INDIRA GANDHI NATIONAL OPEN UNIVERSITY

LEARNING OUTCOMES-BASED CURRICULUM FRAMEWORK

CENTRE FOR INTERNAL QUALITY ASSURANCE &
STAFF TRAINING & RESEARCH INSTITUTE OF DISTANCE EDUCATION

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Chapter 3

BACHELOR OF SCIENCE (HONOURS) DEGREE PROGRAMME IN CHEMISTRY

3.1 Introduction

The learning outcomes-based curriculum framework for a B.Sc degree in Chemistry is intended to provide a broad framework within which a chemistry programme that responds to the needs of students and to the evolving nature of chemistry as a subject could be developed. The framework is expected to assist in the maintenance of the standard of chemistry degrees/programmes across the country and periodic programme review within a broad framework of agreed expected graduate attributes, qualification descriptors, programme learning outcomes and course-level learning outcomes. The framework, however, does not seek to bring about uniformity in syllabi for a programme of study in chemistry, or in teaching-learning process and learning assessment procedures. Instead, the framework is intended to allow for flexibility and innovation in programme design and syllabi development, teaching-learning process, assessment of student learning levels.

3.2 Nature and Scope of the B.Sc degree programme

Chemistry is normally referred to as the science that studies systematically the composition, properties, and reactivity of matter at the atomic and molecular level. The scope of chemistry as a subject is very broad. The key areas of study within the disciplinary/subject area of chemistry comprise: organic chemistry, inorganic chemistry, physical chemistry and analytical chemistry. Organic chemistry deals with the study of (most) substances containing the element carbon; Inorganic chemistry involves the study of all other substances; and physical chemistry deals with the application of concepts and laws to chemical phenomena. Analytical chemistry is concerned with the identification and quantification of materials and the determination of composition.

Degree programmes in Chemistry covers topics that overlap with the areas outlined above and that address the interfaces of chemistry with other subjects (such as chemical biology and chemical physics) and with applied fields (such as environmental chemistry, pharmaceutical chemistry, materials chemistry etc.). The depth and breadth of study of individual topics dealt with would vary with the nature of specific chemistry programmes.

As a part of the efforts to enhance the employability of graduates of chemistryprogrammes, the curricula for these programmes are expected to include learning experiences that offer opportunities for a period of study in industry. These may involve both a major work-related chemistry project and some guided study.

3.3 Aims of the Bachelor's degree programme in chemistry

The overall aims of bachelor's degree programme in chemistry are to:

 provide students with learning experiences that help instill deep interests in learning chemistry; develop broad and balanced knowledge and understanding of key chemical concepts, principles, and theories related to chemistry; and equip students with appropriate tools of analysis to tackle issues and problems in the field of chemistry.

 develop in students the ability to apply the knowledge and skills they have acquired to the solution of specific theoretical and applied problems in chemistry,

 provide students with the knowledge and skill base that would enable them to undertake further studies in chemistry and related areas or in multidisciplinary areas that involve chemistry and help develop a range of generic skills that are relevant to wage employment, self-employment and entrepreneurship.

3.4 Characteristic attributes of a graduate in chemistry

Some of the characteristic attributes of a graduate in chemistry may include the following:

Disciplinary knowledge and skills: Capable of demonstrating (i) comprehensive knowledge and understanding of major concepts, theoretical principles and experimental findings in chemistry and its different subfields (analytical, inorganic, organic and physical), and other related fields of study, including broader interdisciplinary subfields such as life science, environmental science and material sciences; (ii) ability to use modern instrumentation for chemical analysis and separation.

Skilled communicator: Ability to transmit complex technical information relating to chemistry in a clear and concise manner in writing and orally skills.

Critical thinker and problem solver: Ability to employ critical thinking and efficient problem solving skills in the four basic areas of chemistry (analytical, inorganic, organic, and physical).

Sense of inquiry: Capability for asking relevant/appropriate questions relating to issues and problems in the field of chemistry, and planning, executing and reporting the results of an experiment or investigation.

