

COMMON POOL OF GENERIC ELECTIVES (GE) COURSES
OFFERED BY DEPARTMENT OF CHEMISTRY FOR ODD SEMESTER

GE 1: Chemistry: Atomic Structure and Chemical Bonding

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 |
|---|----------|-----------------------------------|----------|---------------------|----------------------|-------------------------------------|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Atomic Structure and Chemical Bonding (GE-1) | 4 | 2 | | 2 | | Basic knowledge of Chemistry |

Learning Objectives

The Learning Objectives of this course are as follows:

- To discuss the structure of atom as a necessary pre-requisite in understanding the nature of chemical bonding in compounds.
- To provide basic knowledge about ionic and covalent bonding.

Learning Outcomes

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

- Solve the conceptual questions using the knowledge gained by studying the quantum mechanical model of the atom, quantum numbers, electronic configuration, radial and angular distribution curves, and shapes of s, p, and d orbitals
- Understand the concept of lattice energy and solvation energy.
- Draw the plausible structures and geometries of molecules using radius ratio rules, VSEPR theory and MO diagrams (homo- & hetero-nuclear diatomic molecules).

SYLLABUS OF GE 1

Theory:

Unit – 1: Atomic Structure

(14 Hours)

Review of: Bohr's theory and its limitations, Heisenberg uncertainty principle, Dual behaviour of matter and radiation, De-Broglie's relation, Hydrogen atom spectra, need of a new approach to atomic structure. Time independent Schrodinger equation and meaning of various terms in it. Significance of ψ and ψ^2 , Schrödinger equation for hydrogen atom, radial

and angular parts of the hydrogen 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, radial distribution functions and the concept of the most probable distance with special reference to 1s and 2s atomic orbitals. Significance of quantum numbers, orbital angular momentum and quantum numbers m_l and m_s . Shapes of s, p and d atomic orbitals, nodal planes, discovery of spin, spin quantum number (s) and magnetic spin quantum number (m_s). Rules for filling electrons in various orbitals, electronic configurations of the atoms, stability of half-filled and completely filled orbitals, concept of exchange energy, relative energies of atomic orbitals, anomalous electronic configurations.

Unit – 2: Chemical Bonding and Molecular Structure

(16 Hours)

Ionic Bonding: 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, statement of Born-Landé equation for calculation of lattice energy (no derivation), Born Haber cycle and its applications, covalent character in ionic compounds, polarizing power and polarizability, Fajan's rules. Ionic character in covalent compounds, bond moment, dipole moment and percentage ionic character. **Covalent bonding:** VB Approach: Shapes of some inorganic molecules and ions on the basis of VSEPR (H_2O , NH_3 , PCl_5 , SF_6 , ClF_3 , SF_4) and hybridization with suitable examples of linear, trigonal planar, square planar, tetrahedral, trigonal bipyramidal and octahedral arrangements. Concept of resonance and resonating structures in various inorganic and organic compounds. **MO Approach:** Rules for the LCAO method, bonding and antibonding MOs and their characteristics for ss, s-p and p-p combinations of atomic orbitals, nonbonding combination of orbitals, MO treatment of homonuclear diatomic molecules of 1st and 2nd periods (including idea of s-p mixing) and heteronuclear diatomic molecules such as CO, NO and NO^+ .

Practicals:

(60 Hours)

(Laboratory Periods: 60)

1. Acid-Base Titrations: Principles of acid-base titrations to be discussed.

- (i) Estimation of sodium carbonate using standardized HCl.
- (ii) Estimation of carbonate and hydroxide present together in a mixture.
- (iii) Estimation of carbonate and bicarbonate present together in a mixture.
- (iv) Estimation of free alkali present in different soaps/detergents

2. Redox Titrations: Principles of oxidation-reduction titrations (electrode potentials) to be discussed.

- (i) Estimation of oxalic acid by titrating it with $KMnO_4$.
- (ii) Estimation of Mohr's salt by titrating it with $KMnO_4$.
- (iii) Estimation of oxalic acid and sodium oxalate in a given mixture.
- (iv) Estimation of Fe (II) ions by titrating it with $K_2Cr_2O_7$ using internal indicator (diphenylamine/ N-phenylanthranilic acid).

References:

Theory:

1. Lee, J.D.; (2010), **Concise Inorganic Chemistry**, Wiley India.
2. Huheey, J.E.; Keiter, E.A.; Keiter; R. L.; Medhi, O.K. (2009), **Inorganic Chemistry-Principles of Structure and Reactivity**, Pearson Education.
3. Douglas, B.E.; McDaniel, D.H.; Alexander, J.J. (1994), **Concepts and Models of Inorganic Chemistry**, John Wiley & Sons.
4. Atkins, P.W.; Overton, T.L.; Rourke, J.P.; Weller, M.T.; Armstrong, F.A. (2010), **Shriver and Atkins Inorganic Chemistry**, 5th Edition, Oxford University Press.

Practicals:

- Jeffery, G.H.; Bassett, J.; Mendham, J.; Denney, R.C. (1989), **Vogel's Textbook of Quantitative Chemical Analysis**, John Wiley and Sons.

Additional Resources:

1. Wulfsberg, G (2002), **Inorganic Chemistry**, Viva Books Private Limited.
2. Miessler, G.L.; Fischer P.J.; Tarr, D. A. (2014), **Inorganic Chemistry**, 5th Edition, Pearson.

GE 3: Chemistry: Bioinorganic Chemistry

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 |
|-------------------------------|---------|-----------------------------------|----------|---------------------|----------------------|------------------------------|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Bioinorganic Chemistry (GE-3) | 4 | 2 | | 2 | | Basic knowledge of Chemistry |

Learning Objectives

The Learning Objectives of this course are as follows:

- To introduce students to bioinorganic chemistry, currently a frontier area of chemistry providing an interface between organic chemistry, inorganic chemistry and biology.
- To make students learn about the importance of inorganic chemical species, especially metals, in biological systems, through discussions on topics such as the sodium-potassium pump, the applications of iron in physiology, including iron transport and storage system, role of magnesium in energy production and chlorophyll, toxicity of heavy metal ions and their antidotes.

