

## **Learning Outcomes-based Curriculum Framework for Undergraduate Education**

### **SECTION 1**

#### **1.1 Introduction**

A high priority task in the context of future education development agenda in India is fostering quality higher education. Further improvement of quality of higher education is considered critical for enabling effective participation of young people in knowledge production and participation in the knowledge economy, improving national competitiveness in a globalized world and for equipping young people with skills relevant for global and national standards and enhancing the opportunities or social mobility. Sustained initiatives are required for institutionalizing an outcome-oriented higher education system and enhancing employability of graduates through curriculum reform based on a learning outcomes-based curriculum framework, improving/upgrading academic resources and learning environment, raising the quality of teaching and research across all higher education institutions; technology use and integration to improve teaching-learning processes and reach a larger body of students through alternative learning modes such as open and distance learning modes and use of MOOCs.

Other priority areas of action for fostering quality higher education include translation of academic research into innovations for practical use in society and economy, promoting efficient and transparent governance and management of higher education system, enhancing the capacity of the higher education system to govern itself through coordinated regulatory reform and increasing both public and private sector investment in higher education, with special emphasis on targeted and effective equity-related initiatives.

#### **1.2 Learning outcomes-based approach to curriculum planning and development**

The fundamental premise underlying the learning outcomes-based approach to curriculum planning and development is that higher education qualifications such as a Bachelor's Degree programmes are awarded on the basis of demonstrated achievement of outcomes (expressed in terms of knowledge, understanding, skills, attitudes and values) and academic standards expected of graduates of a programme of study. Learning outcomes specify what graduates completing a particular programme of study are expected to know, understand and be able to do at the end of their programme of study.

The expected learning outcomes are used as reference points that would help formulate graduate attributes, qualification descriptors, programme learning outcomes and course learning outcomes which in turn will help in curriculum planning and development, and in the design, delivery and review of academic programmes. They provide general guidance for articulating the essential learnings associated with programmes of study and courses within a programme.

It may be noted that the learning outcomes-based curriculum framework is not intended to promote designing of a national common syllabus for a programme of study or learning contents of courses within each programme of study or to prescribe a set of approaches to teaching-learning process and assessment of student learning levels. Instead, they are intended to allow for flexibility and innovation in (i) programme design and syllabi development by higher education institutions (HEIs), (ii) teaching-learning process, (iii) assessment of student learning levels, and (iv) periodic programme review within a broad framework of agreed expected graduate attributes, qualification descriptors, programme learning outcomes and course learning outcomes.

The overall objectives of the learning outcomes-based curriculum framework are to:

- help formulate graduate attributes, qualification descriptors, programme learning outcomes and course learning outcomes that are expected to be demonstrated by the holder of a qualification;
- enable prospective students, parents, employers and others to understand the nature and level of learning outcomes (knowledge, skills, attitudes and values) or attributes a graduate of a programme should be capable of demonstrating on successful completion of the programme of study;
- maintain national standards and international comparability of learning outcomes and academic standards to ensure global competitiveness, and to facilitate student/graduate mobility; and
- provide higher education institutions an important point of reference for designing teaching-learning strategies, assessing student learning levels, and periodic review of programmes and academic standards.

### **1.3 Key outcomes underpinning curriculum planning and development**

The learning outcomes-based curriculum framework for undergraduate education is a framework based on the expected learning outcomes and academic standards that are expected to be attained by graduates of a programme of study and holder of a qualification. The key outcomes that underpin curriculum planning and development at the undergraduate level include Graduate Attributes, Qualification Descriptors, Programme Learning Outcomes, and Course Learning Outcomes:

#### **1.3.1 Graduate attributes**

The graduate attributes reflect the particular quality and feature or characteristics of an individual, including the knowledge, skills, attitudes and values that are expected to be acquired by a graduate through studies at the higher education institution (HEI) such as a college or university. The graduate attributes include capabilities that help strengthen one's abilities for widening current knowledge base and skills, gaining new knowledge and skills, undertaking future studies, performing well in a chosen career and playing a constructive role as a responsible citizen in the society. The graduate attributes define the characteristics of a student's university degree programme(s), and describe a set of characteristics/competencies that are transferable beyond study of a particular subject

area and programme contexts in which they have been developed. Graduate attributes are fostered through meaningful learning experiences made available through the curriculum, the total college/university experiences and a process of critical and reflective thinking.