Team player/worker: Capable of working effectively in diverse teams in both classroom, laboratory and in industry and field-based situations.

Skilled project manager: Capable of identifying/mobilizing appropriate resources required for a project, and manage a project through to completion, while observing responsible and ethical scientific conduct; and safety and chemical hygiene regulations and practices.

Digitally literate: Capable of using computers for chemical simulation and computation and appropriate software for analysis of data, and employing modern library search tools to locate, retrieve, and evaluate chemistry-related information.

Ethical awareness/reasoning: Avoiding unethical behaviour such as fabrication, falsification or misrepresentation of data or committing plagiarism, and appreciate environmental and sustainability issues.

Lifelong learners: Capable of self-paced and self-directed learning aimed atpersonal development and for improving knowledge/skill development and reskilling.

3.5 Qualification descriptors for a Bachelor's Degree programme in Chemistry

The qualification descriptors for a Bachelor's Degree programme in Chemistry may include the following:

Demonstrate (i) a fundamental/systematic or coherent understanding of the academic field of chemistry, its different learning areas and applications, and its linkages with related disciplinary areas/subjects; (ii) procedural knowledge that creates different types of professionals related to chemistry area of study, including research and development, teaching and government and public service; (iii) skills in areas related to specialization area relating the subfields and current developments in the academic field of chemistry.

Use knowledge, understanding and skills required for identifying problems and issues relating to chemistry, collection of relevant quantitative and/or qualitative data drawing on a wide range of sources, and their application, analysis and evaluation using methodologies as appropriate to the subject(s) for formulating evidence-based solutions and arguments;

Communicate the results of studies undertaken accurately in a range of different contexts using the main concepts, constructs and techniques of the subject(s);

Meet one's own learning needs, drawing on a range of current research and development work and professional materials;

Apply one's subject knowledge and transferable skills to new/unfamiliar contexts to identify and analyse problems and issues and solve complex problems with well-defined solutions.

Demonstrate subject-related and transferable skills that are relevant to chemistry related job trades and employment opportunities

3.6 Qualification descriptors for B.Sc (Honours) programme in chemistry

The qualification descriptors for a B.Sc (Honours) programme in Chemistry may include the following:

Demonstrate (i) a systematic, extensive and coherent knowledge and understanding of the academic field of study as a whole and its applications, and links to related disciplinary areas/subjects of study; including a critical understanding of the established theories, principles and concepts, and of a number of advanced and emerging issues in the field of chemistry; (ii) procedural knowledge that creates different types of professionals related to the subject area of chemistry, including research and development, teaching and government and public service; (iii) skills in areas related to one's specialization area and current developments in the academic field of chemistry, including a critical understanding of the latest developments in the area of specialization, and an ability to use established techniques of analysis and enquiry within the area of specialization.

Demonstrate comprehensive knowledge about materials, including current research, scholarly, and/or professional literature, relating to essential and advanced learning areas pertaining to chemistry, and techniques and skills required for identifying chemistry-related problems and issues.

Demonstrate skills in identifying information needs, collection of relevant quantitative and/or qualitative data drawing on a wide range of sources, analysis and interpretation of data using methodologies as appropriate to the subject of chemistry for formulating evidence-based solutions and arguments;

Use knowledge, understanding and skills for critical assessment of a wide range of ideas and complex problems and issues relating to the academic field of chemistry.

Communicate the results of studies undertaken in the academic field of chemistry accurately in a range of different contexts using the main concepts, constructs and techniques of the subject of chemistry;

Address one's own learning needs relating to current and emerging areas of study relating to chemistry, making use of research, development and professional materials as appropriate, including those related to new frontiers of knowledge in chemistry.

Apply one's knowledge and understandings relating to chemistry and transferable skills to new/unfamiliar contexts and to identify and analyze problems and issues and seek solutions to real-life problems.

Demonstrate subject-related and transferable skills that are relevant to some of the chemistry-related jobs and employment opportunities.

