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DEPARTMENT OF CHEMISTRY

BSc (Analytical Chemistry)

Semester-III

Category II

B.SC. (H)WITH ANALYTICAL CHEMISTRY

DISCIPLINE SPECIFIC CORE COURSE – 7: DSC-7:AC-3

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		
Course Title: Quantitative Methods of Analysis **Course Code:** Analytical Chemistry-3 (DSC7:AC-3)	**04**	**02**	**00**	**02**	**Physics, Chemistry and Mathematics**	**-**

Learning Objectives

The Learning Objectives of this course are as follows:

- To acquire knowledge about the basic principles underlying gravimetric and volumetric analysis, different types of titration curves, equilibria principles and environmental analysis

Learning outcomes

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

- By the end of this course, students will be able to:
- Know the concept of volumetric and gravimetric analysis and deducing the conversion factor for determination
- Understand the various titration curves
- Stability of complexes
- Know and analyse various pollutants present in the environment.

SYLLABUS OF Analytical Chemistry-2 (DSC-7: AC-3)

Theory Component

UNIT – I: Gravimetric Analysis (4 Weeks)

Requisites of precipitation, Nucleation, precipitation, and growth of precipitates; Particle size and filterability of precipitates; Factors influencing precipitation, Co-precipitation, post-precipitation. Super saturation, digestion, precipitation from homogeneous solution, washing of precipitate and ignition of precipitate, Brief idea about method of filtration and drying of precipitate, Use of reagents used in gravimetry (8-hydroxy quinoline (oxine) and dimethyl glyoxime (DMG).

UNIT – II: Basic principles underlying titrimetric analysis (6 Weeks)

- **Acid-base:** pH of strong and weak acid solutions. Buffer solutions. Henderson equations. Preparation of acidic and basic buffers. Relative strength of acids and bases from K_a and K_b values. Neutralisation-titration curve, theory of indicators, choice of indicators.
- **Theory of redox indicator**s: Principle and detection of equivalence point by visual & potentiometric methods
- **Precipitation titrations** Argentometric titrations, indicators for precipitation titrations involving silver nitrate- Volhard's method., Mohr's method, Adsorption indicators.
- **Complexometric titrations:** Stability of complexes, titration involving EDTA: . direct, back, displacement and indirect determinations, Metal ion indicators and characteristics. Application-determination of hardness of water

UNIT – III: Introduction to Environmental Analysis (5 weeks)

- Environmental analysis of water: colour, odour, taste, conductivity, dissolved solids, hardness, DO, COD, BOD, chlorides, sulphates, nitrates and phosphates
- Environmental analysis of air: Sampling, particulate matter, gaseous pollutants-SOx, NOx, COx, and organic pollutants
- Environmental analysis of industrial effluents-estimation of toxic metals Hg, Cd, Pb, As, radiochemical wastes

Practical component

(Credits: 02; Laboratory Periods: 60; 15 Classes of 4 hours each)

1. Determination of the pK_a of a weak acid by potentiometric and pH metric titrations.
2. Determination of the strength of the given ferric chloride solution by titrating it against EDTA.
3. Estimation of chloride in water by precipitation method.
4. Estimation of amount of nickel present in given solution as *bis*(dimethylglyoximato)nickel (II) /Aluminium as oxinate.
5. Draw the absorbance curve of bromophenol blue using a colorimeter.

6. Determination of the composition of the Fe^{3+}-salicylic acid complex in solution by Job's method (*Plot curve using excel also*).
7. Determination of the formula of the chelate formed between iron (III) and Tiron.
8. Determination of dissolved oxygen (DO) /biological oxygen demand (BOD),/chemical oxygen demand (COD) (*Use at least two water samples from different sources*)

Essential/recommended readings

- Willard, Merritt, Dean, Settle (2004), Instrumental Methods of Analysis, CBS Publishers & Distributors.
- Skoog, D.A.; West, D.M.; Holler, F.J.; Crouch, S.R. (2014), Fundamentals of Analytical Chemistry, Cengage Learning.
- Harris, D.C. (2015),Quantitative Chemical Analysis, W.H. Freeman & Company.
- Mendham, J., Denney, R.C., Barnes, J.D.; Thomas, M.J.K. (2000); Vogel's Quantitative Chemical Analysis, Prentice Hall.
- Manahan, S.E. (2017)Environmental Chemistry, CRC Press
- De, A.K. (2012)Environmental Chemistry, New Age International Pvt. Lt