The learning outcomes-based curriculum framework is based on the premise that every student and graduate is unique. Each student or graduate has his/her own characteristics in terms of previous learning levels and experiences, life experiences, learning styles and approaches to future career-related actions. The quality, depth and breadth of the learning experiences made available to the students while at the higher education institutions help develop their characteristic attributes. The graduate attributes reflect both disciplinary knowledge and understanding, generic skills, including global competencies, that all students in different academic fields of study should acquire/attain and demonstrate. Some of the characteristic attributes that a graduate should demonstrate areas follows:

- **Disciplinary knowledge:** Capable of demonstrating comprehensive knowledge and understanding of one or more disciplines that form a part of an undergraduate programme of study.
- **Communication Skills:** Ability to express thoughts and ideas effectively in writing and orally; Communicate with others using appropriate media; confidently share one's views and express herself/himself; demonstrate the ability to listen carefully, read and write analytically, and present complex information in a clear and concise manner to different groups.
- **Critical thinking:** Capability to apply analytic thought to a body of knowledge; analyse and evaluate evidence, arguments, claims, beliefs on the basis of empirical evidence; identify relevant assumptions or implications; formulate coherent arguments; critically evaluate practices, policies and theories by following scientific approach to knowledge development.
- **Problem solving:** Capacity to extrapolate from what one has learned and apply their competencies to solve different kinds of non-familiar problems, rather than replicate curriculum content knowledge; and apply one's learning to real life situations.
- **Analytical reasoning:** Ability to evaluate the reliability and relevance of evidence; identify logical flaws and holes in the arguments of others; analyse and synthesise data from a variety of sources; draw valid conclusions and support them with evidence and examples, and addressing opposing viewpoints.
- **Research-related skills:** A sense of inquiry and capability for asking relevant/appropriate questions, problematising, synthesising and articulating; Ability to recognise cause-and-effect relationships, define problems, formulate hypotheses, test hypotheses, analyse, interpret and draw conclusions from data, establish hypotheses, predict cause-and-effect relationships; ability to plan, execute and report the results of an experiment or investigation.
- **Cooperation/Team work:** Ability to work effectively and respectfully with diverse teams; facilitate cooperative or coordinated effort on the part of a group, and act together as a group or a team in the interests of a common cause and work efficiently as a member of a team.
- **Scientific reasoning:** Ability to analyse, interpret and draw conclusions from quantitative/qualitative data; and critically evaluate ideas, evidence and experiences

from an open-minded and reasoned perspective.

- **Reflective thinking:** Critical sensibility to lived experiences, with self awareness and reflexivity of both self and society.
- **Information/digital literacy:** Capability to use ICT in a variety of learning situations, demonstrate ability to access, evaluate, and use a variety of relevant information sources; and use appropriate software for analysis of data.
- **Self-directed learning:** Ability to work independently, identify appropriate resources required for a project, and manage a project through to completion.
- **Multicultural competence:** Possess knowledge of the values and beliefs of multiple cultures and a global perspective; and capability to effectively engage in a multicultural society and interact respectfully with diverse groups.
- **Moral and ethical awareness/reasoning:** Ability to embrace moral/ethical values in conducting one's life, formulate a position/argument about an ethical issue from multiple perspectives, and use ethical practices in all work. Capable of demonstrating the ability to identify ethical issues related to one's work, avoid unethical behaviour such as fabrication, falsification or misrepresentation of data or committing plagiarism, not adhering to intellectual property rights; appreciating environmental and sustainability issues; and adopting objective, unbiased and truthful actions in all aspects of work.
- **Leadership readiness/qualities:** Capability for mapping out the tasks of a team or an organization, and setting direction, formulating an inspiring vision, building a team who can help achieve the vision, motivating and inspiring team members to engage with that vision, and using management skills to guide people to the right destination, in a smooth and efficient way.
- **Lifelong learning:** Ability to acquire knowledge and skills, including 'learning how to learn', that are necessary for participating in learning activities throughout life, through self-paced and self-directed learning aimed at personal development, meeting economic, social and cultural objectives, and adapting to changing trades and demands of work place through knowledge/skill development/reskilling.