3.7 Programme learning outcomes relating to B.Sc degree programme in chemistry

The programme learning outcomes relating to B.Sc degree programme in chemistry may include the following:

Demonstrate (i) a systematic or coherent understanding of the fundamental concepts, principles and processes underlying the academic field of chemistry, its different subfields (analytical, inorganic, organic and physical), and its linkages with related disciplinary areas/subjects; (ii) procedural knowledge that creates different types of professionals in the field of chemistry and related fields such as pharmaceuticals, chemical industry, teaching, research, environmental monitoring, product quality, consumer goods industry, food products, cosmetics industry, etc.; (iii) skills related to specialization areas within chemistry as well as within subfields of chemistry (analytical, inorganic, organic and physical), and other related fields of study, including broader interdisciplinary subfields (life, environmental and material sciences).

Apply appropriate methodologies in order to conduct chemical syntheses, analyses or other chemical investigations; and apply relevant knowledge and skills to seek solutions to problems that emerge from the subfields of chemistry as well as from broader interdisciplinary subfields relating to chemistry;

Use chemical techniques relevant to academia and industry, generic skills and global competencies, including knowledge and skills that enable students to undertake further studies in the field of chemistry or a related field, and work in the chemical and non-chemical industry sectors.

Undertake hands on lab work and practical activities which develop problem solving abilities required for successful career in pharmaceuticals, chemical industry, teaching, research, environmental monitoring, product quality, consumer goods industry, food products, cosmetics industry, etc.

Recognize and appreciate the importance of the chemical sciences and its application in an academic, industrial, economic, environmental and social contexts.

3.8 Programme learning outcomes relating to B.Sc (Honours) degree programme in chemistry

The programme learning outcomes relating to B.Sc (Honours) degree programme in chemistry may include the following:

- Demonstrate (i) in-depth knowledge and understanding about the fundamental concepts, principles and processes underlying the chemistryand its different subfields (analytical, inorganic, organic and physical), and its linkages with related disciplinary areas/subjects (ii) the procedural knowledge that creates different types of professionals in the field of chemistry and related fields such as pharmaceuticals, chemical industry, teaching, research, environmental monitoring, product quality, consumer goods industry, food products, cosmetics industry, etc; (iii) practical skills related to specialization area(s) within chemistry as well within the subfields of chemistry (analytical, inorganic, organic and physical), and other related fields of study, including broader interdisciplinary subfields (life, environmental and material sciences);

- Demonstrate skills relating to quantitative analysis of metal ions and other inorganic/organic compounds utilized in materials, polymers and food analysis and apply appropriate methodologies in order to conduct chemical syntheses, analyses or other chemical investigations, including quantitative analysis of metal ions and other inorganic/organic compounds utilized in materials, polymers and food analysis;

- Use skills required for the extraction, separation, identification and synthesis of a variety of organic compounds utilized in chemical and pharma industry in India and abroad.

- Use newer techniques of molecular modelling, electrochemical methods of analysis and use of IR, NMR and other spectroscopic techniques in the identification of inorganic and organic compounds at semi-micro level.

- Employ chemical techniques relevant to academia, industry and government, and generic skills and global competencies, including relevant disciplinary knowledge and skills that enable students to undertake further studies in the field of chemistry or multi-disciplinary areas involving chemistry, and apply standard methodology to the solution of problems in chemistry, including problems that emerge from both the subfields of chemistry (analytical, inorganic, organic and physical), and broader interdisciplinary subfields (eg. life, environmental and material sciences).

- Undertake hands on lab work and activities that help develop in students practical knowledge and skills, that are required for pursuing career in pharmaceuticals, chemical industry, teaching, research, environmental monitoring, product quality, consumer goods industry, food products, cosmetics industry, etc. and skills for working safely and competently in the laboratory;

- Recognize and appreciate the importance of the chemical sciences and its application in academic, industrial, economic, environmental and social contexts.

