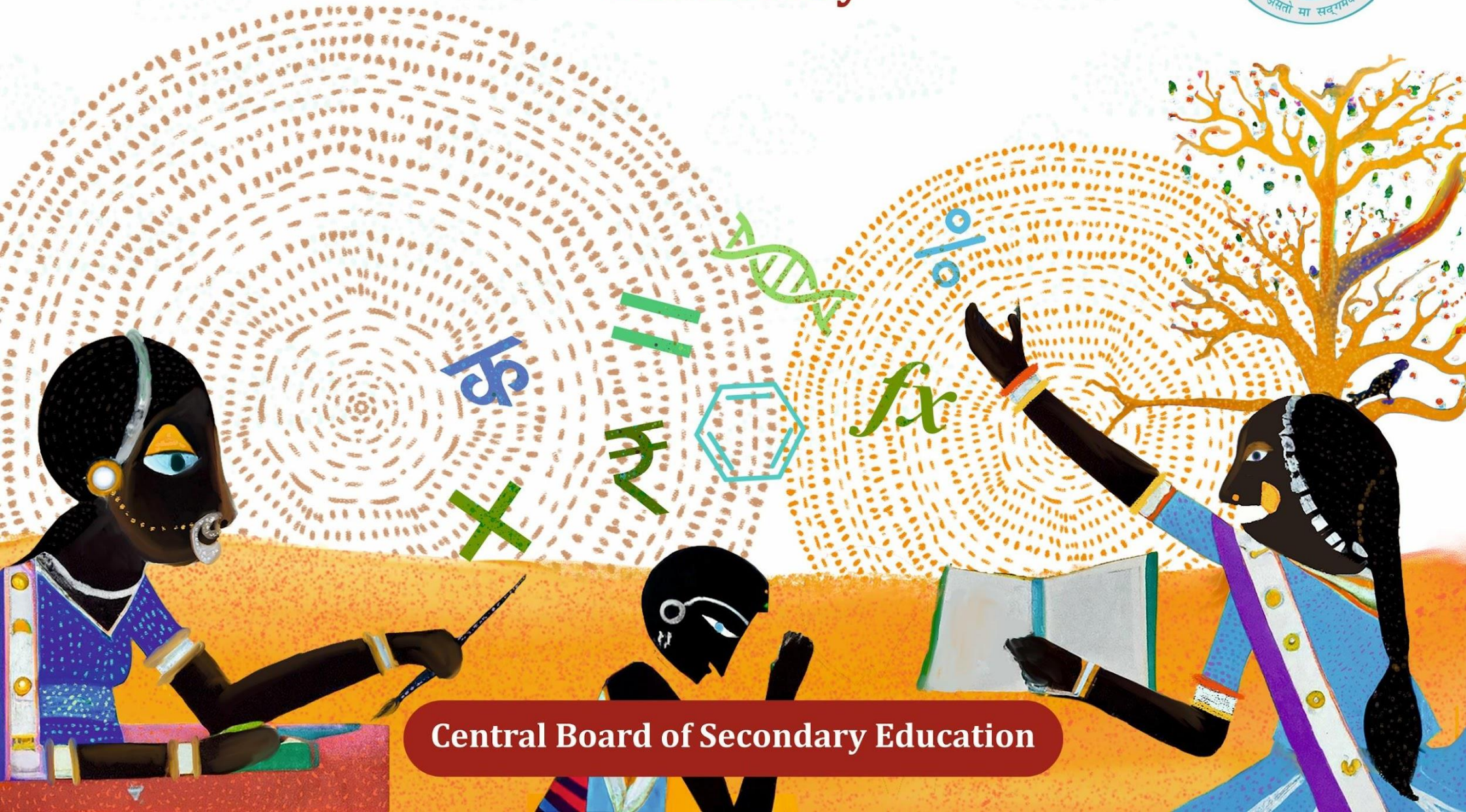
Learning Framework Classes 11-12
Chemistry



Central Board of Secondary Education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Chemistry

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Co-created by
CBSE Centre for Excellence in Assessment
and
Educational Initiatives

FOREWORD

The vision of the National Education Policy (NEP) 2020 released by the Government of India, directs that children not only learn but more importantly learn how to learn. Education must move towards less content, and more towards learning about how to think critically and solve problems, how to be creative and multidisciplinary, and how to innovate, adapt, and absorb new material in novel and changing fields. Pedagogy must evolve to make education more experiential, holistic, integrated, inquiry-driven, discovery-oriented, learner-centred, discussion-based, flexible, and, of course, enjoyable. The policy has a clear mandate for competency-based education (CBE) to enhance the acquisition of critical 21st-century skills by the learners. The first determinant for implementing CBE is a curriculum which is aligned with defined learning outcomes and that clearly states the indicators to be achieved.

The Central Board of Secondary Education (CBSE) has collaborated with Educational Initiatives, to develop the Learning Framework for twelve subjects of Grades 11 and 12, i.e. English, Hindi, Mathematics, Physics, Chemistry, Biology, History, Geography, Economics, Accountancy, Business Studies and Computer Science. The Learning Frameworks comprise explicitly stated knowledge, skills and dispositions that an education system should try to achieve. These frameworks will help develop a common shared understanding among teachers, students and other stakeholders and serve as a benchmark for teaching, learning and assessment across the country.

These frameworks present indicators aligned with the CBSE curriculum and the NCERT learning outcomes. They further outline samples of pedagogical processes and assessment strategies to encourage curiosity, objectivity, and creativity to nurture scientific temper. This framework would be a key resource for teachers executing the curriculum. They have been developed to ensure that teachers align the learning to meet the set quality standards and also use it to track the learning levels of students. The effort has been to synchronise focus on quality education with uniformity in quality of standards across CBSE schools.

We hope, these frameworks not only become a reference point for competency-based education across the country but also facilitate planning and design of teaching-learning processes and assessment strategies by teachers and other stakeholders.

Please note that the learning frameworks have been drafted based on the 2022-23 curriculum. Certain chapters and topics rationalized in the 2023-24 curriculum are retained in this document. In this learning framework, the content units and topics are based on 2022-23 syllabus, even as there is no change in the rationalized syllabus of 2023-24.

Feedback regarding the framework is welcome. Any further feedback and suggestions will be incorporated in subsequent editions.

Team CBSE

PREFACE

The National Education Policy 2020 has outlined the importance of competency-based education in classrooms, leading to curricular and pedagogical reforms in the school systems. The policy emphasizes on the development of higher-order skills such as analysis, critical thinking and problem-solving through classroom instructions and aligned assessments. These skills are important indicators which will further the dissemination of pedagogy and learning outcomes across schools and boards.

To propagate indicator-based learning through 'Learning Frameworks', the Central Board of Secondary Education has collaborated with Educational Initiatives (Ei). Learning frameworks are a comprehensive package which provides learning outcomes, indicators, assessment frameworks, samples of pedagogical processes, tools and techniques for formative assessment, blueprints, assessment items and rubrics. 12 such frameworks have been developed for English, Hindi, Mathematics, Physics, Chemistry, Biology, History, Geography, Economics, Accountancy, Business Studies and Computer Science in Classes 11 and 12.

The frameworks are adopted from the learning outcomes outlined in the NCERT which are mapped to key concepts of the content. These content domain-specific learning outcomes are broken down into indicators which define the specific skills a learner needs to attain. A clear understanding of these LOs will be immensely helpful for teachers and students to learn better. This document will help teachers to focus on skills of the subject in addition to concepts.

As per the National Focus Group Position Paper on Teaching of Science, "At the higher secondary stage, science should be introduced as separate disciplines with emphasis on experiments/technology and problem-solving. The content should not be information-laden, and not aim to widely cover all aspects of the subject. Considering the vast breadth of knowledge in any subject, the exigencies of time and the student's capacity, some delimitation, or rather, identification of core areas has to be done. At this stage, core topics of a discipline, taking into account recent advances, should be carefully identified and treated with appropriate rigour and depth" (Sec 5.2.4). As per NCERT Learning Outcomes for Higher Secondary Stage." Students reach this stage after 10 years of general education and opt for Chemistry with the purpose of mostly for pursuing their career in basic sciences or professional courses like medicine, engineering, technology and studying courses in applied areas of science and technology at tertiary level. Therefore, at this stage, there is a need to provide learners with sufficient conceptual background of Chemistry, which will make them competent to meet the challenges of academic and professional courses after higher secondary stage. Pedagogical process in chemistry should facilitate learners to get engaged with various scientific processes such as observing, questioning, planning investigations, hypothesising, collecting, analysing and interpreting data, constructing and communicating explanations with evidences, justifying explanations, thinking critically to consider and evaluate alternative explanation, etc."

CONTENTS

1. NATURE OF THE SUBJECT

Chemistry is often chosen with a clear career-oriented purpose and marks the transition to specialised, content-oriented courses. Hence, it should emphasise the importance of providing learners with a solid conceptual foundation to prepare them for the demands of academic and professional courses at the tertiary level. The framework is designed to be disciplined, rigorous, and comparable to international standards, focusing on key ideas within the discipline, proper sequencing for effective learning, and an emphasis on problem-solving methods and historical context. Overall, the nature of chemistry at this stage is oriented toward preparing students for future academic and professional challenges in a comprehensive and disciplined manner.