### 1.3.2 Qualification descriptors

A qualification descriptor indicates the generic outcomes and attributes expected for the award of a particular type of qualification (for eg. a bachelor's degree or a bachelor's degree with honours). The qualification descriptors also describe the academic standard for a specific qualification in terms of the levels of knowledge and understanding, skills and competencies and attitudes and values that the holders of the qualification are expected to attain and demonstrate. These descriptors also indicate the common academic standards for the qualification and help the degree-awarding bodies in designing, approving, assessing and reviewing academic programmes. The learning experiences and assessment procedures are expected to be designed to provide every student with the opportunity to achieve the intended programme learning outcomes. The qualification descriptors reflect both disciplinary knowledge and understanding as well as generic skills, including global competencies, that all students in different academic fields of study should acquire/attain and demonstrate.

***Qualification descriptors for a Bachelor's Degree programme:*** The students who complete three years of full-time study of an undergraduate programme of study will be awarded a Bachelor's Degree. Some of the expected learning outcomes that a student should be able to demonstrate on completion of a degree-level programme may include the following:

- Demonstrate (i) a fundamental/systematic or coherent understanding of an academic field of study, 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 the disciplinary/subject area of study, including research and development, teaching and government and public service; (iii) skills in areas related to one's specialization and current developments in the academic field of study.
- Use knowledge, understanding and skills required for identifying problems and issues, 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 in an academic field 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 disciplinary knowledge and transferable skills to new/unfamiliar contexts, rather than replicate curriculum content knowledge, 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 some of the job trades and employment opportunities.

***Qualification descriptors for a Bachelor's Degree with honours:*** The qualification descriptors for a Bachelor degree with honours may include the following:

- Demonstrate (i) a systematic, extensive and coherent knowledge and understanding of an 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 study; (ii) procedural knowledge that creates different types of professionals related to the disciplinary/subject area of study, including research and development, teaching and government and public service; (iii) skills in areas related to one's specialization and current developments in the academic field of study, 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 specialisation.
- Demonstrate comprehensive knowledge about materials, including current

- research, scholarly, and/or professional literature, relating to essential and advanced learning areas pertaining to the chosen disciplinary areas (s) and field of study, and techniques and skills required for identifying problems and issues relating to the disciplinary area and field of study.
- 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(s) 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 chosen field of study.
  - Communicate the results of studies undertaken in an academic field accurately in a range of different contexts using the main concepts, constructs and techniques of the subject(s) of study;
  - Address one's own learning needs relating to current and emerging areas of study, making use of research, development and professional materials as appropriate, including those related to new frontiers of knowledge.
  - Apply one's disciplinary knowledge and transferable skills to new/unfamiliar contexts and to identify and analyse problems and issues and seek solutions to real-life problems.
  - Demonstrate subject-related and transferable skills that are relevant to some of the job trades and employment opportunities.

### **1.3.3 Programme learning outcomes**

The outcomes and attributes described in qualification descriptors are attained by students through learning acquired on completion of a programme of study. The term 'programme' refers to the entire scheme of study followed by learners leading to a qualification. Individual programmes of study will have defined learning outcomes which must be attained for the award of a specific certificate/diploma/degree. The programme learning outcomes are aligned with the relevant qualification descriptors.

Programme learning outcomes will include subject-specific skills and generic skills, including transferable global skills and competencies, the achievement of which the students of a specific programme of study should be able to demonstrate for the award of the certificate/Diploma/Degree qualification. The programme learning outcomes would also focus on knowledge and skills that prepare students for further study, employment, and citizenship. They help ensure comparability of learning levels and academic standards across colleges/universities and provide a broad picture of the level of competence of graduates of a given programme of study. A programme of study may be monodisciplinary, multi-disciplinary or inter-disciplinary. Some examples of programme learning outcomes for B.Sc (Physics) and Bachelor programme in Education are given in Section 2.

### **1.3.4 Course learning outcomes**

The programme learning outcomes are attained by learners through the essential learnings acquired on completion of selected courses of study within a programme. The

term 'course' is used to mean the individual courses of study that make up the scheme of study for a programme. Course learning outcomes are specific to the learning for a given course of study related to a disciplinary or interdisciplinary/multi-disciplinary area. Some programmes of study are highly structured, with a closely laid down progression of compulsory/core courses to be taken at particular phases/stages of learning. Some programmes allow learners much more freedom to take a combination of courses of study according to the preferences of individual student that may be very different from the courses of study pursued by another student of the same programme.

Course-level learning outcomes will be aligned to programme learning outcomes. Course-level learning outcomes are specific to a course of study within a given programme of study. The achievement by students of course-level learning outcomes lead to the attainment of the programme learning outcomes. At the course level, each course may well have links to some but not all graduate attributes as these are developed through the totality of student learning experiences across the years of their study. A course map would indicate the linkage between course learning outcomes and each programme learning outcome (Table 1). Some examples of course learning outcomes are indicated in Section 3.