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

DISCIPLINE SPECIFIC CORE COURSE – 8: DSC8:C3

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		
Course Title: CHEMICAL ENERGETICS AND EQUILIBRIA **Course Code:** CHEMISTRY-3 (DSC8-C3)	**04**	**02**	**00**	**02**	**Physics, Chemistry and Mathematics**	**-**

Learning Objectives

The Learning Objectives of this course are as follows:

- The objective of this paper is to develop basic understanding of the chemical energetics, laws of thermodynamics and ionic equilibrium. It provides basic understanding of the behaviour of electrolytes and their solutions.
- The students will also learn about the properties of ideal and real gases and deviation from ideal behaviour.

Learning outcomes

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

- Understand the laws of thermodynamics, thermochemistry and equilibria.
- Understand concept of pH and its effect on the various physical and chemical properties of the compounds.
- Use the concepts learnt to predict feasibility of chemical reactions and to study the behaviour of reactions in equilibrium.

SYLLABUS OF Chemistry-3 (DSC-8:C3)

Theory Component

UNIT – I: Chemical Energetics (7 Weeks)

Review of Intensive and extensive variables; state and path functions; isolated, closed and open systems, concept of heat, Q, work, W, internal energy, U, and enthalpy, H.

First law
Concept of heat, Q, work, W, internal energy, U, and statement of first law; enthalpy, H, relation between heat capacities, Joule Thompson Porous Plug experiment, Nature of Joule Thompson coefficient, calculations of Q, W, ΔU and ΔH for reversible, irreversible and free expansion of ideal gases under isothermal conditions.

Thermochemistry
Enthalpy of reactions: standard states; enthalpy of neutralization, enthalpy of hydration, enthalpy of formation and enthalpy of combustion and its applications, bond dissociation energy and bond enthalpy; effect of temperature (Kirchhoff's equations) on enthalpy of reactions.

Second Law
Concept of entropy; statement of the second law of thermodynamics. Calculation of entropy change for reversible processes and irreversible processes (for ideal gases). Free Energy Functions: Gibbs and Helmholtz energy; variation of S, G, A with T, V, P; Free energy change and spontaneity (for ideal gases), Gibbs-Helmholtz equation.

Third Law
Statement of third law, unattainability of absolute zero, calculation of absolute entropy of molecules, concept of residual entropy, calculation of absolute entropy of solid, liquid and gases.

UNIT – II: Chemical Equilibrium (2 Weeks)

Criteria of thermodynamic equilibrium, chemical equilibrium in ideal gases. Thermodynamic derivation of relation between Gibbs free energy of reaction and reaction quotient. Equilibrium constants and their qualitative dependence on T, P and concentration (Le Chatelier's principle). Free energy of mixing and spontaneity.

UNIT – III: Ionic Equilibria (6 Weeks)

Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization, Ostwald's dilution law, ionization constant and ionic product of water, ionization of weak acids and bases, pH scale, common ion effect, salt hydrolysis-calculation of hydrolysis constant, degree of hydrolysis and pH for different salts. Buffer solutions, Henderson-Hasselbach equation. Solubility and solubility product of sparingly soluble salts – applications of solubility product principle.

Practical component

(Credits: 02; Laboratory Periods: 60; 15 Classes of 4 hours each)

Chemical Energetics:

1. Determination of heat capacity of calorimeter.
2. Determination of enthalpy of neutralization of hydrochloric acid with sodium hydroxide.

3. Determination of the enthalpy of ionization of ethanoic acid.
4. Determination of basicity of a dibasic acid by thermochemical method.
5. Determination of integral enthalpy of solution of salts (KNO_3 or NH_4Cl).
6. Determination of enthalpy of hydration of copper sulphate.