The pedagogical process in chemistry should facilitate learners to engage in various scientific processes such as observing, questioning, planning, investigating, hypothesising, collecting, analysing and interpreting data, constructing and communicating explanations with evidence, justifying explanations, thinking critically to consider and evaluate alternative explanations, etc. A wide range of strategies and their imaginative combinations such as activities, experiments, projects, field visits, surveys, problem-solving, group discussions, debates, etc. can comprise pedagogical processes.

In a progressive society, chemistry can play a genuinely liberating role in helping people out of the vicious circle of poverty, ignorance and superstition. Learners at this stage should be encouraged to reflect on the societal issues so that chemistry learning becomes meaningful in a social context. Therefore, participation in various curricular activities including projects that bear on local issues and problem-solving approaches using science and technology must be regarded as equally important.

2. STAGE SPECIFIC CURRICULAR EXPECTATIONS

CE1. Develops an interest in students to study chemistry as discipline

CE2. Promotes understanding of basic principles in chemistry while retaining the excitement in chemistry

CE3. Develops perception for chemistry not only as a discipline of science but make them realise the need and importance in the world around us

CE4. Strengthens the concepts developed at the secondary stage and to provide firm foundation for further learning of Chemistry at tertiary level more effectively

CE5. Develops ability to acquire and use the methods and processes of science, such as, observing, questioning, planning investigations, hypothesising, collecting, analysing and interpreting data, communicating explanations with evidences, justifying explanations, thinking critically to consider and evaluate alternative explanation, etc

CE6. Develops positive scientific attitude and appreciate contribution of Chemistry towards the improvement of quality of human life

CE7. Appreciates how concepts of Chemistry evolve with time giving importance to its historical prospective

CE8. Develops problem solving skills and nurture curiosity, aesthetic sense and creativity

CE9. Inculcate values of honesty, integrity, cooperation, concern for life and preservation of the environment

CE10. Makes the learner realise the interface of Chemistry with other disciplines of science such as Physics, Biology, Geology, Geography, Pharmaceutical Science etc

CE11. Equips students to face challenges related to health, nutrition, environment, population, whether, industries, agriculture etc

CE12. Develops an appreciation for chemistry as a career option in future

CE13. Develops respect for human dignity and rights, equity and equality

3. CONTENT DOMAINS

The content for chemistry for grades 11-12 in the CBSE curriculum has been organized around content units.

Content units for the two grades, along with the chapters from the NCERT textbooks are mentioned in the tables below.

Table 3.1 Grade 11 Content units and textbook chapters

Content units	NCERT textbook chapters
I. Basic concepts of chemistry	1. Basic concepts of chemistry
II. Structure of atom	2. Structure of atom
III. Classification of Elements & Periodicity in Properties	3. Classification of Elements & Periodicity in Properties
IV. Chemical bonding and Molecular structure	4. Chemical bonding and Molecular structure
V. Chemical Thermodynamics	5. Chemical Thermodynamics
VI. Equilibrium	6. Equilibrium
VII. Redox reactions	7. Redox reactions
VIII. Organic Chemistry: Basic principles and techniques	8. Organic Chemistry: Basic principles and techniques
IX. Hydrocarbons	9. Hydrocarbons

Table 3.2 Grade 12 Content units and textbook chapters

Content units	NCERT textbook chapters
I. Solutions	1. Solutions
II. Electrochemistry	2. Electrochemistry
III. Chemical kinetics	3. Chemical kinetics
IV. d and f block elements	4. d and f block elements
V. Coordination compounds	5. Coordination compounds
VI. Haloalkanes and haloarenes	6. Haloalkanes and haloarenes
VII. Alcohols, phenols and ethers	7. Alcohols, phenols and ethers
VIII. Aldehydes, ketones and carboxylic acids	8. Aldehydes, ketones and carboxylic acids
IX. Amines	9. Amines
X. Biomolecules	10. Biomolecules

4. SUBJECT SPECIFIC COGNITIVE DOMAINS

"As the Board is progressively allowing more space to 'learning outcome based' assessment in place of textbook driven assessment, question papers of Board examinations will have more questions based on real-life situations requiring students to apply, analyse, evaluate and synthesize information as per the stipulated outcomes. The core-competencies to be assessed in all questions, however, will be from the prescribed syllabus and textbooks recommended therein. This will eliminate predictability and rote learning to a large extent."

[CBSE Curriculum for classes 11-12]

CATEGORIES OF COGNITIVE DOMAINS

Revised Bloom's taxonomy (Anderson and Krathwohl, 2001) of cognitive process dimension has six categories, each associated with a set of specific cognitive processes. CBSE curriculum intends to have a balance of these categories of intellectual tasks in the teaching-learning and assessment of learning of a subject. These six categories as described in the revised Bloom's taxonomy, with their specific cognitive processes, are mentioned below.

COGNITIVE DOMAIN – REMEMBER

'Remember' involves retrieving relevant knowledge from long-term memory. Recognising and recalling are the specific cognitive skills associated with this cognitive domain. For example: Asking students to provide the definition of a concept, name, reaction, SI unit, etc. e.g. State Dalton's law of partial pressure.

COGNITIVE DOMAIN – UNDERSTAND

'Understand' involves 'constructing meaning from instructional messages, including oral, written and graphic communication'. Interpreting, exemplifying, classifying, summarizing, inferring, comparing, and explaining are the specific cognitive skills associated with this cognitive domain. Asking students to explain a phenomenon in terms of physical concepts/principles, e.g. Explain why the dipole moment of NH_3 is greater than NF_3

COGNITIVE DOMAIN – APPLY

'Apply' involves carrying out or using a procedure in a given situation. Executing and implementing are the specific cognitive skills associated with this cognitive domain. Assessment tasks wherein students have to use the knowledge and/or procedures to solve a problem or to arrive at a decision in a given real-life situation cover this cognitive domain. Example: Why is salt used to make ice cube necklaces?

COGNITIVE DOMAIN – ANALYSE

'Analyse' involves breaking material into constituent parts and determining how parts relate to one another and to an overall structure and purpose. Differentiating, organising and attributing are the specific cognitive skills associated with this cognitive domain. Asking students to compare and explain the relationship between two physical quantities from the same content domain, e.g. Between the following pair of orbitals which orbital will experience the larger effective nuclear charge?4d and 4f . Also, give reasons to justify your answer.

COGNITIVE DOMAIN – EVALUATE

'Evaluate' involves making judgments based on criteria and standards. Checking and critiquing are the specific cognitive skills associated with this cognitive domain. Assessment tasks that require a deeper level of understanding wherein students are required to provide justification for their choice, e.g. Equal volumes of 0.002 M solutions of sodium iodate and cupric chlorate are mixed together. Will it lead to the precipitation of copper iodate? (For cupric iodate $K_{sp} = 7.4 \times 10^{-8}$)

COGNITIVE DOMAIN – CREATE

'Create' involves combining elements to form a coherent or functional whole, or reorganizing elements into a new pattern or structure. Generating, planning and producing are the specific cognitive skills associated with this cognitive domain. Tasks that require students to produce new artefacts based on what they have learnt, e.g. You are provided with common laboratory apparatus and the following chemicals: iron powder zinc powder aqueous ammonia distilled water. Describe how, zinc sulphate crystals can be obtained from a solid sample of zinc sulphate containing copper (II) sulphate as impurity. (Not all chemicals must be used.)

ASSESSMENT TASKS FOR DIFFERENT COGNITIVE DOMAINS

Some more examples of kinds of assessment tasks that can be associated with the different cognitive domains are given below. The following list should be taken as an indicative not an exhaustive one.

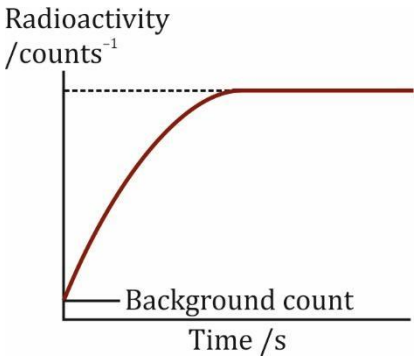
Cognitive domain	Assessment tasks
Remember • recognizing • recalling	• recognizing the symbols of chemical elements, IUPAC names, Name, reactions etc • recalling the dates of historical chemical innovations • defining scientific terms, laws, factors, processes etc.
Understand • exemplifying • classifying • summarizing • inferring • comparing • explaining	• giving examples to substantiate any theory/concept • classification of elements/compounds/processes based on the physical/chemical properties • summarizing any scientific discovery/process/principles and their development • comparing elements/compounds/solutions in terms of their reactivity and other characteristics • explaining the reasoning behind the physical/chemical properties/nature of elements/compounds/reactants/products/catalyst, etc
Apply • executing • implementing	• identify the relevant information and rules to arrive at a solution and solve problems using known algorithms. • relate scientific laws/definitions/processes to solve problems and provide explanations in different situations
Analyze • differentiating • organizing • attributing	• interpretation and analysis of graphic representation, diagrams, and reaction mechanisms by mapping to scientific laws/concepts • differentiate between physical and chemical properties, concepts, laws using qualitative or quantitative data/information. • Identify or formulate questions that can be answered by a given experiment or scientific investigation.