3.9 Course-level learning outcomes

Some examples of course-level learning outcomes relating to courses within B.Sc (Honours) degree programme in chemistry are indicated in the following sections:

Physical Chemistry I: States of Matter & Ionic Equilibrium (Semester–I/ Core Course– II): Some examples of course-level learning outcomes that a student of this course is required to demonstrate are indicated below:

 Explain the origin of Keq and its relation to fugacity and activity and apply these concepts to ideal and real solutions of electrolytes and non-electrolytes and to colligative properties.

 Apply the principles of electrochemistry to conductance, voltaic, and electrolytic systems. Provide a physical basis for Debye-Huckel theory.

 List the methods for arriving at a plausible mechanism and/or rate law based on kinetic information. Manipulate the gas laws to describe real and ideal gas behavior.

 Apply the steady-state hypothesis to obtain rate equations. Explain the basic principles of photochemical and radiation-chemical reactions.

Inorganic Chemistry I: Atomic Structure & Chemical Bonding(Semester–I/ Core Course–I):Some examples of course-level learning outcomes that a student of this course is required to demonstrate are indicated below:

 Explain the atomic theory of matter, composition of the atom, which defines the identity of a given element.

 Explain the relative sizes, masses, and charges of the proton, neutron, and electron, and their assembly to form different atoms.

 Define the term isotope, and their atomic and mass numbers.

 Use the Periodic Table to rationalize similarities and differences of elements, including physical and chemical properties and reactivity.

 Predict common ionic charges of group 1A, 2A, 3A, 6A, and 7A elements based on position in the periodic table.

Organic Chemistry I: Basics and Hydrocarbons (Semester–II/ Core Course–III):Some examples of course-level learning outcomes that a student of this course is required to demonstrate are indicated below:

 Describe molecular structure and bonding in organic molecules.

 Classify organic compounds by structure, use the IUPAC nomenclature, and identify conformational effects in organic compounds.

 Predict the products of reactions of alkenes and describe the mechanisms showing how the products are formed.

 Draw and interpret reaction coordinate diagrams, and relate the energetic changes associated with chemical reactions to equilibrium constants and rate; and differentiate kinetic versus thermodynamic control of reactions.

- Identify the types of isomerism in organic compounds, to identify and classify chiral centers, and explain the physical and chemical consequences of chirality.

- Correctly represent the structures and bonding of alkynes, and describe the mechanisms for reactions of alkynes and predict the products of such reactions.

- Identify compounds in which resonance is important, predict the effect of resonance on the stability of compounds and reactive intermediates, and draw resonance structures.

- Identify conjugated pi systems and explain the effect of conjugation on molecular structure and reactivity; and predict the products of reactions of dienes.

- Describe mechanisms for substitution and elimination reactions, and predict the effect of nucleophile, leaving group, and solvent on the relative rates of S 1 versus S 2 reactions, and E1 versus E2 reactions, as well as on the relative rates of substitution versus elimination.

Physical Chemistry II: **Chemical Thermodynamics and its Applications** (Semester–II/ Core Course–IV):Some examples of course-level learning outcomes that a student of this course is required to demonstrate are indicated below:

- Apply the basic concepts of calculus to concepts in chemistry.

- Describe the Three Laws of Thermodynamics and their development.

- Use the Maxwell equations and other thermodynamic relations to compute thermodynamic quantities from thermodynamic data tables.

- Derive the relationships between thermodynamic quantities; Interpret phase diagrams and explain phase equilibriums in terms of chemical potentials.

- Recognize the forces which drive the chemical reactions in forward direction and the concept of the interchange of energy in a system.

- Explain the use of electrical energy for initiating chemical reactions and also how chemical reactions can be utilized to produce electrical energy, and the basic principle used in the formation of cells and batteries.

Inorganic Chemistry III: Coordination Chemistry (Semester–IV/ Core Course– VIII):Some examples of course-level learning outcomes that a student of this course is required to demonstrate are indicated below:

- Recognize the role played by transition metal complexes play in Inorganic Chemistry.

- Describe the structure and bonding theories, electronic and magnetic properties of the transition metal complexes and their kinetic studies.

- Explain the theories of bonding in coordination compounds and their experimental behaviour.
- Recognize and explain the interaction of metal ions with biological ligands.