Ionic equilibria:

7. Preparation of buffer solutions: (i) Sodium acetate-acetic acid or (ii) Ammonium chloride-ammonium acetate. Measurement of the pH of buffer solutions and comparison of the values with theoretical values.
8. Study the effect of addition of HCl/NaOH on pH of the buffer solutions (acetic acid, and sodium acetate).
9. pH metric titration of (i) strong acid with strong base, (ii) weak acid with strong base

Essential/recommended readings

- Castellan, G. W. (2004), Physical Chemistry, Narosa.
- Kapoor, K. L. (2015), A Textbook of Physical Chemistry, Vol 1, 6th Edition, McGraw Hill Education.
- Kapoor, K. L. (2015), A Textbook of Physical Chemistry, Vol 2, 6thEdition, McGraw Hill Education.
- Puri, B. R., Sharma, L. R. and Pathania M. S. (2020), Principles of Physical Chemistry, Vishal Publishing Co.
- Khosla, B. D.; Garg, V. C.; Gulati, A. (2015), Senior Practical Physical Chemistry, R. Chand & Co.
- Kapoor, K. L. (2019), A Textbook of Physical Chemistry, Vol 7, 1st Edition, McGraw Hill Education.
- Batra, S. K., Kapoor, V and Gulati, S. (2017) 1st Edition, Experiments in Physical Chemistry, Book Age series.

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DISCIPLINE SPECIFIC ELECTIVES (DSE)

Credit distribution, Eligibility and Pre-requisites of the Course

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE-1

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Course Title: ANALYTICAL BIOCHEMISTRY **Course Code:** (DSE-1)	**04**	**02**	**00**	**02**	**Physics, Chemistry and Mathematics**	**-**

Learning Objectives

The Learning Objectives of this course are as follows:

- Students will learn about proteins, enzymes, nucleic acids and lipids, using suitable examples, drug-receptor interaction and Structure-Activity Relation (SAR) relationship.
- Students will also learn about the genetic code and concept of heredity.

Learning outcomes

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

- Learn about the structures of carbohydrates and Proteins
- Learn about the molecules, macromolecules, polymers and their formations
- Learn about the metabolism of a few biomolecules.
- Know basic principles of drug-receptor interaction and strucstructure-activitytionship (SAR).
- Know the biochemistry of diseases.

SYLLABUS OF DSE-1

Theory Component

UNIT – I: Carbohydrates and Proteins (8 Weeks)

Basic understanding of the structures and properties of carbohydrates, biological importance of Carbohydrates.
Monosaccharides: Constitution and absolute configuration of glucose and fructose, epimers and anomers, mutarotation, Haworth projections and conformational structures; Structure elucidation of glucose and fructose (Fischer's proof), Interconversions of aldoses and ketoses; Killiani-Fischer synthesis and Ruff degradation;
Disaccharides – Structure elucidation of maltose, lactose and sucrose.
Polysaccharides – Elementary treatment of starch, cellulose and glycogen.
Amino Acids, Peptides and Proteins:
α-Amino Acids - Classification and characterization, Zwitterions, pKa values, isoelectric point and electrophoresis;
Proteins: Classification, Primary, secondary and tertiary structures of proteins, test for proteins, isolation, characterization, biological importance; denaturation of proteins.
Enzymes: Introduction, classification and characteristics of enzymes. Salient features of active site of enzymes. Mechanism of enzyme action (taking trypsin as an example), factors affecting enzyme action, coenzymes and cofactors (ATP, NAD, FAD), specificity of enzyme action (including stereospecificity).

UNIT – II: Lipids (3 Weeks)

Introduction to oils and fats; common fatty acids present in oils and fats, Hydrogenation of fats and oils, Classification. Biological importance of triglycerides and phosphoglycerides and cholesterol; Liposomes and their biological functions and underlying applications. Lipoproteins. Properties, functions and biochemical functions of steroid hormones and peptide hormones.

UNIT – III: Biochemistry of Diseases (4 Weeks)

A diagnostic approach by blood/ urine analysis. **Blood:** Composition and functions of blood, blood coagulation. Blood collection and preservation of samples. Causes and symptoms of Anemia.
Urine: Collection and preservation of samples. Formation of urine. Composition and estimation of constituents of normal and pathological urine. Regulation, estimation and interpretation of data for blood sugar, urea, creatinine, cholesterol and bilirubin.