Evaluate • checking • critiquing	• make judgements about the value or merits of an idea, purpose, solution to a problem, procedure, method or product. • checking the reasonableness of the solution and critiquing of different chemical methods • evaluate conclusions drawn from a scientific investigation/laws
Create • generating • planning • producing	• generating a hypothesis and verifying it using experiments • design a scientific model/solution illustrating different concepts of chemistry • writing scientific essays/journals and communicate it effectively

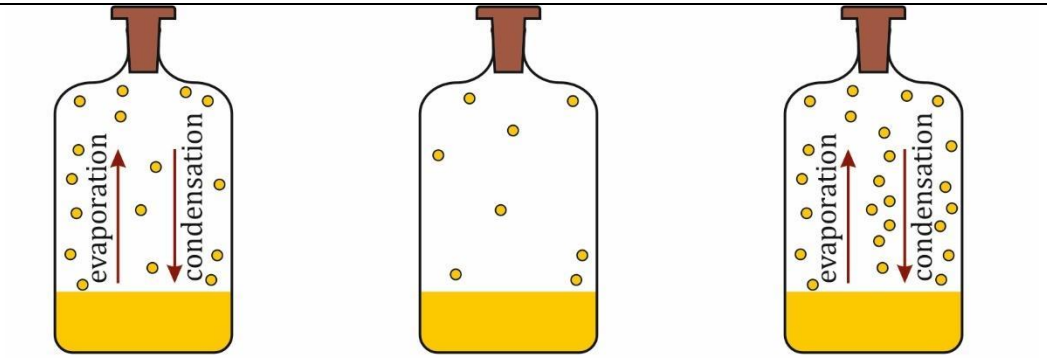
SAMPLE TASKS FROM DIFFERENT COGNITIVE DOMAINS SPECIFIC TO A CONTENT UNIT

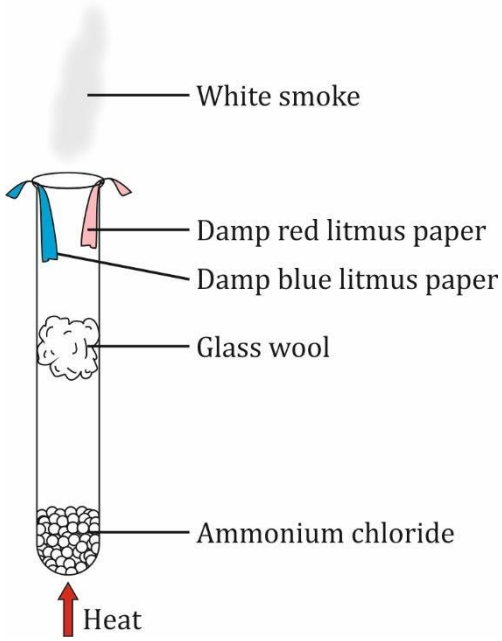
Some specific examples of tasks from different cognitive domains are described below for two content chapters from classes 11 and 12 NCERT chemistry textbooks. A chapter may not always cover all six cognitive domains. The following list of tasks should be taken as an indicative list, not a comprehensive one.

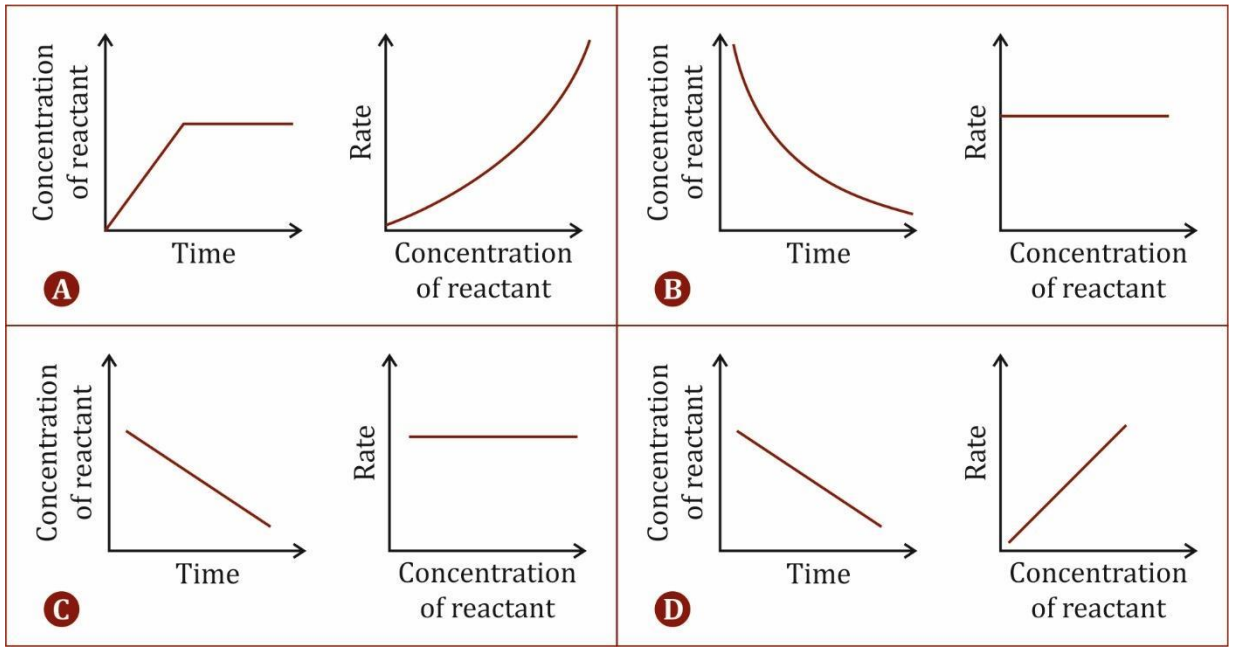
CHAPTER (EQUILIBRIUM)– CLASS: XI

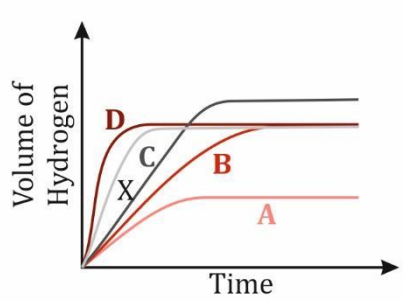
Cognitive domain	Sample tasks
Remember	i. Describe the effect of temperature changes on the equilibrium constant if the forward reaction is exothermic in nature. ii. Predict the effect of adding a catalyst on the time taken to reach equilibrium.
Understand	iii. The graph below shows the radioactivity of the saturated solution of $PbCl_2$ eventually reaches the constant value. Why is this?  iv. One of the key factors which dictate the position of equilibrium in physical or chemical processes is the tendency for materials to exist in the lowest energy state. Will equilibrium ever be achieved in the waterfall shown below?

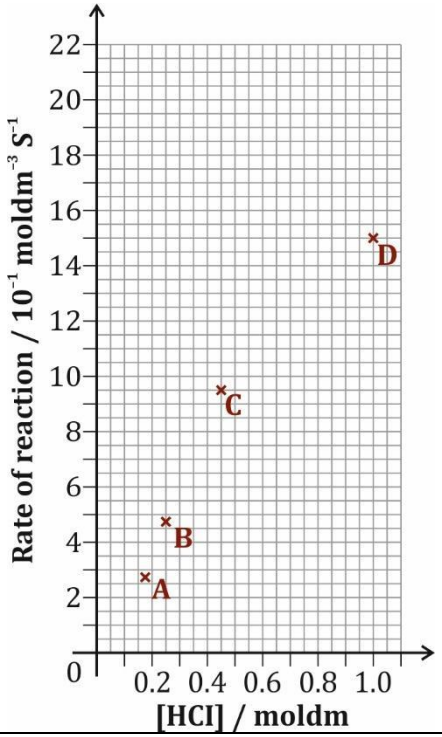
	
Apply	• The following equilibria is established in this bottle of sparkling water.  $CO_2(g) \rightleftharpoons CO_2(aq)$ $CO_2(aq) + H_2O(I) \rightleftharpoons HCO_3(aq) + H^+(aq)$ • In the above case, why is the screw cap important for the equilibria inside the bottle? • Explain what happens to the acidity of the sparkling water when the cap is opened.
Analyse	• The image below shows liquid-vapour equilibria of bromine liquid and bromine vapor in three different cases.

	 **(a) Equilibrium** rate of evaporation = rate of condensation **(b) Imbalance** gas removed from vapour phase **(c) Imbalance** gas added to vapour phase Rate of condensation > rate of evaporation (i) Will the rate of condensation of gas molecules still be equal to the rate of evaporation of liquid molecules in Figure (b)? Explain. (ii) What happens to the concentration of molecules in the gas phase as time goes on? Explain.
Evaluate	● The image below shows what happens when ammonium chloride is heated forming ammonia and hydrogen chloride. The red litmus paper first turns blue, and then both pieces of litmus paper turn red.

	 (i) Which gas is detected first and why? (i) Why do the gases produced separate as they pass up the tube through glass wool?
Create	• Indian Oil Corporation (IOC) is worried about the impurity, M, in its petrol. 1 dm^3 of petrol contains 5g of M. In an effort to reduce the concentration of M in the petrol, IOC discovered a secret solvent S. The k_{pc}(partial coefficient) of M between petrol and s is 0.01 at room temperature (298 K). Explain how you will use the above information to help IOC to extract impurities from the petrol. • Using the above information, what will be the total mass of M removed from 1 dm^3 of petrol by shaking it with 100 cm3 of solvent S at 298 K?