<b>Programme outcomes</b>	<b>Courses</b>						
	Course 1	Course 2	Course ...				
Outcome 1	X	X	X	X	X	X	X
Outcome 2	X		X	X		X	
Outcome ...		X		X	X	X	X
Outcome ...		X		X	X	X	
Outcome ...	X		X		X		X
Outcome ...	X		X		X	X	X
Outcome ...		X		X		X	

#### **1.4 Teaching - learning process**

The *Learning Outcomes-Based Approach* to curriculum planning and transaction requires that the teaching-learning processes are oriented towards enabling students to attain the defined learning outcomes relating to the courses within a programme. The outcome-based approach, particularly in the context of undergraduate studies, requires a significant shift from teacher-centric to learner-centric pedagogies, and from passive to active/participatory pedagogies. Planning for teaching therein becomes critical. Every programme of study lends itself to well-structured and sequenced acquisition of knowledge and skills. Practical skills, including an appreciation of the link between theory and experiment, will constitute an important aspect of the teaching-learning process. Teaching methods, guided by such a framework, may include: lectures supported by group tutorial work; practicum and field-based learning; the use of prescribed textbooks and e-learning resources and other self-study materials; open-ended project work, some of which may be team-based; activities designed to promote the development

of generic/transferable and subject-specific skills; and internship and visits to field sites, and industrial or other research facilities etc.

### **1.5 Assessment methods**

A variety of assessment methods that are appropriate to a given disciplinary/subject area and a programme of study will be used to assess progress towards the course/programme learning outcomes. Priority will be accorded to formative assessment. Progress towards achievement of learning outcomes will be assessed using the following: time-constrained examinations; closed-book and open-book tests; problem based assignments; practical assignment laboratory reports; observation of practical skills; individual project reports (case-study reports); team project reports; oral presentations, including seminar presentation; viva voce interviews; computerised adaptive testing; peer and self-assessment etc. and any other pedagogic approaches as per the context .

## **SECTION 2**

### **Programme Learning Outcomes**

#### **2.1 Programme learning outcomes relating to B.Sc physics**

Some examples of expected learning outcomes (subject-specific skills, generic/global skills and attributes) that an undergraduate student of a programme of study in Physics should be able to demonstrate for the award of the qualification may include the following:

- Demonstrate (i) a fundamental/systematic or coherent understanding of the academic field of Physics, 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 the disciplinary/subject area of Physics, including professionals engaged in research and development, teaching and government/public service; (iii) skills in areas related to one's specialisation area within the disciplinary/subject area of Physics and current and emerging developments in the field of Physics.
- Demonstrate the ability to use Physics skills such as formulating and tackling Physics-related problems and identifying and applying appropriate physical principles and methodologies to solve a wide range of problems associated with Physics.
- Recognise the importance of mathematical modeling and computing, and the role of approximation and mathematical approaches to describing the physical world.
- Plan and execute physics-related experiments or investigations, analyse and interpret data/information collected using appropriate methods, including the use of appropriate software such as programming languages and purpose-written packages, and report accurately the findings of the experiment/investigations while relating the conclusions/findings to relevant theories of Physics.
- Demonstrate relevant generic skills and global competencies such as (i) problem-solving skills that are required to solve different types of physics-related problems

- with well-defined solutions, and tackle open-ended problems that may cross disciplinary-area boundaries; (ii) investigative skills, including skills of independent investigation of physics-related issues and problems; (iii) communication skills involving the ability to listen carefully, to read texts and research papers analytically and to present complex information in a concise manner to different groups/audiences; (iv) analytical skills involving paying attention to detail and ability to construct logical arguments using correct technical language related to physics; (v) ICT skills; (vi) personal skills such as the ability to work both independently and in a group.
- Demonstrate professional behaviour such as (i) being objective, unbiased and truthful in all aspects of work and avoiding unethical behavior such as fabricating, falsifying or misrepresenting data or to committing plagiarism; (ii) the ability to identify the potential ethical issues in work-related situations; (iii) appreciation of intellectual property, environmental and sustainability issues; and (iv) promoting safe learning and working environment.