Learning Outcomes

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

- Classify metal ions in biological systems as essential, non-essential, trace & toxic.
- Diagrammatically explain the working of the sodium-potassium pump in organisms and the factors affecting it
- Understand the role of metal ions such as Mg, Ca and Fe in biological systems.
- Understand the toxicity of heavy metal ions (Hg, Pb, Cd and As) in the physiological system
- Explain the use of chelating agents in medicine

SYLLABUS OF GE-3

Theory:

Unit 1: Introduction (6 Hours)

A brief introduction to bio-inorganic chemistry. Metal ions present in biological systems and their classification on the basis of action (essential, non-essential, trace & toxic). Classification of metallobiomolecules (enzymes, transport and storage proteins and non-proteins). Brief idea about membrane transport, channels, pumps.

Unit 2: Role of s-block Elements in Biological System (8 Hours)

Role of metal ions present in biological systems with special reference to Na^+ , K^+ and Mg^{2+} and Ca^{2+} ions: Na/K pump; Ca pump, role of Mg^{2+} ions in energy production and chlorophyll. Role of calcium in bone formation.

Unit 3: Role of iron in Biological System (8 Hours)

Role of iron in oxygen transport and storage (haemoglobin and myoglobin), Perutz mechanism, Cooperative effect, Bohr effect, comparison of oxygen saturation curves of haemoglobin and myoglobin, carbon monoxide. Storage and transport of iron in humans (ferritin and transferrin).

Unit 4: Toxicity of Heavy Metal Ions (8 Hours)

Toxicity of heavy metal ions (Hg, Pb, Cd and As), reasons for toxicity and their antidotes

Practicals: (60 Hours)

WEEKS)

(Laboratory Periods: 60)

1. Spectrophotometric estimation:

- Verify Lambert-Beer's law and determine the concentration of $\text{CuSO}_4/\text{KMnO}_4/\text{K}_2\text{Cr}_2\text{O}_7/\text{CoSO}_4$ in a solution of unknown concentration
- Spectrophotometric estimation of Fe^{2+} ions by using 1, 10-phenanthroline

(iii) Determination of the composition of the Fe^{3+} - salicylic acid complex in solution by Job's method.

2. Complexometric titrations using disodium salt of EDTA:

- Estimation of Zn^{2+} using EBT / Xylenol orange as indicator
- Estimation of Mg^{2+}
- Estimation of Ca^{2+} by substitution method
- To estimate the concentration of Ca in commercially available medicines.
- To estimate the Mg present in multivitamins.

References:

Theory:

- Huheey, J.E.; Keiter, E.A., Keiter; R. L.; Medhi, O.K. (2009), **Inorganic Chemistry- Principles of Structure and Reactivity**, Pearson Education.
- Shriver, D.D.; Atkins, P.; Langford, C.H. (1994), **Inorganic Chemistry** 2nd Ed., Oxford University Press.
- Cotton, F.A.; Wilkinson, G.; Gaus, P.L. **Basic Inorganic Chemistry**, 3rd Edition, Wiley India.
- Crichton, R.R. (2008), **Biological Inorganic Chemistry: An Introduction**. Amsterdam, Elsevier.
- Kaim, W., B. Schwederski and A. Klein. (2014), **Bioinorganic Chemistry: Inorganic Elements in the Chemistry of Life: An Introduction and Guide**. 2nd Edition, Wiley.

Practical:

- Jeffery, G.H.; Bassett, J.; Mendham, J.; Denney, R.C. (1989), **Vogel's Textbook of Quantitative Chemical Analysis**, John Wiley and Sons.

Additional Resources:

- Lippard, S.J.; Berg, J.M. (1994), **Principles of Bioinorganic Chemistry**, Panima Publishing Company.
- Greenwood, N.N.; Earnshaw, A. (1997), **Chemistry of the Elements**, 2nd Edition, Elsevier

GE 4: Chemistry: Basic Concepts of Organic Chemistry

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 |
|--|---------|-----------------------------------|----------|---------------------|----------------------|-----------------------------|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Basic Concepts of Organic Chemistry (GE-4) | 4 | 2 | | 2 | | |

Learning Objectives

The Learning Objectives of this course are as follows:

- To teach the fundamentals of organic chemistry and the introduction of a new concept of visualizing the organic molecules in a three-dimensional space.
- To establish the applications of these concepts, different types of organic reactions are introduced.

Learning Outcomes

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

- Understand and explain the differential behavior of organic compounds based on fundamental concepts learnt.
- Formulate the mechanism of organic reactions by recalling and correlating the fundamental properties of the reactants involved.
- Learn and identify many organic reaction mechanisms including free radical substitution, electrophilic addition and electrophilic aromatic substitution.
- Differentiate between various types of organic reactions possible on the basis of reaction conditions

SYLLABUS OF GE-4

Theory:

Unit 1: Basic Concepts

(6 Hours)

Electronic displacements and their applications: Inductive, electromeric, resonance and mesomeric effects and hyperconjugation. Dipole moment, acidity and basicity.

Homolytic and heterolytic fissions with suitable examples. Types, shape and relative stability of carbocations, carbanions and free radicals. Electrophiles and nucleophiles

Concept of Aromaticity: Huckel's rule

Unit 2: Stereochemistry

(10 Hours)

Stereoisomerism: Optical activity and optical isomerism, asymmetry, chirality, enantiomers, diastereomers. specific rotation; Configuration and projection formulae: Newmann, Sawhorse, Fischer and their interconversion. Chirality in molecules with one and two stereocentres; meso configuration.

CIP rules: Erythro/Threo, D/L and R/S designations.

Geometrical isomerism: *cis-trans*, *syn-anti* and *E/Z* notations.

Unit 3: Types of Organic Reactions

(14 Hours)

Introduction to substitution, addition, elimination, isomerization, rearrangement, oxidation and reduction reactions.

Free radical substitutions (Halogenation), concept of relative reactivity v/s selectivity. Free radical reactions in the biological reactions

Mechanisms of E1, E2, Saytzeff, Hoffmann eliminations and Cope elimination. Biological dehydration reactions

Electrophilic Additions reactions of alkenes and alkynes: mechanism with suitable examples, (Markownikoff/Antimarkownikoff addition), syn and anti-addition; addition of H₂, X₂, hydroboration-oxidation, ozonolysis, hydroxylation.

Nucleophilic substitution reactions – S_N1 and S_N2 mechanisms with stereochemical aspects and effect of solvent; nucleophilic substitution vs. elimination. Biological methylating agents
Electrophilic aromatic substitution: halogenation, nitration, sulphonation, Friedel Crafts alkylation/ acylation with their mechanism. Directing effects of groups in electrophilic substitution.