Cognitive domain	Sample tasks
Remember	v. Which of the following will affect the rate at which a candle burn? Explain. i. the temperature of the air ii. the shape of the candle. iii. the air pressure. iv. the length of the wick vi. State two other factors that will affect the rate at which candle burn.
Understand	• Which of the following pairs of graphs represents the same order of reaction? 

Apply	● The graph below shows the volume of hydrogen produced during different reactions between Mg and HCl. Curve X is obtained when 1 g of Mg ribbon reacts with 100 cm3 (excess) of HCl at 30 ^{0}c.  Which curve would you expect to obtain if: (i) 1 g of Mg ribbon reacts with 100 cm3 of the same acid at 50 ^{0}c. (ii) 1 g of Mg ribbon reacts with 100 cm3 of the same acid at 15 ^{0}c. ● Sketch the reaction profile which fits the following data. Note that compound A is converted to compound C via B which can be isolated. A → B ΔH is positive. B → C ΔH is negative.
Analyse	● Calcium carbonate decomposes to CaO and CO2 as shown below: CaCO3 ----> CaO + CO2 Liya took two different forms (as shown below) of CaCO3 as reactants to carry out this reaction and compare the rate of reaction for these two forms. In both forms, the mass of CaCO3 is the same.

	  Form I Form II (i) Compare the rate of reaction for forms I and II by drawing the graphs of the mass of the products against time. (ii) Explain the reason behind getting the same/different curve for both these two forms.
Evaluate	• Rohit wants to check how the rate of the reaction shown below is affected by changing the concentration of HCl. $CaCO3\ (s) + 2HCl(aq) \rightarrow CaCl2\ (aq) + H2O(l) + CO2\ (g)$ He took 4 readings of the rate of reaction vs concentration and plotted them as shown below. 

	(i) Based on his readings and assuming there is no human error, give one reason for point D being so far away from the other three points A, B, and C. (ii) Draw the best fit line for the above reaction.
Create	• Design an experiment to investigate the effect of acid concentration on the weathering of limestone, which is mainly calcium carbonate.

5. LEARNING OUTCOMES

"Competency based Learning focuses on the student's demonstration of desired learning outcomes as central to the learning process. Learning outcomes are statements of abilities that are expected students will gain as a result of learning the activity. Learning outcomes are, thus, statements of what a learner is expected to know, understand and/or be able to demonstrate after completion of a process of learning. Therefore, the focus is on measuring learning through attainment of prescribed learning outcomes, rather than on measuring time."

[Senior School Curriculum, CBSE]

Following learning outcomes for the senior secondary stage developed by the National Council for Educational Research and Training (NCERT) state important knowledge, skills and dispositions students need to attain at the end of an academic year in classes 11 and 12 in the context of learning chemistry.

CLASS 11 LEARNING OUTCOMES FOR CHEMISTRY

(1) differentiates technical terms/ phenomena/ processes, based on, properties/ characteristics, such as, gaseous state and vapours; atomic and molecular masses; extensive and intensive properties; close, open and isolated systems; alkanes, alkenes and alkynes; aliphatic and aromatic compounds etc.

(2) classifies materials/ phenomena/ processes, based on, properties/characteristics, such as, elements, compounds and mixtures; elements into metals, metalloids and non – metals; s, p, d, f blocks; organic compounds on the basis of functional groups; substances as acids or bases according to Arrhenius, Bronsted -Lowry and Lewis concepts etc

(3) plans and conducts investigations/ experiments/projects to arrive at and verify the facts/ principles/ phenomena or to seek answers to queries on their own, such as, what will be the melting point of oxalic acid? Is there any difference in the pH of apple juice and pineapple juice? What is the effect of dilution on pH of acid/base? Does rate of evaporation of different liquids depend on density, mass, surface tension, viscosity, humidity and temperature of the surroundings? Etc

(4) takes appropriate precautionary measures (do's and don'ts) while handling apparatus, chemicals during laboratory work such as use of safety glasses; wearing of laboratory coat; handling chemicals safely and judiciously; handling glass wares; performs reactions with harmful gases in fuming hood; discard or disposal of chemicals and broken glass wares properly etc.

(5) relates processes and phenomena with causes/ effects, such as, variation of pH of the solution with the hydrogen ion concentration; water is liquid whereas hydrogen sulphide is gas; ozone layer depletion causes skin cancer, eutrophication and its adverse effects,

(6) explains scientific terms/ factors / laws / theories governing processes and phenomena, such as, bonding in three states of matter; various laws of chemical combination; discovery of electron, proton and neutron; photoelectric effect; Periodic Law; characteristic of metals, non-metals and metalloids; VSEPR Theory to explain the shapes of molecules; Types of hydrogen bonding; ionization of water and its dual role as acid and base; ; hard and soft water; bonding in allotropic forms of carbon; spontaneous and nonspontaneous processes; various factors affecting the equilibrium state of a reaction; preparation of hydrocarbons; aromaticity; mechanism of substitution reactions; cause of atmospheric pollution etc handles tools and laboratory apparatus properly;

(7) draws diagrams/ flow charts/ concept map/graphs, such as, Lewis structures of simple molecules; draw shapes of simple covalent molecules based on different types of hybridisation involving s, p and d orbitals; geometry of simple molecules on the basis of VSEPR theory; setup of experiments; flow chart of classification of matter, organic compounds etc.; graphs on pressure-volume relationship, volume temperature relationship, pressure temperature relationship etc.

(8) derives equations, such as, gas laws; second law of thermodynamics etc.

(9) analyses and interprets graph/figure, such as variation of atomic radius with atomic number; variation of ionization enthalpies with atomic number; geometry of molecules etc.

(10) calculates using the data given, such as, mass per cent of different elements constituting a compound; wavelength of electromagnetic radiation; energy changes as work and heat contributions in chemical systems; enthalpy changes for various types of reactions; solubility product constant etc.

(11) uses scientific conventions, symbols, chemical formulae, chemical equations as per international standards such as, SI units; symbols and names of elements; formulae of chemical compounds; chemical equations; electronic configurations of atoms; names of organic compounds (according to IUPAC) etc.

(12) measures physical quantities using appropriate apparatus, such as, mass of chemical/object using analytical balance; volume of liquid using pipette, burette, volumetric flask, measuring cylinder; temperature using thermometer etc

(13) takes initiative to know about scientific discoveries/ inventions, such as, fundamental particles in an atom; discovery of various atomic models; development of Periodic Table; discovery of VSEP; synthesis of urea R; etc

(14) appreciates the contribution of ancient chemistry of India and its role in different spheres of life such as, ancient India knowledge of chemistry was applied in metallurgy, medicine, manufacture of cosmetics, glass, dyes, baked bricks, pottery etc.

(15) realizes and appreciates the interface of chemistry with other disciplines, such as with Physics, Biology, Mathematics, Geology, Geography; Pharmaceutical Science etc. Chemistry helps in understanding the chemical reactions happening inside the living organisms; chemical composition of rocks, soil; simple mathematical equations etc

(16) applies scientific concepts in daily life and solving problems, such as weather patterns; manufacturing fertilisers; alkalis, acids, salts, dyes, polymers, drugs, soaps, detergents; metals; alloys; health care products; effects of pesticides; acid rain, green houses gases; use of heavy metals etc.

(17) exhibits creativity in designing models using eco- friendly resources and out of box thinking in solving problems, such as, 3-D model of sodium chloride structure; 3 D molecular models of organic molecules; models of Periodic Table; water purification; garbage management etc.

(18) exhibits values of honesty/ objectivity/ rational thinking/ freedom from myth/superstitious beliefs while taking decisions, respect for life, etc., such as, records and reports experimental data honestly; listens to others patiently; open-mindedness; questioning attitude

(19) communicates the findings and conclusions effectively, such as, those of experiment/ activity/ project orally and in written form using appropriate figures/ tables/ graphs/ digital forms, etc.

(20) makes efforts to conserve environment such as, causes of ozone layer depletion; reasons for water pollution; causes of soil pollution; appreciates the importance of green chemistry; responsibility as a human being to protect environment; judicious use of chemical; use of micro-scale experimental techniques wherever possible s etc.

CLASS 12 LEARNING OUTCOMES FOR CHEMISTRY

(1) differentiates technical terms /phenomena/ processes, based on properties/ characteristics, such as molecularity and order of a reaction; ionic and electrical conductivity; ideal and nonideal solutions; amorphous and crystalline solids; DNA and RNA etc.

(2) classifies materials/ phenomena/ processes, based on, properties/ characteristics such as, crystalline solids on the basis of their properties ;primary, secondary and tertiary alcohols; primary, secondary and tertiary amines; various types of polymers etc.

(3) plans and conducts projects/ investigations/ experiments/ to arrive at and verify the facts/ principles/ phenomena or to seek answers to queries on their own, such as, How many pigments are present in the spinach leaves or rose flower or marigold flower? What will be the amount of oxalate ions in guava fruit at different stages of ripening? What are the functional groups present in an organic compound? Whether different samples of milk contain same or different quantity of casein? etc.

(4) takes appropriate precautionary measures (do's and don'ts) while handling apparatus, chemicals during laboratory work such as use of safety glasses; wearing of laboratory coat; handling chemicals safely and judiciously; handling glass wares; performs reactions with harmful gases in fuming hood; discard or disposal of chemicals and broken glass wares properly etc.