- Explain the role of Inorganic “substances” in living systems and the use of metal ions in medicinal therapy and diagnosis.

Organic Chemistry IV: Biomolecules (Semester–V/ Core Course–XI):Some examples of course-level learning outcomes that a student of this course is required to demonstrate are indicated below:

 Recognize that it is the harmonious and synchronous progress of chemical reactions in body which leads to life.

 Recognize that chemical reactions involve certain molecules called biomolecules or molecules of life, and that these molecules constitute the source of energy in body, build the body, act as catalyst in many processes and also responsible for the transfer of characters to off springs.

 Explain the structures of biomolecules (carbohydrates, proteins, enzymes, lipids and nucleic acids) and their role in life related processes. The basic types of molecules included are carbohydrates, proteins, enzymes, lipids and nucleic acids.

Physical Chemistry V: Quantum Chemistry & Spectroscopy(Semester–V/ Core Course–XII):Some examples of course-level learning outcomes that a student of this course is required to demonstrate are indicated below:

 Recognize the importance of the quantum chemistry and quantization of energy.

 Explain atomic structure and the application of the concept of quantization of energy of different orbitals.

 Explain how the absorption of energy by the molecules produces spectra which help in structure determination and identification of the molecules, and how this energy can initiate the photo-chemical reactions.

 Explain how phase equilibriums help in understanding the formation of various materials, allotropic forms of different substances

Analytical Methods in Chemistry(Semester–V/ VI):An example of course-level learning outcomes that a student of this course is required to demonstrate is indicated below:

 Demonstrate up-to-date analytical skills required to deal with the detection, identification, separation, and estimation of atomic, molecular, and ionic species in various states.

Molecular Modelling & Drug Design(Semester–V/ VI/ DSE -2-4):Examples of course level learning outcomes that a student of this course is required to demonstrate are indicated below:

 Recognize the he relation between human health and plants and that most of the drugs in the market are either plant products or their derivatives. Demonstrate skills required for employment in the pharmaceutical industries in India

Green Chemistry(Semester–V/ VI/ DSE -2-4):Examples of course-level learning outcomes that a student of this course is required to demonstrate is indicated below:

 Recognize the impact of green chemistry on human health and the environment.

 Demonstrate the knowledge of the twelve principles of Green Chemistry which they can apply to a range of work places for a safer, less toxic and healthier environment.

IT Skills for Chemists (Semester–III/ IV/ SEC -1-2):Examples of course-level learning outcomes that a student of this course is required to demonstrate is indicated below:

 Formulate a set of calculations that can address a relevant research question;

 Use one or several computer programs and extract useful information;

 Write a research paper that describes methods, results, and interpretation;

 Assess the meaning and validity of calculations that appear in the chemical literature.

3.10 Teaching-learning processes

As a programme of study in chemistry is designed to encourage the acquisition of disciplinary/subject knowledge, understanding and skills and academic and professional skills required for chemistry-based professions and jobs, learning experiences should be designed and implemented to foster active/participative learning. Development of practical skills will constitute an important aspect of the teaching-learning process. A variety of approaches to teaching-learning process, including lectures, seminars, tutorials, workshops, peer teaching and learning, practicum and project-based learning, field-based learning, substantial laboratory-based practical component and experiments, open-ended project work, games, technology-enabled learning, internship in industry and research establishments etc. will need to be adopted to achieve this. Problem-solving skills and higher-order skills of reasoning and analysis will be encouraged through teaching strategies.

3.11 Assessment methods

The assessment of students' achievement in chemistry will be aligned with the course/programme learning outcomes and the academic and professional skills that the programme is designed to develop. A variety of assessment methods that are appropriate within the disciplinary area of chemistry will be used. Learning outcomes will be assessed using the following: oral and written examinations, closed-book and open-book tests; problem-solving exercises, practical assignment laboratory reports, observation of practical skills, individual project reports, seminar presentation; viva voce interviews; computerized adaptive testing, literature surveys and evaluations, outputs from collaborative work, portfolios on chemical activities undertaken etc.