Practicals:

(60 Hours)

(Laboratory Periods: 60)

1. Calibration of a thermometer and determination of the melting points of the organic compounds (Kjeldahl method, electrically heated melting point apparatus and BODMEL)
2. Purification of the organic compounds by crystallization using the following solvents:
3. a. Water b. Alcohol c. Alcohol-Water
4. Determination of boiling point of liquid compounds. (Boiling point lower than and more than 100 °C by distillation, capillary method and BODMEL)
5. Acetylation of one of the following compounds: amines (aniline, *o*-, *m*-, *p*- toluidines and *o*-, *m*-, *p*-anisidine) and phenols (β -naphthol, salicylic acid) either by conventional or green method.
6. Bromination of acetanilide/aniline/phenol either by conventional or green method.
7. Nitration of chlorobenzene/nitrobenzene.

References:

Theory:

1. Sykes, P. (2005), **A Guide Book to Mechanism in Organic Chemistry**, Orient Longman.
2. Eliel, E. L. (2000), **Stereochemistry of Carbon Compounds**, Tata McGraw Hill.
3. Morrison, R. N.; Boyd, R. N., Bhattacharjee, S.K. (2010), **Organic Chemistry**, 7th Edition, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
4. **Mehta B.; Mehta M. (2015)**, Organic Chemistry, **PHI Learning Private Limited**
5. **Bahl, A; Bahl, B. S. (2012)**, Advanced Organic Chemistry, **S. Chand.**

Practicals:

1. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. (2012), **Vogel's Textbook of Practical Organic Chemistry**, Pearson.
2. Mann, F.G.; Saunders, B.C. (2009), **Practical Organic Chemistry**, Pearson Education.

GE 7: Chemistry: States of Matter

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 |
|-------------------------|---------|-----------------------------------|----------|---------------------|----------------------|-----------------------------|
| | | Lecture | Tutorial | Practical/ Practice | | |
| States of Matter (GE-7) | 4 | 2 | | 2 | | |

Learning Objectives

The Learning Objectives of this course are as follows:

- To make students learn about the properties of ideal and real gases deviation from ideal behaviour, properties of liquid, types of solids with details about crystal structure.
- To make student learn about the reaction rate, order, activation energy and theories of reaction rates.

Learning Outcomes

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

- Derive ideal gas law from kinetic theory of gases and explain why the real gases deviate from ideal behaviour.
- Explain Maxwell-Boltzmann distribution, critical constants and viscosity of gases.
- Explain the properties of liquids especially surface tension and viscosity.
- Explain symmetry elements, crystal structure specially NaCl, KCl and CsCl
- Define rate of reactions and the factors that affect the rates of reaction.
- Understand the concept of rate laws e.g., order, molecularity, half-life and their determination
- Learn about various theories of reaction rates and how these account for experimental observations.

SYLLABUS OF GE-7

Theory:

Unit 1: Kinetic Theory of Gases

(12 Hours)

Postulates of kinetic theory of gases and derivation of the kinetic gas equation, deviation of real gases from ideal behaviour, compressibility factor, causes of deviation, van der Waals

equation of state for real gases. Boyle temperature (derivation not required), critical phenomena, critical constants and their calculation from van der Waals equation, Andrews isotherms of CO₂, Maxwell Boltzmann distribution laws of molecular velocities and molecular energies (graphic representation – derivation not required) and their importance. Temperature dependence of these distributions, most probable, average and root mean square velocities (no derivation), collision cross section, collision number, collision frequency, collision diameter and mean free path of molecules, viscosity of gases and effect of temperature and pressure on coefficient of viscosity (qualitative treatment only).

Unit 2: Liquids State

(6 Hours)

Surface tension and its determination using stalagmometer, Viscosity of a liquid and determination of coefficient of viscosity using Ostwald viscometer, effect of temperature on surface tension and coefficient of viscosity of a liquid (qualitative treatment only). Effect of addition of various solutes on surface tension and viscosity. Explanation of cleansing action of detergents.

Unit 3: Solid State

(12 Hours)

Forms of solids, symmetry elements, unit cells, crystal systems, Bravais lattice types and identification of lattice planes. Laws of crystallography - law of constancy of interfacial angles. Law of rational indices, Miller indices. X-ray diffraction by crystals, Bragg's law and powder XRD. Powder diffraction patterns of NaCl, CsCl and KCl (qualitative treatment only), defects in crystals. Glasses and liquid crystals.

Practicals:

(60 Hours)

(Laboratory periods: 60)

1. Surface tension measurement (use of organic solvents excluded): Determination of the surface tension of a liquid or a dilute solution using a stalagmometer.
2. Viscosity measurement (use of organic solvents excluded):
 - a) Determination of the relative and absolute viscosity of a liquid or dilute solution using an Ostwald viscometer.
 - b) Study of the variation of viscosity of an aqueous solution with concentration of solute.
3. Solid State: Powder XRD
 - c) Differentiate and classify the given set of the diffraction pattern as crystalline materials or amorphous (Glass) substance.
 - d) Carry out analysis of a given set of powder XRD and determine the type of the cubic crystal structure
 - e) Determination of approximate crystal size from a given set of powder XRD

References:

Theory:

1. Atkins, P.W.; Overton, T.L.; Rourke, J.P.; Weller, M.T.; Armstrong, F.A. (2010), **Shriver and Atkin's Inorganic Chemistry**, Oxford.
2. Miessler, G. L.; Tarr, D.A. (2014), **Inorganic Chemistry**, Pearson.
3. Castellan, G. W. (2004), **Physical Chemistry**, Narosa.

4. Kapoor, K.L. (2015), **A Textbook of Physical Chemistry**, Vol.1, 6th Edition, McGraw Hill Education.
5. Kapoor, K.L. (2015), **A Textbook of Physical Chemistry**, Vol.5, 3rd Edition, McGraw Hill Education.

Practicals:

1. Khosla, B.D.; Garg, V.C.; Gulati, A. (2015), **Senior Practical Physical Chemistry**, R. Chand & Co.

GE 9: Chemistry: Conductance and Electrochemistry

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 |
|--|----------|-----------------------------------|----------|---------------------|----------------------|-------------------------------------|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Conductance and Electrochemistry (GE-9) | 4 | 2 | | 2 | | Basic knowledge of Chemistry |

Learning Objectives

The Learning Objectives of this course are as follows:

- To make students learn about conductance, its measurement and applications.
- To make students learn the principles of electrochemical cells: Electrolytic and Galvanic cell, measurement of, measurement of emf and its applications.