(5) relates processes and phenomena with causes/ effects, such as, the electrical and magnetic properties of solids and their structure; physical properties of alcohol, phenol and ethers with their structures; physical and chemical reactions of aldehyde, ketones and carboxylic acids with their structures etc.

(6) explains scientific terms/ factors/ laws/ theories governing processes and phenomena, such as, the terms minerals, ores, roasting, calcification ,refining etc; close packing of particles; Henry's law and Raoult's law; preparation, properties and uses of di-oxygen, ozone, chlorine and some important compounds ; allotropic forms of sulphur; properties and characteristics of dblock and f- block elements; preparation and properties of haloalkanes, haloarens, alcohols, phenols, ethers , aldehydes, ketones etc; structure of carbohydrate, proteins and nucleic acids; types of polymers and their functions etc.

(7) draws structures of molecules/ diagrams/ flow charts/ concept map/graph/tables, such as, Daniell cell, Cottrell smoke precipitator; set up of froth flotation process; Blast furnace; structure of sulphuric acid, sulphurous acid, manufacture of sulphuric acid; structures of protein, DNA etc.; flow chart for the manufacture of ammonia and extraction of metals etc ; electronic configuration of outer shell of transition elements in tabular form; properties of different type of solids in tabular form; Freundlich adsorption isotherm in graphic form; etc

(8) derives/ writes expression for equations, such as, integrated rate law for the zero order and first order reactions; Raoult's law; etc.

(9) analyses and interprets data/ graph/figure, such as interprets graph for predicting order of reaction; interprets figure showing effect of catalyst on activation energy; analyses data to explain tends in melting points of organic compounds , atomic radii of transition elements, ionic radii of lanthanoids etc.

(10) calculates using the data given, such as, packing efficiency of different types of cubic unit cells; concentration of solutions; Henry's law constant; emf of galvanic cells using Nernst equation; calculates values for standard electrode potential ; calculates rate constant of a reaction etc.

(11) uses scientific conventions, symbols, chemical formulae, chemical equations as per international standards such as, SI units; symbols and names of elements; formulae of chemical compounds; chemical equations; electronic configurations of atoms; name the compounds according to IUPAC system etc.

(12) measures physical quantities using appropriate apparatus, such as mass of chemical/object using analytical balance; volume of liquid using pipette, burette, volumetric flask, measuring cylinder; temperature using thermometer etc.

(13) takes initiative to know about scientific discoveries/ inventions such as in ancient India chemistry was called Rasayan Shastra, Rastantra, Ras Kriyaor Ras vidya., discovery of optical activity in certain coordination compounds; Grignard reagents; structure of DNA; cracking the genetic code etc.

(14) appreciates the contribution of ancient chemistry of India and its role in different spheres of life such as, ancient India knowledge of chemistry was applied in metallurgy, medicine, manufacture of cosmetics, glass, dyes, baked bricks, pottery etc.

(15) realizes and appreciates the interface of chemistry with other disciplines, such as with Physics, Biology, Mathematics, Geology, Geography etc. Chemistry helps in understanding the role of bio molecules in bio-system; chemical composition of rocks, soil etc

(16) applies scientific concepts in daily life and solving problems, such as role of alcohol as hand sanitizer; role of polymers (polyester, rubber, nylon etc); antacids to treat acidity; tranquilizers to treat stress; antibiotics to treat infection; antifertility drugs to control population; artificial sweetening agents for diabetic people; food preservatives prevent food spoilage; cleaning action of soap etc.

(17) exhibits creativity in designing models using eco- friendly resources and out of box thinking in solving problems, such as, 3-D model of graphite, diamond; 3 D molecular models of organic compounds; Daniell cell; DNA model etc.

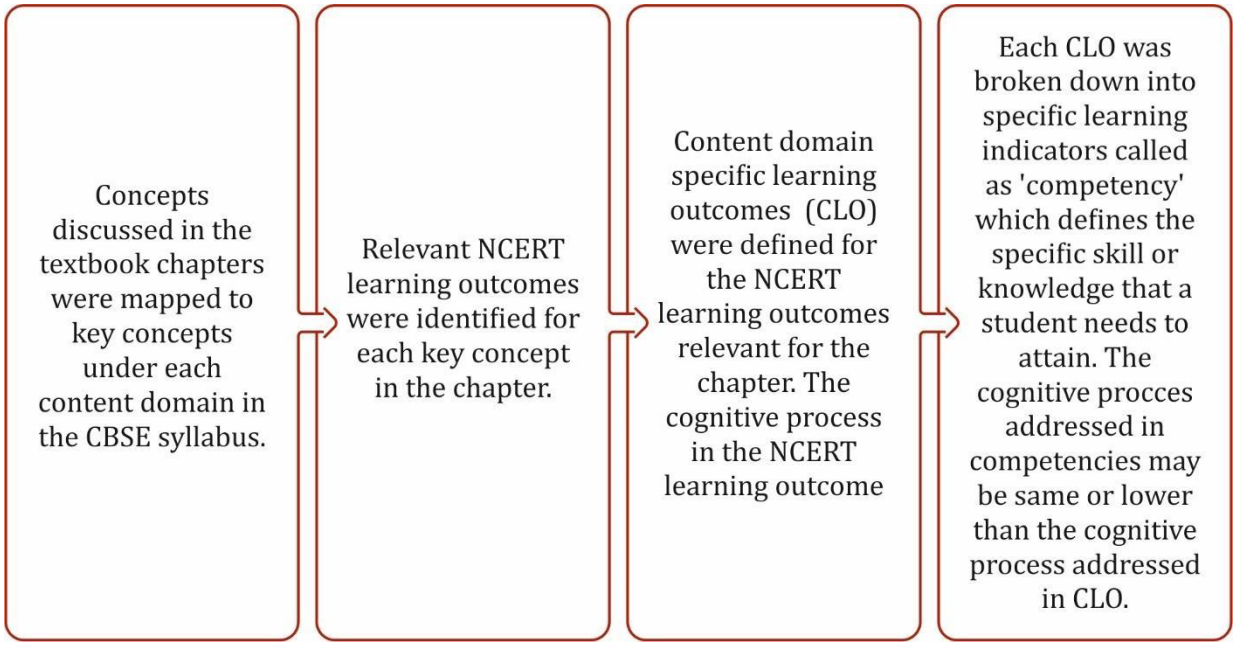
(18) exhibits values of honesty/ objectivity/ rational thinking/ freedom from myth/superstitious beliefs while taking decisions, respect for life, etc., such as, records and reports experimental data honestly; listens to others patiently; open-mindedness; questioning attitude

(19) communicates the findings and conclusions effectively, such as, those of experiment/ activity/ project orally and in written form using appropriate figures/ tables/ graphs/ digital form, etc.

(20) makes efforts to conserve environment, such as, judicious use of chemicals; keep surrounding clean; use of biodegradable soaps and polymers; use of micro-scale experimental techniques wherever possible etc.

6. CONTENT DOMAIN SPECIFIC LEARNING OUTCOMES AND INDICATORS

The learning outcomes defined by NCERT are generic and broadly defined for the content defined in the curriculum. They articulate the discipline-specific skills students need to attain through learning different concepts in the syllabus. A clear understanding of the scope of these learning outcomes for each concept dealt with in the NCERT textbook chapters will be very helpful for both teachers and students in planning teaching and learning better. The following process has been followed to list the content domain-specific learning outcomes (CLOs) and competencies for all the content units and textbook chapters.



CLASS 11 CONTENT DOMAIN SPECIFIC LEARNING OUTCOMES AND INDICATORS

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain-specific learning outcome	Indicators
1. Basic concepts of chemistry	Development of Chemistry	(14) appreciates the contribution of ancient chemistry of India and its role in different spheres of life	CLO1 explore and appreciates the earliest chemical process, in which materials were mixed, moulded and alchemy to transmute from one chemical to others	C1 explore and appreciate the development of metallurgy, chemicals for multiple purposes, medicines from ancient Indian extracts.
		(15) realizes and appreciates the interface of chemistry with other disciplines		C2 understand the role of chemistry in different spheres of life such as metallurgy, medicine, manufacture of cosmetics, glass, dyes, etc
	States of matter	(1) differentiates technical terms/ phenomena/ processes, based on, properties/ characteristics	CLO2explain the characteristics of three states of matter	C3 Explain the difference among solid, liquid, gases based on the arrangement of particles
		(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO2apply the characteristics of states of matter for our advantages in daily life	C4 explore the storage process of LPG cylinders, shaving creams, and oxygen cylinders used by scuba divers based on the compressibility of gases
	Nature of matter	(1) differentiates technical terms/ phenomena/ processes, based on, properties/ characteristics	CLO3 classify different substances into elements, compounds and mixtures	C5 differentiate between Pure substances and mixtures