## **2.2 Programme learning outcomes relating to bachelor degree in education**

Some examples of expected learning outcomes (disciplinary area-specific skills, generic skills and attributes) that an undergraduate student of a Bachelor Degree programme in education should be able to demonstrate on completion of the programme for the award of the qualification may include the following:

- Demonstrate core values such as (i) Commitment to the profession or job requirements; values that guide the profession; and seeking out new challenges/assignments that improve student learning; (ii) Honouring diversity and ensuring inclusion by treating all students and colleagues with respect and dignity, showing respect for and sensitivity to gender, cultural and religious difference; and challenging prejudice, biases and intolerance in the workplace etc.; (iii) Ethical integrity which involves maintaining ethical standards; resisting pressure in decision making; displays honest behaviour; and not abusing power/authority.
- Core competencies such as (i) communication skills required to articulate thoughts and ideas clearly/effectively using oral and written communication skills, and to present information and explanations in a well-structured and logical manner; (ii) working effectively with students and their parents which involves interacting with students, parents and community members to know the students, their family and social and cultural contexts; determining learning readiness/prerequisites required by students; and Identifying their learning difficulties; and (iii) drive for achieving improved student learning outcomes.
- Demonstrate professional/technical knowledge (What prospective teachers are expected to know) of the physical, social and intellectual development and characteristics of students and how these may affect learning; undertaking research into how students learn and the implications for teaching; and identifying teaching strategies that are responsive to the learning strengths and needs of students from diverse linguistic, cultural, religious and socioeconomic backgrounds.

- Demonstrate knowledge and understanding of: strategies for differentiating teaching to meet the specific learning needs of students across the full range of abilities; teaching strategies that support participation and learning of differently-abled students; both school education and teacher education-related subjects, including concepts, substance and structure of the content, and approaches to organising content into an effective learning sequence.
- Demonstrate knowledge required to design learning sequences and lesson plans; implement teaching strategies using ICT to improve teaching-learning process; set explicit, challenging and achievable learning goals for all students; and plan and implement well-structured learning and teaching programmes or lesson sequences that engage students and promote learning.
- Demonstrate professional competencies/practice (What prospective teachers will be able to do) that are required to select and use relevant teaching strategies to develop knowledge, skills, problem solving and critical and creative thinking; select and/or create and use a range of resources, including ICT, to engage students in their learning; use effective verbal and non-verbal communication strategies to support student understanding, participation, engagement and achievement; evaluate teaching and learning programmes using evidence, including feedback from students and student assessment data, to inform planning; establish and implement inclusive and positive interactions to engage and support student participation in classroom activities.
- Demonstrate professional competencies/practice that are required to manage classroom activities by establishing and maintaining orderly and workable routines to create an environment where student time is spent on learning tasks; manage challenging behaviour by establishing and negotiating clear expectations with students and address discipline issues promptly, fairly and respectfully; ensure students' well-being and safety within school by implementing school and/or system, curriculum and legislative requirements; and incorporate strategies to promote the safe, responsible and ethical use of ICT in learning and teaching.
- Demonstrate professional competencies/practice that are required to develop, select and use informal and formal, diagnostic, formative and summative assessment strategies to assess student learning; provide timely, effective and appropriate feedback to students about their achievement relative to their learning goals; participate in assessment moderation activities to support consistent and comparable assessment of student learning; use student assessment data to analyse and evaluate student understanding of subject/content, identifying interventions and modifying teaching practice; and report on student achievement, making use of accurate and reliable records.
- Demonstrate competencies and actions required for keeping oneself professionally engaged and participate in learning to update knowledge and practice, targeted to professional needs and school and/or system priorities; contribute to collegial discussions and apply constructive feedback from colleagues to improve professional knowledge and practice; meet codes of ethics and conduct established by the education systems and schools; establish and maintain respectful collaborative relationships with parents/guardians regarding

their children's learning and well-being; and participate in professional and community networks and forums to broaden knowledge and improve practice.

## **Section 3**

### **Learning Outcomes-Based Curriculum Framework for B.Sc (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 respond 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 extent 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 chemistry programmes, 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/mobilising 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 at personal 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 specialisation.

- 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 analyse 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 specialisation 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 chemistry and 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 specialisation 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  $K_{eq}$  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<sub>1</sub> versus S<sub>2</sub> reactions, and E<sub>1</sub> versus E<sub>2</sub> 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 equilibria in terms of chemical potentials.
- Recognise 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:

- Recognise 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.
- Recognise 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:

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

- Recognise 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 equilibria 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:

- Recognise the 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:

- Recognise 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; computerised adaptive testing, literature surveys and evaluations, outputs from collaborative work, portfolios on chemical activities undertaken etc.