Learning outcomes

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

- Explain the factors that affect conductance, migration of ions and application of conductance measurement.
- Understand different types of galvanic cells, their Nernst equations, measurement of emf, calculations of thermodynamic properties and other parameters from the emf measurements.
- Understand applications of Emf measurements in relation to determination of activity coefficients, pH of a solution and Potentiometric titrations.

SYLLABUS OF GE-9

Theory:

Unit 1: Conductance

(10 Hours)

Quantitative aspects of Faraday's laws of electrolysis. Arrhenius theory of electrolytic dissociation. Conductivity: equivalent and molar conductivity and their variation with dilution for weak and strong electrolytes, Kohlrausch Law of independent migration of ions. Wien Effect and Debye–Falkenhagen Effect.

Transference number and its experimental determination using Hittorf and moving boundary methods, Ionic mobility, applications of conductance measurements: determination of degree of ionization of weak electrolytes, solubility and solubility products of sparingly soluble salts, ionic product of water, hydrolysis constant of a salt. Conductometric titrations (only acid-base).

Unit 2: Electrochemistry

(20 Hours)

Reversible and irreversible cells with Examples, concept of EMF of a cell, measurement of EMF of a cell, Nernst equation and its importance, types of electrodes, standard electrode potential (reduction Potential) and its application to Gas-ion half-cell. Electrochemical series. Thermodynamics of a reversible cell, calculation of thermodynamic properties: G, H and S from EMF data. Calculation of equilibrium constant from EMF data. Concentration cells with transference and without transference, liquid junction potential; determination of activity coefficients and salt bridge, pH determination using hydrogen electrode. Potentiometric titrations-qualitative treatment (acid-base and oxidation-reduction only).

Practicals:

(60 Hours)

(Laboratory periods: 60)

1. Conductance

- (i) Determination of cell constant.
- (ii) Determination of equivalent conductance, degree of dissociation and dissociation constant of a weak acid.
- (iii) Perform the following conductometric titrations:
 - a) Strong acid vs strong base
 - b) Weak acid vs strong base.

2. Potentiometry

Perform the potentiometric titrations of (i) Strong acid vs strong base, (ii) Weak acid vs strong base and (iii) Mohr's salt vs KMnO_4 .

References:

Theory:

1. Castellan, G.W. (2004), **Physical Chemistry**, Narosa.
2. Kapoor, K.L. (2015), **A Textbook of Physical Chemistry**, Vol 1, 6th Edition, McGraw Hill Education.
3. Kapoor, K.L. (2013), **A Textbook of Physical Chemistry**, Vol 3, 3rd Edition, McGraw Hill Education.

Practicals:

1. Khosla, B.D.; Garg, V.C.; Gulati, A. (2015), **Senior Practical Physical Chemistry**, R. Chand & Co.

GE 11: Chemistry: Chemistry of Food Nutrients

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 |
|--|----------|-----------------------------------|----------|---------------------|----------------------|-----------------------------|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Chemistry of Food Nutrients (GE-11) | 4 | 2 | | 2 | | |

Learning Objectives

The Learning Objective of this course is as follows:

- To help the students develop a basic understanding of the components of food, their source, properties and interactions as well as changes that occur during processing, storage, and utilization.

Learning Outcomes

On completion of the course, the student will be able to:

- Build a strong understanding of chemistry of food: composition of food, role of each component.
- Understand some of the reactions and changes in individual food components which occur during processing, handling and storage

SYLLABUS OF GE-11

Theory:

Unit 1: Carbohydrates

(6 Hours)

Introduction, sources, functions, classification: monosaccharide, oligosaccharide and polysaccharide, structure and importance of polysaccharides in food chemistry (pectin, cellulose, starch, gums), chemical reactions of sugar: mutarotation, caramelisation; non enzymic browning and its prevention, role of carbohydrates as sweeteners in food.

Unit 2: Lipids

(8 Hours)

Introduction, sources, classification (fatty acids, phospholipids, fats & oils, waxes), common fatty acids present in oils and fats, Omega- 3&6 fatty acids, trans fats, chemical properties- Reichert Meissel value, Polenski value, iodine value, peroxide value, saponification value,

effect of frying on fats, changes in fats and oils- rancidity, lipolysis, flavor reversion, auto-oxidation and its prevention.

Unit 3: Proteins

(8 Hours)

Introduction, sources, classification (simple, conjugated, derived), structure of protein (primary, secondary and tertiary), physico-chemical & functional properties of proteins, protein denaturation.

Unit 4: Vitamins & Minerals

(8 Hours)

Vitamins: Introduction, classification: fat-soluble vitamins & water-soluble vitamins.

Minerals: Introduction, classification: macrominerals (Ca, P, Mg) & microminerals (Se, Fe, I, Co, Zn, Cu, Se, Cr).

Physiological importance of vitamins and minerals, effect of food processing on vitamins and minerals.

Practicals:

(60 Hours)

(Laboratory periods: 60)

1. Determination of moisture in food products by hot air oven-drying method.
2. Colorimetric determination of Iron in vitamin / dietary tablets.
4. 2, 6-Dichlorophenol indophenol method for estimation of vitamin C in a given solution/ lemon Juice/chillies.
5. Estimation of total soluble sugar content by ferricyanide method (volumetric analysis).
6. Determination of saponification value of the given fat/oil.
7. Determination of iodine value of the given fat/oil.
8. Qualitative tests for proteins and carbohydrates.
9. Qualitative estimation of cholesterol by Liebermann Burchard method.

References:

Theory:

1. deMan, J.M., Finley, J.W., Hurst, W.J., Lee, C.Y. (2018), **Principles of Food Chemistry**, 4th Edition, Springer.
2. Msagati, T.A.M. (2013), **Chemistry of Food Additives and Preservatives**, Wiley-Blackwell.
3. Fennema, O.R. (2017), **Food Chemistry**, 5th Edition, CRC Press.
4. Attokaran, M. (2017), **Natural Food Flavors and Colorants**, 2nd Ed., Wiley-Blackwell.
5. Potter, N.N., Hotchkiss, J.H, (1995) **Food Science**, 5th Ed., Chapman & Hall.