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain-specific learning outcome	Indicators
1. Basic concepts of chemistry		(1) differentiates technical terms/ phenomena/ processes, based on, properties/ characteristics	CLO3 classify different substances into elements, compounds and mixtures	C6 understand the difference between homogenous and heterogenous mixtures
		(6) explains scientific terms/factors/laws/theories governing processes and phenomena		C7 Explain compounds and elements based on the combination of atoms and molecules
		(1) differentiates technical terms/ phenomena/ processes, based on, properties/ characteristics		C8 Compare and contrast the freezing time of the same amount of cold water and warm water.
	Properties of matter and their measurement	(5) relates processes and phenomena with causes/ effects	CLO4 define SI base units and convert physical quantities from one system of units to another	C9 Understand the importance of maintaining a standard for the measurement of physical properties of matter
		(11) uses scientific conventions, symbols, chemical formulae, chemical equations as per international standards	CLO5 define SI base units and convert physical quantities from one system of units to another	C10 describe seven base physical quantity with their symbols and SI units with symbols
				C11 explain the prefix used in the SI system
	Mass and weight	(1) differentiates technical terms/ phenomena/ processes, based on, properties/ characteristics	CLO5 define SI base units and convert physical quantities from one system of units to another	C12 differentiate between mass and weight along with their SI units
	Volume	(11) uses scientific conventions, symbols, chemical formulae, chemical	CLO5 define SI base units and convert physical quantities	C13 understand different units used to measure volume and their relationship

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain-specific learning outcome	Indicators
1. Basic concepts of chemistry		equations as per international standards	from one system of units to another	
		(12) measures physical quantities using appropriate apparatus		C14 differentiate among different apparatus used to measure volume of a liquid in a lab
	Density	(8) derives equations	CLO5 define SI base units and convert physical quantities from one system of units to another	C15 Calculate the SI unit of density using the density formula
	Temperature	(8) derives equations	CLO5 define SI base units and convert physical quantities from one system of units to another	C16 understand three scales for measuring temperature and their relationship using equations
		(10) calculates using the data given		C17 calculate the room temperature, freezing/boilingpoint of water, normal human body temperature using all the three scales
	Scientific notation	(11) uses scientific conventions, symbols, chemical formulae, chemical equations as per international standards	CLO6 use scientific notations and determine significant figures	C18 convert a decimal number in terms of scientific notation
	Scientific notation	(10) calculates using the data given	CLO6 use scientific notations and determine significant figures	C19 perform multiplication/division using the scientific notation

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain-specific learning outcome	Indicators
1. Basic concepts of chemistry				C20 performs addition/subtraction using the scientific notation
	significant figures	(6) explains scientific terms/factors/laws/theories governing processes and phenomena	CLO6 use scientific notations and determines significant figures	C21 explain significant figures and their importance
		(11) uses scientific conventions, symbols, chemical formulae, chemical equations as per international standards		C22 apply the rules for identifying significant figures to find the significant figure of a measurement
		(6) explains scientific terms/factors/laws/theories governing processes and phenomena		C23 collate the shooting data of two Olympic field archers from an Olympic game and compare the precision and accuracy of their shoots.
		(11) uses scientific conventions, symbols, chemical formulae, and chemical equations as per international standards		C24 performs addition and subtraction of significant figures
		(11) uses scientific conventions, symbols, chemical formulae, and chemical equations as per international standards		C25 performs multiplication and division of significant figures
	Dimensional analysis	(11) uses scientific conventions, symbols, chemical formulae, chemical	CLO7 define SI base units and convert physical quantities	C26 Convert measurement from one unit to other

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain-specific learning outcome	Indicators
1. Basic concepts of chemistry		equations as per international standards	from one system of units to another	(example cm to inch, day to seconds)
	Laws of chemical combination	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO8 explain various laws of chemical combination	C27 explain the law of conservation of mass
				C28 explain the law of definite proportion
				C29 explain the law of multiple proportion
				C30 explain Gay Lussac's Law of Gaseous Volumes
				C31 explain Avogadro law
				C32 understand and explain Dalton's atomic theory
	Atomic Mass	(10) calculates using the data given	CLO9appreciate significance of atomic mass, average atomic mass, molecular mass and formula mass	C33 explain unified mass (u) and calculate atomic mass
	Atomic Mass	(10) calculates using the data given	CLO9appreciate significance of atomic mass, average atomic mass, molecular mass and formula mass	C34 calculate average atomic mass
	Molecular mass			C35 calculate molecular mass of any molecule
	formula mass			C36 calculate formula mass of any ionic compound

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain-specific learning outcome	Indicators
1. Basic concepts of chemistry	Mole concept		CLO10 describe the terms – mole and molar mass	C37 calculate mole concept using Avogadro constant
	Percentage combination of elements			C38 calculate mass percentage of different elements in a molecule using molar mass
	Empirical and molecular formula	(8) derives equations	CLO11 calculate the mass per cent of component elements constituting a compound	C39 derive the empirical and molecular formula using the mass percentage of elements
	Stoichiometry and Stoichiometric Calculations	(1) differentiates technical terms/ phenomena/ processes, based on, properties/ characteristics		C40 differentiate between reactants and products in an equation
	Stoichiometry and Stoichiometric Calculations	(10) calculates using the data given		C41 Identify stoichiometric coefficients in a balanced chemical equation
		(6) explains scientific terms/ factors / laws / theories governing processes and phenomena		C42 apply stoichiometric coefficients to understand the limiting reagent in a chemical equation
	Reaction in solution	(10) calculates using the data given	CLO11 calculate the mass per cent of component elements constituting a compound	C43 calculate mass percentage of different elements using mass of solute and solvent
			CLO12determine empirical formula and molecular formula for a compound from the given experimental data	C44 calculate mole fraction of a component in a solution

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain-specific learning outcome	Indicators
1. Basic concepts of chemistry		(3) plans and conducts projects/ investigations/ experiments/ to arrive at and verify the facts/ principles/ phenomena or to seek answers to queries on their own	CLO11 calculate the mass per cent of component elements constituting a compound	C45 investigate the relative atomic mass of magnesium using its reaction with dilute hydrochloric acid to give hydrogen gas.
		(10) calculates using the data given	CLO12determine empirical formula and molecular formula for a compound from the given experimental data	C46 calculate the molality of a solution
2. Structure of atom	Sub-atomic particles	(3) plans and conducts investigations/ experiments/projects to arrive at and verify the facts/ principles/ phenomena or to seek answers to queries on their own	CLO13 know about the discovery of the electron, proton and neutron and their characteristics	C47 understand the working of cathode ray discharge tube and result of the experiment
				C48 analyse the relationship among electric filed/magnetic field, electric charge, mass and deviation of a charged particle in a field
2. Structure of atom		(10) calculates using the data given	CLO13 know about the discovery of the electron, proton and neutron and their characteristics	C49 calculate the charge to mass ratio of an electron
		(3) plans and conducts investigations/ experiments/projects to arrive at and verify the facts/ principles/ phenomena or to seek answers to queries on their own	CLO13 know about the discovery of the electron, proton and neutron and their characteristics	C50 explain the process of oil drop experiment and determine the charge on an electron

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain-specific learning outcome	Indicators
2. Structure of atom		(3) plans and conducts investigations/ experiments/projects to arrive at and verify the facts/ principles/ phenomena or to seek answers to queries on their own	CLO13 know about the discovery of electron, proton and neutron and their characteristics	C51 explain the characteristics of positive charged particles in cathode ray tube experiment
		(1) differentiates technical terms/ phenomena/ processes, based on, properties/ characteristics	CLO13 know about the discovery of electron, proton and neutron and their characteristics	C52 differentiate among protons, electrons and neutrons
	Atomic model	(3) plans and conducts investigations/ experiments/projects to arrive at and verify the facts/ principles/ phenomena or to seek answers to queries on their own	CLO14 describe Thomson, Rutherford and Bohr atomic models	C53 describe Thompson's model of an atom and its significance
				C54 describe Rutherford's experiment and key findings from it
		(6) explains scientific terms/ factors / laws / theories governing processes and phenomena		C55 differentiate between Thomson's model and Rutherford's nuclear model of atom
		(10) calculates using the data given		C56 Determine atomic number and mass number of an atom
		(1) differentiates technical terms/ phenomena/ processes, based on, properties/ characteristics		C57 differentiate between isotopes/isobars

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain-specific learning outcome	Indicators
2. Structure of atom	Bohr's model of atom	(5) relates processes and phenomena with causes/ effects	CLO14 describe Thomson, Rutherford and Bohr atomic models	C58 Understand the wave nature of electromagnetic radiation
		(2) classifies materials/ phenomena/ processes, based on, properties/characteristics		C59 understand different types of electromagnetic radiation and its frequency-wavelength spectrum
		(10) calculates using the data given		C60 apply wavelength formula to calculate wavelength, frequency, wave number
	Planck's Quantum Theory	(5) relates processes and phenomena with causes/ effects	CLO15 understand nature of electromagnetic radiation and Planck's quantum theory	C61 explain the phenomena black body radiation and its relation to particle nature of electromagnetic radiation
		(8) derives equations		C62 Understand Planck's quantum theory, and energy equation with Planck's constant
	Photoelectric effect	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO16 explain the photoelectric effect and describe features of atomic spectra	C63 explain photoelectric effect, and the importance of threshold frequency for it
		(8) derives equations		C64 derive the relationship between kinetic energy and frequency of radiation
	Duality of light	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO15 understand nature of electromagnetic radiation and Planck's quantum theory	C65 explain the duality of light: wave nature and particle nature

