; Earnshaw, A. (1997), **Chemistry of the Elements**, 2nd Edition, Elsevier.
23. Lee, J.D.; (2010), **Concise Inorganic Chemistry**, Wiley India.

Practicals:

4. Jeffery, G.H.; Bassett, J.; Mendham, J.; Denney, R.C. (1989),Vogel's Textbook of Quantitative Chemical Analysis, John Wiley and Sons.
5. Marr, G.; Rockett, B.W. (1972), Practical Inorganic Chemistry, Van Nostrand Reinhold.
6. Dua A, Manav N, **Practical Inorganic Chemistry,** (2017), Manakin Press.

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