6. Brannen, D., Davidsin, P.M., Salminen, T. Thorngate III, J.H. (2002), **Food Additives**, 2nd Edition, CRC Press.
7. Coultate, T. (2016), **Food: The Chemistry of its Components**, 6th Edn., Royal Society of Chemistry.
8. Belitz, H. D.; Grosch, W. (2009), **Food Chemistry**, Springer.
10. Course: FOOD CHEMISTRY (iasri.res.in)

Practical:

1. Ranganna, S. (2017). **Handbook of analysis and quality control for fruits and vegetable products**, 2nd Edn., McGraw Hill Education
2. Sawhney, S.K., Singh, R. (2001), **Introductory Practical Biochemistry**, Narosa Publishing House

GE 12: Chemistry: Statistical Methods and Data Analysis

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 |
|---|----------|-----------------------------------|----------|---------------------|----------------------|-----------------------------|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Chemistry: Statistical Methods and Data Analysis (GE-12) | 4 | 2 | | 2 | | |

Learning Objectives

The Learning Objectives of this course are as follows:

- To give the students insight about the statistical treatment on the chemical analysis data along with illustration about the analysis of collected analytical data that will help them to take up a job of technician, scientist and laboratory manager.
- To explain the presentation of data in different form such as “Table, Graph, Bar Diagram, Pie Chart, Venn diagram” along with their reliability and validity.

Learning Outcomes

At the end of this course student will be:

- Familiar with interpretation and use of analytical data collected by different techniques, significance of different analytical techniques and their applications, reliability and presentation of data for reporting to different forum.

SYLLABUS OF GE-12

Theory:

Unit 1: Basics of Chemical Analysis (4 Hours)

Analytical Chemistry, Qualitative and quantitative analysis, Analytical methodology. Calibration of glass wares, recording laboratory data.

Unit 2: Different Methods of Chemical Analysis (8 Hours)

Titrimetric method: volumetric titrimetry, standard solution, titrimetric curve, calculation; Gravimetric method: precipitation gravimetry, calculation and applications of gravimetry; and Spectrometric methods: introduction, principle and instrument, working quantitative aspects absorbance, applications in chemical analysis

Unit 3: Statistical Method of Chemical Analysis (8 Hours)

Accuracy and Precision, Comparison of precision, Errors, Distribution of random errors, propagation of errors, measurement of errors, significant figure, inter laboratory error, methods of least square analysis of variance, Q test, Z test, T test, statistical treatment of finite sample, recommendations for treating outliers. Minimising errors in analytical procedure.

Unit 4: Data Analysis and Validation (4 Hours)

Confidence interval, Testing of hypothesis, plotting of data, least square method, Figures of merit: sensitivity, detection limit, linear dynamic range, control test, upper control limit and lower control limit, Validation, reporting analytical results and significant figures

Unit 5: Sampling, Standardisation, Labelling and Calibration (6 Hours)

Analytical samples, sample size, constituent sample, real samples, sample, sample handling, preparing laboratory samples, automated sample handling, lab on chip and General laboratory principles, recording laboratory data, standards, comparison of standards, internal standard, external standards calibration, least square method, and multivariant calibration.

Practicals: (60 Hours)

(Laboratory periods: 60)

1. Calibrate the volume of laboratory glass wares i.e. volumetric flask, beaker, burette and calibration constant.
2. Demonstrate the good laboratory practices like effect of dilution, temperature, taking observation, personal and apparatus safety.
3. Determine the quantitative presence of heavy metals like copper, chromium and iron in natural and laboratory samples using volumetric and gravimetric titration.
4. Determine the presence of magnesium ion in heavy water by EDTA method and prepare calibration curve.
5. Evaluate the absolute and method errors in a set of data collected during determination of nitrogen in an organic compound.
6. Calculate the standard deviation and predict precision of analytical results.

- Determine the concentration of pollutant in natural sample after using external standards methods.
- Compare the inter laboratory error of a spectroscopic results.
- Evaluate the limit of detection for colorimetric analysis of dyes and coloured metals in wastes water samples.
- Demonstrate the control of interference by masking by complexation.
- Report the ten analytic results in significant numbers along with standard deviation.
- Determine the confidence limit and interval for a laboratory instrument like breath alcohol analyser
- Demonstrate the internal standard method for calibration of metal estimation.
- Estimate the comparative effectiveness of different types of graphs like line, pi chart and bar graph.
- Demonstrate the working of lab on chip like glucose sensor.

References:

- Dey, R. A. and Underwood, A. L., **Quantitative Analysis**, 6th Edition, Pearson.
- Skoog, D. A., West, D. M., Holler, F. J., Crouch, S. R., **Fundamental an alytical chemistry**, Thomson Asia Ltd.
- Encyclopaedia of analytical chemistry: Applications, Theory, and Instrumentation, R A Meyor (Eds) Wiley and Sons (2000).

GE 13: Chemistry: Medicines in Daily Life

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 |
|---------------------------------|---------|-----------------------------------|----------|------------------------|----------------------|-----------------------------|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Medicines in Daily Life (GE-13) | 4 | 2 | | 2 | | |

Learning Objectives

The Learning Objectives of this course are as follows:

- To make students study the basic details about various medicines of general uses, which are crucial for the various diseases.
- To make students learn about the active pharmaceutical ingredient in some medicines, their synthesis; therapeutic effect and side effects on human physiology.

- To make students aware about the positive and negative effects of medicines those are essential for a healthy day-to-day life.

Learning Outcomes

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

- Understand the role of different medicines on human physiology.
- Gain the knowledge of active pharmaceutical ingredient and their roles in different disease.
- Learn the proper use of different medicines and their effect and side effects.
- Learn the techniques of administering blood group, pulse rate, blood pressure and may other general diagnostic applications.

SYLLABUS OF GE-13

Theory:

Unit 1: General Introduction

(8 Hours)

Introduction-Health, disease, drugs, chemotherapy, approaches in drug designing, classification of drugs and their origin.

Unit 2: Different class of medicines

(22 Hours)

Structure of active ingredients, uses, dosage, side effects and their natural remedies:

Analgesics and antipyretics- Aspirin, paracetamol, ibuprofen, morphine, codeine

Antibiotics- Amoxicillin, norfloxacin, ciprofloxacin

Antihistamines or antiallergics- Cetirizine and Levocetirizine (role of stereoisomers)

Antiparasitic- Albendazole

Antidiabetics- Insulin, Glipizide and metformin

Antihypertensive – Amlodipine and its natural remedies- Rauwolfia.