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain-specific learning outcome	Indicators
2. Structure of atom	Atomic Spectra	(1) differentiates technical terms/ phenomena/ processes, based on, properties/ characteristics	CLO15 understand nature of electromagnetic radiation and Planck's quantum theory	C66 explain the difference between emission and absorption spectrum
		(6) explains scientific terms/ factors / laws / theories governing processes and phenomena		C67 understand the formation of a spectrum from a white light through a prism
	Atomic Spectra	(10) calculates using the data given	CLO15 understand nature of electromagnetic radiation and Planck's quantum theory	C68 understand Lyman, Balmer, Paschen, Brackett, Pfund series of spectral lines described by Rydeberg's formula
	Bohr's model of hydrogen atom	(5) relates processes and phenomena with causes/ effects	CLO14 describe Thomson, Rutherford and Bohr atomic models	C69 explain the concept of orbit and derive the formula for angular momentum
		(8) derives equations		C70 Derive the formula for Bohr's frequency rule
		(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO14 describe Thomson, Rutherford and Bohr atomic models	C71 describe the quantum nature of angular momentum of an electron
		(10) calculates using the data given		C72 apply the formula for calculating energy of stationary states
		(5) relates processes and phenomena with causes/ effects		C73 understand the limitations of Bohr's model

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain-specific learning outcome	Indicators
2. Structure of atom	Quantum mechanical model	(8) derives equations	CLO16 state the de Broglie relation, Heisenberg uncertainty principle and Schrodinger's Wave Equation	C74 understand the de Broglie relationship between wavelength and momentum
				C75 describe Heisenberg's uncertainty principles with the help of mathematical equation
	Quantum mechanical model	(6) explains scientific terms/factors/laws/theories governing processes and phenomena	CLO16 state the de Broglie relation, Heisenberg uncertainty principle and Schrodinger's Wave Equation	C76_i apply Schrodinger's Wave Equation to understand the wave nature of electrons in space-time
		(6) explains scientific terms/factors/laws/theories governing processes and phenomena		C76_ii draw and analyze graph of Probability density of Electrons in different orbitals and types of nodes.
		(5) relates processes and phenomena with causes/ effects	CLO17 define an atomic orbital in terms of quantum numbers	C77 understand atomic orbital in terms of quantum number
		(5) relates processes and phenomena with causes/ effects		C78 understand the relation between number of orbitals and principal, azimuthal, spin quantum numbers
		(7) draws diagrams/ flow charts/ concept map/graphs		C79 draw shapes of different atomic orbitals
		(7) draws diagrams/ flow charts/ concept map/graphs		C80 draw energy level diagram of different orbitals and explain the terms degenerate, ground, excited states

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain-specific learning outcome	Indicators
2. Structure of atom	Orbitals	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO18 state Aufbau principle, Pauli exclusion principle and Hund's rule of maximum multiplicity	C81 apply Aufbau Principle for order offilling of orbitals
	Orbitals	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO19 state Aufbau principle, Pauli exclusion principle and Hund's rule of maximum multiplicity	C82 understand Pauli Exclusion Principle for filling orbitals
		(11) uses scientific conventions, symbols, chemical formulae, chemical equations as per international standards	CLO20 state Aufbau principle, Pauli exclusion principle and Hund's rule of maximum multiplicity	C83 understand Hund's rule for multiple multiplicity
		(7) draws diagrams/ flow charts/ concept map/graphs	CLO21 write the electronic configurations of atoms	C84 write electronic configuration of an atom
3. Classification of Elements & Periodicity in Properties	Periodic classification	(2) classifies materials/ phenomena/ processes, based on, properties/characteristics	CLO22 appreciate how the concept of grouping elements in accordance to their properties led to the development of Periodic Table.	C85 understand the purpose of the classification of elements
		(6) explains scientific terms/factors/laws/theories governing processes and phenomena		C86 explain the law of octaves and triads for periodic classification
		(1) differentiates technical terms/ phenomena/ processes, based on properties/ characteristics	CLO23 understand the significance of atomic number and electronic configuration as the basis for periodic classification	C87 explain the modification done in modern periodic tablecompared to Mendeleev's table

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain-specific learning outcome	Indicators
3. Classification of Elements & Periodicity in Properties		(11) uses scientific conventions, symbols, chemical formulae, chemical equations as per international standards	CLO24name the elements with Z >100 according to IUPAC nomenclature	C88 apply IUPAC nomenclature to identify the name of elements having atomic number greater than 100
	Electronic configuration	(11) uses scientific conventions, symbols, chemical formulae, chemical equations as per international standards	CLO25 understand the significance of atomic number and electronic configuration as the basis for periodic classification	C89 identify number of electrons, shells/orbitals and write electronic configuration based on period number
				C90 write electronic configuration of the elements present in the same group
		(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO26 classify elements into s, p, d, f blocks and learn their main characteristics	C91 understand the properties of s, p, d, and f block elements and write down their electronic configuration
	Periodic trends in properties of elements	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO27 recognise the periodic trends in physical and chemical properties of elements	C92 explain properties of metals, non-metals, metalloids based on the four blocks in periodic table
			CLO28 use scientific vocabulary appropriately to communicate ideas related to certain important properties of atoms e.g., atomic/ ionic radii, ionization enthalpy, electron gain enthalpy, electronegativity, valence of elements.	C93 understand the trend in atomic radius across groups and periods
				C94 understand the concept of ionic radius and explain cation and anion
				C95 understand different levels of ionisation enthalpy

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain-specific learning outcome	Indicators
3. Classification of Elements & Periodicity in Properties				in an element and explain shielding/screening effect
	Periodic trends in properties of elements	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO28 use scientific vocabulary appropriately to communicate ideas related to certain important properties of atoms e.g., atomic/ ionic radii, ionization enthalpy, electron gain enthalpy, electronegativity, valence of elements.	C96 understand different levels of electron gain enthalpy in an element and its periodic trends
				C97 understand electronegativity and its periodic trends
			CLO29 compare the reactivity of elements and correlate it with their occurrence in nature	C98 understand oxidation states and their periodicity
		(5) relates processes and phenomena with causes/ effects	CLO30 recognise the periodic trends in physical and chemical properties of elements	C99 understand the relation betweenchemical properties and size, charge, radius, electronegativity of second period elements
	Chemical reactivity of elements	(5) relates processes and phenomena with causes/ effects	CLO31 compare the reactivity of elements and correlate it with their occurrence in nature	C100 understand the trends in chemical reactivity of an element across groups and periods
				C101 explain the acidic/basic nature of oxide based on chemical reaction with water

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain-specific learning outcome	Indicators
4. Chemical bonding and Molecular structure	Chemical bonding	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO32 understand the KÖssel-Lewis approach to chemical bonding	C102 understand the KÖssel-Lewis approach to chemical bonding;
			CLO33 explain the Octet rule and its limitations, draw Lewis structures of simple molecules	C103 understand octet rule for chemical bonding
		(7) draws diagrams/ flow charts/ concept map/graphs	CLO34 explain the formation of different types of bonds	C104 understand how covalent bonds are formed using Lewis representation
				C105 draw Lewis dot structure of molecules and calculate formal charge on the element
		(6) explains scientific terms/factors/laws / theories governing processes and phenomena		C106 appreciate the limitation of octet rule
		(5) relates processes and phenomena with causes/ effects		C107 apply the concept of ionisation and electron gain enthalpy to understand the formation of ionic bond
				C108 understand lattice enthalpy in its application in formation of ionic bonds
	Bond parameters	(5) relates processes and phenomena with causes/ effects	CLO34 explain the formation of different types of bonds	C109 apply the concept of covalent and vander wall radii to calculate bond length

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain-specific learning outcome	Indicators
4. Chemical bonding and Molecular structure		(3)plans and conducts projects/ investigations/ experiments/ to arrive at and verify the facts/ principles/ phenomena or to seek answers to queries on their own		C110 Investigate the enthalpy change of thermal decomposition of potassium hydrogen-carbonate
		(6) explains scientific terms/ factors / laws / theories governing processes and phenomena		C111 explain about resonance structure with the help of resonance diagram
	Polarity	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO34 explain the formation of different types of bonds	C112 understand dipole moment and calculate dipole moments of molecules such as water, HF, etc
		(5) relates processes and phenomena with causes/ effects	CLO34 explain the formation of different types of bonds	C113 explain why dipole moment of NH_3 is higher than NF_3
				C114 understand the character of bond based on the size of cation and anion
	VSEPR theory	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO35 describe the VSEPR theory and predict the geometry of simple molecules	C115 understand the postulates of VSEPR theory
	VSEPR theory	(5) relates processes and phenomena with causes/ effects	CLO35 describe the VSEPR theory and predict the geometry of simple molecules	C116 apply VSEPR theory to describe the shapes of molecules

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain-specific learning outcome	Indicators
4. Chemical bonding and Molecular structure	Valence bond theory	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO36 explain the valence bond approach for the formation of covalent bonds	C117 understand and apply valence bond theory to understand different forces acting during formation of a bond
				C118 explain the potential energy curve for the formation of H_2 molecule
		(5) relates processes and phenomena with causes/ effects	CLO37 predict the directional properties of covalent bonds	C119 apply VBT to explain the formation and directional properties of bonds in polyatomic molecules like CH_4 NH_3 and H_2O, etc. in terms of overlapping and hybridisation of atomic orbitals
	Orbital overlap	(7) draws diagrams/ flow charts/ concept map/graphs	CLO37 predict the directional properties of covalent bonds	C120 understand and draw diagrams for positive, negative and zero overlap of atomic orbitals
		(5) relates processes and phenomena with causes/ effects		C121 explain why CH_4 is tetrahedral in shape
	Orbital overlap	(7) draws diagrams/ flow charts/ concept map/graphs	CLO38 explain the different types of hybridisation involving s, p and d orbitals and draw shapes of simple covalent molecules	C122 understand the formation of sigma bond using s-s overlap, s-p overlap and p-p axial overlap
		(6) explains scientific terms/ factors / laws / theories		C123 explain the formation of pie bond using p-p side by side overlap