Practical component

(Credits: 02; Laboratory Periods: 60; 15 Classes of 4 hours each)

1. Carbohydrate- qualitative and quantitative both.
2. Proteins-qualitative tests
4. Determination of the iodine number of oil.
5. Determination of the saponification value of an oil.
6. Determination of acid value of fats and oils.
7. Determination of cholesterol using Liebermann- Burchard reaction.
8. Estimation of DNA by diphenylamine reaction
9. Isolation and characterization of DNA from Onion/cauliflower.
10. Determination of amount of protein using Lowry's method/ Biuret method.
11. To study the activity of α-amylase.
12. To study the effect of temperature and pH on the activity of α-amylase.

Essential/recommended readings

- Devlin, T. M. (2010), Textbook of Biochemistry with Clinical Correlations, John Wiley & Sons.
- Berg, J.M., Tymoczko, J.L.; Stryer, L. (2010), Loose-leaf Version for Biochemistry, W.H.Freeman.
- Lehninger, A.L., Nelson, D.L.;Cox, M. (2004), Principle of Biochemistry, W.H.Freeman.
- Morrison, R. N.; Boyd, R. N. (2016) Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Finar, I. L. (2015) Organic Chemistry (Volume 1& 2), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Swahney, S.K.; Singh, R. (2001), Introductory Practical Biochemistry, Narosa Publishing House.
- Cooper, T.G. (2011),The Tools of Biochemistry, Wiley India Pvt Ltd.
- Wilson, K.; Walker, J. (2000), Principles and Techniques of Practical Biochemistry, Cambridge University Press.

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DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE-2

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		
Course Title: Green Chemistry **Course Code:** (DSE-2)	**04**	**02**	**00**	**02**	**Physics, Chemistry and Mathematics**	**-**

Learning Objectives

The Learning Objectives of this course are as follows:

- Huge rise in environmental pollution, depleting resources, climate change, ozone depletion, heaps and heaps of landfills piling up has forced the society to become more and more environmentally conscious. Future chemists and innovators are compelled to work towards sustainable practices. Green chemistry has arisen from these concerns. It is not a new branch of chemistry but helps to improve the creative and innovative thinking in undergraduate students. Green chemistry is a way to boost profits, increase productivity and ensure sustainability with absolute zero waste. Innovations and applications of green chemistry in education have helped companies to gain environmental benefits as well as to achieve economic and societal goals also.
- Undergraduate students are the ultimate scientific community of tomorrow. Training them to practice chemistry in the safest way possible is key towards safe working conditions in the laboratories as well as the chemical industry and extends to society in a sustainable future for the planet.

Learning Outcomes:

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

- Understand the twelve principles of green chemistry and also build the basic understanding of toxicity, hazard and risk related to chemical substances.
- Calculate atom economy, E-factor and relate them in all organic synthesis.
- Appreciate the use of catalyst over stoichiometric reagents.

- Learn to use green solvents, renewable feedstock and renewable energy sources for carrying out safer chemistry.
- Appreciate the use of green chemistry in problem solving skills and critical thinking to innovate and find solutions to environmental problems.
- Learn to design safer processes, chemicals and products through understanding of inherently safer design (ISD).
- Appreciate the success stories and real-world cases as motivation for them to practice green chemistry.

SYLLABUS OF DSE-2

Theory Component

Unit-I: Introduction (4 weeks)

Definition of green chemistry and how it is different from conventional chemistry and environmental chemistry.

• Need of green chemistry

• Importance of green chemistry in- daily life, Industries and solving human health problems (four examples each).

• A brief study of Green Chemistry Challenge Awards (Introduction, award categories and study about five last recent awards).

Unit-II: Twelve Principles of Green Chemistry (6 weeks)

The twelve principles of the Green Chemistry with their explanation's. Special emphasis on the following:

• Prevention of waste / byproducts, pollution prevention hierarchy.

• Green metrics to assess greenness of a reaction: environmental impact factor, atom economy and calculation of atom economy.

• Green solvents-supercritical fluids, water as a solvent for organic reactions, ionic liquids, solvent less reactions, solvents obtained from renewable sources.