Diuretic- Lasix

Antidepressant-Zoloft and its natural treatment

Antifungal – fluconazole, Itraconazole

Antacids- Ideal properties of antacids, combinations of antacids, Sodium 40 Bicarbonate, rantidine, milk of magnesia, aluminium hydroxide gel

Anticoagulants/antiplatelet drugs- Warfarin, heparin and Ecosprin

Anaesthetics- Atracurium, Desflurane

Poison and Antidote: Sodium thiosulphate, Activated charcoal, Sodium nitrite

Astringents: Zinc Sulphate, Potash Alum

Supplements- zinc and calcium, vitamins

Synthesis of small molecule drugs like aspirin and paracetamol

Practicals:

(60 Hours)

(Laboratory periods: 60)

1. Determination of heart rate and pulse rate, blood pressure and discussion on medicines affecting them.
2. Identification test- Magnesium hydroxide, Sodium bicarbonate, Calcium gluconate.

- Preparation of inorganic pharmaceuticals- Boric acid Potash alum
- Determination of sugar content in the given solution.
- Estimation of zinc and calcium in a given solution.
- Qualitative analysis of carbohydrates (Glucose, Fructose, Lactose, Maltose, Sucrose).
- Qualitative tests for Proteins
- Qualitative analysis of vitamin C.
- Isolation of paracetamol (API) from a commercial tablet
- Isolation of aspirin (API) from tablet and recording of melting point (synthesis needs discussion)

References:

Theory:

- Patrick, G. L. (2001) **Introduction to Medicinal Chemistry**, Oxford University Press.
- Lemke, T. L. & William, D. A. (2002), **Foye's Principles of Medicinal Chemistry**, 5th Ed., USA,
- Singh H.; Kapoor V.K. (1996), **Medicinal and Pharmaceutical Chemistry**, Vallabh Prakashan.
- Chatwal, G.R. (2010), **Pharmaceutical chemistry**, inorganic (vol. 1), Himalayan publishing house
- <https://go.drugbank.com/>

Practicals:

- Jeffery, G.H., Bassett, J., Mendham, J., Denney, R.C. (1989), **Vogel's Textbook of Quantitative Chemical Analysis**, John Wiley and Sons.
- Ahluwalia, V.K., Dhingra, S. (2004), **Comprehensive Practical Organic Chemistry: Qualitative Analysis**, University Press.
- Munwar, S., Ammaji, S.(2019), **Comprehensive Practical Manual of Pharmaceutical Chemistry**, Educreation Publishing.
- Mondal, P., Mondal, S.(2019), **Handbook of Practical Pharmaceutical Organic, Inorganic and Medicinal chemistry**, Educreation Publishing.

GE 15: Chemistry and Society

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 |
|-------------------------------|---------|-----------------------------------|----------|---------------------|----------------------|-----------------------------|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Chemistry and Society (GE-15) | 4 | 2 | | 2 | | |

Learning Objectives

The Learning Objectives of this course are as follows:

- To expand the literacy of chemistry, and increase general awareness, background of chemistry and its importance among the non-chemistry student even arts as well as commerce.
- To make a common student understand the importance and role of chemistry in development of civilization, societal issues related to chemistry and their expected solutions.

Learning Outcomes

At the end of this course the student will be able to:

- Increase the literacy of chemistry even in non-science students
- Understand the basic concept, principle and importance of chemistry
- Realize the importance of chemistry in daily life and future requirement

SYLLABUS OF GE-15

Theory:

Unit 1: Basics of chemistry (4 Hours)

Periodic table, Atom and molecules, chemical bonding, properties and chemical reactions with simple examples and illustration.

Unit 2: Chemistry in Heritage (8 Hours)

Extraction and uses of metals like iron and stone in ancient times, metals in ornaments, medicines, weapons and chemistry for preservatives, basics of preservation and few examples of preservatives.

Unit 3: Chemistry in Life (10 Hours)

Edible and non-edible molecules, biochemistry of foods and medicine with examples: Aspirin, Paracetamol. Ibuprofen and Penicillin, Cephalosporin, Chemistry for industry: Artificial sweeteners, Soaps and detergents and cosmetics, Polymer and Plastics: Uses and environmental issues.

Unit 4: Chemical pollution and Toxicity (2 Hours)

Chemical source of water, air and soil pollution, biomagnification and metal toxicity with example and illustrations. monitoring of air pollution.

Unit 5: Testing of chemicals (2 Hours)

Flame test, solubility test, qualitative and quantitative identification of ions in natural samples like metal copper, iron and chromium ores and adulterant in foods.

Unit 6: Future of chemistry (4 Hours)

Basics of green chemistry, Reuse and recycling of by-products, zero waste chemistry and Alternate fuel and energy providing chemicals: biodiesel, natural gas and hydrogen.

Practicals/Hands-on Training:**(60 Hours)****(Laboratory periods: 60)**

1. Determine the calcium and magnesium contents in water samples using EDTA methods.
2. Determine the organic contents and pH of soil sample.
3. Estimate the food adulterants in edible items
4. Quantify the presence metals by flame test method
5. Demonstrate the conversion of PET into bottle into value added products.
6. Determine the quantitative presence of heavy metals like copper and chromium in natural sample like ore.
7. Demonstrate the exothermic and endothermic reaction in laboratory
8. Preparation aspirin and paracetamol as well as identify.
9. Compare the fuel efficiency of biodiesel and petrol.
10. Preparation of representative compound using microwave
11. Demonstrate the biodegradability of natural and synthetic plastics.
12. Demonstrate the protection of rusting of iron after surface spray coating.
13. Estimate the protein contents in edible samples using chemical methods.
14. Small working project on heritage chemistry like bio compatibility of metals and medicinal importance of metals like iron, gold and silver.

References:

1. Lee, J. D., **Concise Inorganic Chemistry**, Wiley India Pvt. Ltd.
2. Sharma, B. K., **Industrial chemistry**, Goel Publishing House, India
3. Christian, Gary D., Dasgupta, Purnendu K., Schug, Kevin A., **Analytical chemistry**, Wiley
4. V. Subramanian, **A text book of Environmental chemistry**, Wiley

GE 19: Radio-chemistry in Energy, Medicine and Environment**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 |
|--|----------|-----------------------------------|----------|---------------------|----------------------|-----------------------------|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Radio-chemistry in Energy, Medicine and Environment (GE-19) | 4 | 3 | | 1 | | |

Learning Objectives

The Learning Objectives of this course is as follows:

- To give an introduction to nuclear and radiochemical concepts to the students.
- To help students gain fundamental knowledge about the radioisotopes and their real-world applications in medicine, diagnostic techniques, energy, research and environment.

Learning Outcomes

By the end of the course, the students will:

- Learn about radioisotopes, radioactive decay
- Use of radiochemistry in various fields
- Effect of radiations on health
- Learn about nuclear energy and nuclear pollution

SYLLABUS OF GE-19

Theory:

Unit 1: Introduction

(9 Hours)

Atoms, composition of nucleus, mass number, isotopes, nuclear stability, radioactive decay, radioactivity in nature: natural and artificial radioisotopes, elementary particles, radioactive decay (α , β and γ decay), half-life period, types of nuclear reactions: nuclear fission and nuclear fusion.

Unit 2: Nuclear power generation

(6 Hours)

Nuclear Power generation from uranium ore (energy production and nuclear waste), introduction to nuclear reactors for energy and nuclear weapons

Unit 3: Applications of radiochemistry

(15 Hours)

C 14 decay and radioactive dating, irradiation of food, radiotracers for studying chemical reactions (photosynthesis, metabolic studies of drugs, metabolism of organisms, fundamental properties of genetic material), medicinal application of radio chemicals in radiotherapy (use in cancer, hyperthyroidism, blood disorders), radio-pharmaceuticals, diagnostic procedures: CT, PET

Unit 4: Environment radioactivity

(6 Hours)

Natural radioactivity, natural process that release radioactive material in environment, man-made events like Chernobyl disaster, bomb test, use of radiotracers in environmental studies.

Unit 5: Nuclear pollution and safety management

(9 Hours)

Radiation protection standards, basics of radiation hazards, international guidelines on radiation protection, disposal of nuclear waste, nuclear disaster and its managements, Effect of radiation on health: Biological effects of radiation, radiation monitors, dose limits for workers and public,

Practicals:

(30 Hours)

(Laboratory periods: 30)

1. Study the background radiation in different places and identify the probable source. (Data to be provided).
2. Survey the diagnostic procedures involving radio-chemistry in different diagnostic laboratories.
3. Write a report on the radio isotopes used in various diagnostic procedures.
4. Write a report on safety measures taken in diagnostic labs.
5. Write a report on any two nuclear and radiation accidents focusing on their impact on human life, environment and economy.

References:

1. Nuclear and radiochemistry, Konya J., Nagy N. 2nd Edition, Elsevier
2. Radiochemistry and Nuclear Chemistry, 4th Edition, Choppin G., Lilijenzin J-O, Rydberg J., Ekberg C. Elsevier.

GE 21: Chemistry in Indology and Physical & Mental Well Being

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 |
|--|---------|-----------------------------------|----------|---------------------|----------------------|-----------------------------|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Chemistry in Indology and Physical & Mental Well Being (GE-21) | 4 | 3 | | 1 | | |

Learning Objectives

The Learning Objectives of this course is as follows:

- To illuminate the students about the scientific basis and approaches related to the practices that promote physical and mental health/balance, that includes meditation,

sports, Yoga and nutrition. The chemical/biochemical mechanisms that underscore the various states of the mind and body, which drives the general homeostasis or anomalies thereof, shall also be illustrated.

- To make students aware about role of metals in ancient and medieval India
- To make students aware of how Alchemists used metals, chemicals, compounds and ores in medicines
- To make students aware of the different types of instruments used in the ancient and medieval India
- To make students aware of the life and work of ancient and medieval scientists/chemists.

Learning Outcomes:

By the end of the course, the students will:

- Understand about the scientific basis and approaches that promote physical and mental health.
- Know about the chemical/biochemical mechanisms that underline the states of the mind and body
- Understand the role of metals in ancient and medieval India
- Understand how alchemists used metals and chemical compounds in medicines
- Know about the life and contributions of ancient scientists and chemists

SYLLABUS OF GE-21

Theory:

Unit 1: Physical Health Practices

(9 Hours)

Principles of Physical Education, Body composition with respect to health and fitness and different methods of body composition analysis, Calculation of energy expenditure (at rest and during exercise), VO_2 and calculation of VO_2 max, respiratory exchange ratio, blood pressure, Means of fitness development- aerobic and anaerobic exercises, yoga and physical fitness, Exercises and their intensities related to heart rate zone, Different fitness levels for different age groups and gender, Kinesiology, Physiology of Exercise

Unit 2: Mind-body Practices

(6 Hours)

States of mind and types of brain waves, mindfulness meditation in clinical psychology and psychiatry, Desbordes' recent studies on brain activities (Harvard's studies), MRI & functional MRI studies.

Types of meditations- focused attention meditation (FA), open monitoring meditation (OM), transcendental meditation (TM), loving-kindness meditation (LKM), mindfulness meditation (MM) and body-mind meditation (B-M).

Biochemical alterations, such as changes in activity/production of hormones, cytokines, chemokines, interferons, etc., oxygen saturation/desaturation, redox-condition and oxidative balance, progression/regression of certain diseases/health conditions, in response to various states of physical and mental well-being.

Unit 3: Nutrition for Mind/body Homeostasis (6 Hours)

Role of nutrition in physical and mental health. Nutrients: carbohydrates, Protein, Fat, Vitamins, Minerals, Water-their functions, role of hydration (water balance) during exercise, daily caloric requirement and expenditure.

Metabolism: An overview of ATP release in glycolysis, TCA cycle, electron transport chain. basic concept of balanced diet vs. fad diet (Atkins, ketogenic etc.), Concept of BMI (Body mass index) and BMR (Basal metabolic rate), Obesity and its hazard, Dieting versus exercise for weight control.

Unit 4: Concepts of Atoms, Molecules and Laws of Motion (3 Hours)

Concepts of atoms and molecules, properties and categories of atoms and molecules, Laws of motion.

Unit 5: Metallurgy (6 Hours)

Gold, Silver, Copper, Bronze and other alloys; Copper smelting blast furnace and copper extraction; Iron and Steel; Iron smelting blast furnaces from Southern India; Ironworks in Ancient and medieval India; Delhi Iron Pillar; Dhar and Kodachadri Iron pillars; Wootz steel; Zinc and its extraction.

Unit 6: Chemicals (3 Hours)

Drugs, dyes, pigments, glass, cosmetics and perfumes, etc.

Unit 7: Drugs (6 Hours)

Eight categories of Gandhasara; Compounds of mercury (Hg) made and used by the Indian Alchemists for medicinal purposes; Use of chemical, compounds and ores in medicines.