• Catalysis and green chemistry- comparison of heterogeneous and homogeneous catalysis, biocatalysis, asymmetric catalysis and photocatalysis.

• Green energy and sustainability.

• Real-time analysis for pollution prevention.

• Prevention of chemical accidents, designing greener processes, inherent safer design, principle of ISD "What you don't have cannot harm you", greener alternative to Bhopal Gas Tragedy (safer route to carcarbaryl) and Flixiborough accident (safer route to cyclohexanol) subdivision of ISD, minimization, simplification, substitution, moderation and limitation

Unit-III: Real-World Cases (5 weeks)

The following Real-world Cases in green chemistry should be discussed: Surfactants for carbon dioxide – replacing smog producing and ozone depleting solvents with CO_2 for precision cleaning and dry cleaning of garments. Designing of environmentally safe marine antifoulant. Rightfit pigment: Synthetic azo pigments to replace toxic organic and inorganic pigments. An efficient, green synthesis of a compostable and widely applicable plastic (polylactic acid) made from corn.

Practical Component

(Credits: 02; Laboratory periods: 60; 15 Classes of 4 hours each)

Characterization by melting point, UV-Visible spectroscopy, IR spectroscopy and any other specific method should be done (wherever applicable).

1. Preparation and characterization of nanoparticles of gold using tea leaves/silver nanoparticles using plant extracts.
2. Preparation of biodiesel from waste cooking oil and characterization (TLC, pH, solubility, combustion test, density, viscosity, gel formation at low temperature and IR can be provided).
3. Benzoin condensation using thiamine hydrochloride as a catalyst instead of cyanide.
4. Extraction of D-limonene from orange peel using liquid CO_2 prepared from dry ice.
5. Mechanochemical solvent free, solid-solid synthesis of azomethine using *p*-toluidine and *o*-vanillin/*p*-vanillin.
6 Microwave-assisted Knoevenagel reaction using anisaldehyde, ethylcyanoacetate and ammonium formate.
7. Photoreduction of benzophenone to benzopinacol in the presence of sunlight.
8. Photochemical conversion of dimethyl maleate to dimethyl fumarate (*cis-trans* isomerisation)
9. Benzil- Benzilic acid rearrangement: Preparation of benzilic acid in solid state under solvent-free condition.

Essential/recommended readings

1. Anastas, P.T., Warner, J.C. (2014), Green Chemistry, Theory and Practice, Oxford University Press.
2. Lancaster, M. (2016), Green Chemistry: An Introductory Text, 3rd Edition, RSC Publishing.
3. Cann, M. C., Connely, M.E. (2000), Real-World cases in Green Chemistry, American Chemical Society, Washington.
4. Matlack, A.S. (2010), Introduction to Green Chemistry, 2nd Edition, Boca Raton: CRC Press/Taylor & Francis Group publisher.
5. Alhuwalia, V.K., Kidwai, M.R. (2005), New Trends in Green chemistry, Anamalaya Publishers.
6. Sidhwani, I.T, Sharma, R.K. (2020), An Introductory Text on Green Chemistry, Wiley India Pvt Ltd.
7. Kirchoff, M.; Ryan, M.A. (2002), Greener approaches to undergraduate chemistry experiment, American Chemical Society, Washington DC.
8. Sharma, R.K.; Sidhwani, I.T.; Chaudhari, M.K. (2013), Green Chemistry Experiments: A monograph, I.K. International Publishing House Pvt Ltd. New Delhi.

9. Pavia, D.L.; Lamponam, G.H.; Kriz, G.S.W. B. (2012), Introduction to organic Laboratory Technique- A Microscale approach, 4th Edition, Brooks-Cole Laboratory Series for Organic chemistry.
10. Sidhwani I.T. (2015), Wealth from Waste: A green method to produce biodiesel from waste cooking oil and generation of useful products from waste further generated. DU Journal of Undergraduate Research and Innovation, 1(1),131-151. ISSN: 2395-2334.
11. Sidhwani, I.T; Sharma, R.K. (2020), An Introductory Text on Green Chemistry, Wiley India Pvt Ltd.
12. Monograph on Green Chemistry Laboratory Experiments, Green Chemistry Task Force Committee, Department of Science and Technology, Government of India.

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