Unit 8: Life and work of Ancient Indian Scientists/Chemists (6 Hours)

(i) Maharshi Kanada (Ancient text and manuscripts), (ii) Nagarjuna (Ras Ratnakar, Kakshaputtantra, Arogya Manjari, Yog Saar, Yoasthak), (iii) Vaagbhatt (Rasratna Samuchchay), (iv) Govindacharya (Rasarnava), (v) Yashodhar (Ras Prakash Sudhakar), (vi) Ramachandra (Rasendra Chintamani), (vii) Somdev (Rasendra Chudamani)

Practicals: (30 Hours)

(Laboratory periods: 30)

1. Extraction of essential oil from rose petal.
2. Extraction of casein from milk.
3. Determination of pulse rate/blood pressure/oxygen saturation before and after exercise.
4. Determination of acid value of given oil sample.
5. Isolation of piperine from black pepper.
6. Determination of Copper in brass turnings.
7. Extraction of Butea monosperma (Palash) dye for its use in coloration of cloth.
8. Determination of mass loss in mild steel in acidic/basic media.

9. Project on (Do any one):

Ayurveda as alternate medicine system,

Homeopathy in India,

Yogic Practices for mental wellness

Ancient Chemists of India

Other titles can also be suggested by the teacher.

10. Visit to

Iron Pillar, the metallurgical marvel and prepare a brief report.

Industries like Dabur India Ltd.

References:

1. Baer cites Kabat-Zinn, J. (1994): **Wherever you go, there you are: Mindfulness meditation in everyday life**. New York: Hyperion, p.4.
2. Buchholz L (October 2015). "**Exploring the Promise of Mindfulness as Medicine**". JAMA. 314 (13): 1327–1329. doi:10.1001/jama.2015.7023. PMID 26441167.
3. Harrington A, Dunne JD (October 2015). "**When mindfulness is therapy: Ethical qualms, historical perspectives**". The American Psychologist. 70 (7): 621–631. doi:10.1037/a0039460. PMID 26436312.
4. Blanck P, Perleth S, Heidenreich T, Kröger P, Ditzen B, Bents H, Mander J (March 2018). "**Effects of mindfulness exercises as stand-alone intervention on symptoms of anxiety and depression: Systematic review and meta-analysis**". Behaviour Research and Therapy. 102: 25–35. doi:10.1007/s12671-014-0379-y. PMID 29291584.
5. Khoury B, Sharma M, Rush SE, Fournier C (June 2015). "**Mindfulness-based stress reduction for healthy individuals: A meta-analysis**". Journal of Psychosomatic Research. 78 (6): 519–528. doi:10.1016/j.jpsychores.2015.03.009. PMID 25818837.
6. Jain FA, Walsh RN, Eisendrath SJ, Christensen S, Rael Cahn B (2015). "**Critical analysis of the efficacy of meditation therapies for acute and subacute phase treatment of depressive disorders: a systematic review**". Psychosomatics. 56 (2): 140–152. doi:10.1016/j.psych.2014.10.007. PMC 4383597. PMID 25591492.
7. Reangsing C, Punsuwun S, Schneider JK (March 2021). "**Effects of mindfulness interventions on depressive symptoms in adolescents: A meta-analysis**". International Journal of Nursing Studies. 115: 103848. doi:10.1016/j.ijnurstu.2020.103848. PMID 33383273. S2CID 229940390.

8. Sharma M, Rush SE (October 2014). "**Mindfulness-based stress reduction as a stress management intervention for healthy individuals: a systematic review**". *Journal of Evidence-Based Complementary & Alternative Medicine*. 19 (4): 271–286. doi:10.1177/2156587214543143. PMID 25053754.
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10. Chiesa A, Serretti A (April 2014). "**Are mindfulness-based interventions effective for substance use disorders? A systematic review of the evidence**". *Substance Use & Misuse*. 49 (5): 492–512. doi:10.3109/10826084.2013.770027. PMID 23461667. S2CID 34990668.
11. Garland EL, Froeliger B, Howard MO (January 2014). "**Mindfulness training targets neurocognitive mechanisms of addiction at the attention-appraisal emotion interface**". *Frontiers in Psychiatry*. 4: 173. doi:10.3389/fpsy.2013.00173. PMC 3887509. PMID 24454293.
12. Sancho M, De Gracia M, Rodríguez RC, Mallorquí-Bagué N, Sánchez-González J, Trujols J, et al. (2018). "**Mindfulness-Based Interventions for the Treatment of Substance and Behavioral Addictions: A Systematic Review**". *Frontiers in Psychiatry*. 9 (95): 95. doi:10.3389/fpsy.2018.00095. PMC 5884944. PMID 29651257.
13. Paulus MP (January 2016). "**Neural Basis of Mindfulness Interventions that Moderate the Impact of Stress on the Brain**". *Neuropsychopharmacology*. 41 (1): 373. doi:10.1038/npp.2015.239. PMC 4677133. PMID 26657952.
14. Dunning DL, Griffiths K, Kuyken W, Crane C, Foulkes L, Parker J, Dalgleish T (March 2019). "**Research Review: The effects of mindfulness-based interventions on cognition and mental health in children and adolescents - a metaanalysis of randomized controlled trials**". *Journal of Child Psychology and Psychiatry, and Allied Disciplines*. 60 (3): 244–258. doi:10.1111/jcpp.12980. PMC 6546608. PMID 30345511.
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17. Bucher, C. A. (n.d.) **Foundation of physical education**. St. Louis: The C.V. Mosby Co.
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21. Vedas: (i) Rig Veda, (ii) Yajur Veda, (iii) Atharva Veda, (iv) Sama Veda
22. Deb, B. M., **The Peacock in Splendour**, Visva Bharti University.
23. Ray, P. C., **A History of Hindu Chemistry: from the Earliest Times to the Middle of the Sixteenth Century A.D.**, Volume 1 – 1902, Volume 2 – 1908, The Bengal Chemical and Pharmaceutical Works Ltd

24. **“History of Chemistry in Ancient and Mideaval India”** (Edited volume of Acharya Ray’s “History of Hindu Chemistry”), Indian Chemical Society, Calcutta, 1956.
25. Harsha, N. M., Nagaraja, T. N., **The History of Hindu Chemistry**, *Ancient Science of Life*, 2010, 30, 58 – 61.
26. Ray, P. C., **Life and experiences of a Bengali chemist**, Two Volume Set. Calcutta: Chuckervertty, Chatterjee & Co. 1932 and 1935.
27. Ray, P. R., **Chemistry in Ancient India**, *Journal of Chemical Education*, 1948, 25 (6), 327.
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