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain-specific learning outcome	Indicators
4. Chemical bonding and Molecular structure		governing processes and phenomena		C124 differentiate between the strength of sigma and pie bond
	Hybridisation	(7) draws diagrams/ flow charts/ concept map/graphs	CLO38 explain the different types of hybridisation involving s, p and d orbitals and draw shapes of simple covalent molecules	C125 understand various types of hybridisation involving s, p, d orbitals by deciphering Lewis dot structure of a molecule
				C126 draw orbital diagram with electron spins to elaborate hybridisation involving d orbitals
	Molecular orbital theory	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO39 describe the molecular orbital theory of homonuclear diatomic molecules	C127 understandmolecular orbital theory along with bonding and anti-bonding molecular orbitals
				C128 appreciate the conditions for the combination of atomic orbitals
		(7) draws diagrams/ flow charts/ concept map/graphs		C129 draw energy level diagram of molecular orbitals using MOT

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain-specific learning outcome	Indicators
4. Chemical bonding and Molecular structure	Molecular orbital theory	(10) calculates using the data given	CLO39 describe the molecular orbital theory of homonuclear diatomic molecules	C130 calculate bond order of a molecule on the basis of MOT
	Hydrogen bonding	(6) explains scientific terms/factors/laws / theories governing processes and phenomena	CLO40 explain the concept of hydrogen bond.	C131 explain how hydrogen bonds are formed in a molecule
				C132 differentiate between intramolecular and inter-molecular hydrogen bond
5. Chemical Thermodynamics	Thermodynamic terms	(1) differentiates technical terms/ phenomena/ processes, based on properties/ characteristics	CLO41 explain the terms: system and surroundings	C133 explain systems and surroundings and differentiate between them
		(6) explains scientific terms/factors/laws/theories governing processes and phenomena	CLO42 discriminate between close, open and isolated systems	C134 differentiate among open system, closed systems and isolated system
		(1) differentiates technical terms/ phenomena/ processes, based on, properties/ characteristics	CLO43 explain state functions: U, H.	C135 explain different state functions of a thermodynamic system
	State of system	(8) derives equations	CLO44 explain internal energy, work and heat	C136 prove that internal energy of a system is a state function
	Laws of thermodynamics	(6) explains scientific terms/ factors / laws / theories	CLO45 state first law of thermodynamics and express it mathematically	C137 state and derive first of thermodynamics

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain-specific learning outcome	Indicators
5. Chemical Thermodynamics		governing processes and phenomena		
	Laws of thermodynamics	(8) derives equations	CLO45 state first law of thermodynamics and express it mathematically	C138 apply first law of thermodynamics and derive the relation between work, pressure and volume
		(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO46 calculate energy changes as work and heat contributions in chemical systems	C139 explain reversible and irreversible process and derive the equation of work done by the system for both these processes
		(8) derives equations		C140 derive a relationship between work and heat
		(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO47 differentiate between extensive and intensive properties	C141 differentiate between extensive and intensive properties of systems
	Heat capacity	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO48 calculate energy changes as work and heat contributions in chemical systems	C142 define specific heat capacity and derive the equation for it
	Reaction enthalpy	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO49 calculate enthalpy changes for various types of reactions	C143 describe enthalpy change for a reaction and define standard enthalpy
				C144 calculate standard enthalpy of formation
	Hess's law	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO50 state and apply Hess's law of constant heat summation	C145 define Hess's law and derive the equation of Hess law of constant heat summation

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain-specific learning outcome	Indicators
5. Chemical Thermodynamics	Enthalpies for different reactions	(8) derives equations	CLO50 state and apply Hess's law of constant heat summation	C146 derive the equation for standard enthalpy for combustion and atomisation
		(10) calculates using the data given		C147 calculate bond enthalpy for diatomic and polyatomic molecules
		(8) derives equations		C148 calculate lattice enthalpy using Born-Haber cycle
				C149 calculate enthalpy of solution and dilution
	Spontaneity	(8) derives equations	CLO51 define spontaneous and nonspontaneous processes	C150 explain spontaneity and define criteria for spontaneity
		(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO52 explain entropy as a thermodynamic state function and apply it for spontaneity	C151 explain entropy and derive entropy equation
			CLO53 explain Gibbs energy change (ΔG)	C152 derive the equation for Gibbs energy and correlate this with reaction spontaneity
	Entropy and second law of thermodynamics	(5) relates processes and phenomena with causes/ effects	CLO54 establish the relationship between ΔG and spontaneity, ΔG and equilibrium constant.	C153 Apply Gibbs entropy to understand the second and third laws of thermodynamics

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain-specific learning outcome	Indicators
6. Equilibrium	Dynamic nature of equilibrium	(1) differentiates technical terms/ phenomena/ processes, based on, properties/ characteristics	CLO55 identify the dynamic nature of equilibrium involved in physical and chemical processes;	C154 differentiate between chemical and ionic equilibrium
		(6) explains scientific terms/factors/laws/theories governing processes and phenomena		C155 explain the equilibria existing between solid and liquid using examples
				C156 explain the equilibria existing between vapor and liquid using examples
				C157 explain the equilibria existing between solid and vapor using examples
				C158 appreciate the equilibrium involving dissolution of solids or gases in liquid
		(2) classifies materials/ phenomena/ processes, based on, properties/characteristics		C159 identify characteristics of Equilibria Involving Physical Processes
	Dynamic nature of equilibrium	(3) plans and conducts investigations/ experiments/projects to arrive at and verify the facts/ principles/ phenomena or to seek answers to queries on their own	CLO55 identify dynamic nature of equilibrium involved in physical and chemical processes;	C160 demonstrate dynamic nature of equilibrium using test tubes and coloured water

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain-specific learning outcome	Indicators
6. Equilibrium	Equilibrium constant	(8) derives equations	CLO56 state the law of equilibrium;	C161 derive the equation for equilibrium constant using the law of chemical equilibrium for any reaction
			CLO57write expressions for equilibrium constants;	C162 derive the relationship between equilibrium constant for gaseous systems
		(5) relates processes and phenomena with causes/ effects	CLO58 establish a relationship between K_p and K_c ;	C163 establish a relationship between equilibrium constants K_p and K_c
		(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO59 explain various factors that affect the equilibrium state of a reaction;	C164 appreciate the application of equilibrium constants
	Le Chatelier's principle	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO59 explain various factors that affect the equilibrium state of a reaction;	C165 identify and explain factors effecting equilibrium using Le Chatelier's principle
	Acids and Bases	(2) classifies materials/ phenomena/ processes, based on, properties/characteristics	CLO60classify substances as acids or bases according to Arrhenius, Bronsted-Lowry and Lewis concepts;	C166 Classify substances as acids and bases on the basis of Arrhenius Concept of Acids and Bases
				C167 Classify substances as acids and bases on the basis of The Bronsted-Lowry Acids and Bases
				C168 Classify substances as acids and bases on the basis of Lewis Acids and Bases

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain-specific learning outcome	Indicators
6. Equilibrium			CLO61 classify acids and bases as weak or strong in terms of their ionization constants;	C169 calculate ionisation constant and apply it to classify acids and bases as weak or strong
		(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO62 classify acids and bases as weak or strong in terms of their ionization constants;	C170 evaluate factors affecting the acidic strength of a molecule
	Buffer solution	(8) derives equations	CLO63 appreciate use of buffer solutions;	C171 derive Henderson–Hassel Balch equation for buffer solution and explain its significance
	Hydrolysis of salts	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO64 describe pH scale for representing hydrogen ion concentration;	C172 describe hydrolysis of salt and identify pH of their solution
	Ionisation		CLO65 explain ionisation of water and its duel role as acid and base;	C173 describe ionisation of water and its acidic and basic properties in different circumstances
			CLO66 describe ionic product (K_w) and pK_w for water;	C174 explain common ionic effects on the solubility of ionic salts
7. Redox reactions	Basics of redox reaction	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO67 identify redox reactions as a class of reactions in which oxidation and reduction reactions occur simultaneously	C175 infer redox reaction in terms of electron transfer reactions
				C176 analyse a reaction and identify which element goes through oxidation or reduction

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain-specific learning outcome	Indicators
7. Redox reactions				C177 identify oxidising and reducing agent in any reaction
	Oxidation number		CLO67 define the terms oxidation, reduction, oxidant (oxidising agent) and reductant (reducing agent)	C178 calculate oxidation number of an element in terms of electron transfer
	Types of redox reaction	(2) classifies materials/ phenomena/ processes, based on, properties/characteristics	CLO68 classify redox reaction	C179 classify redox reaction into combination (synthesis), decomposition, displacement and disproportionation reactions
	Oxidation number	(5) relates processes and phenomena with causes/ effects	CLO69 balance chemical equations using (i) oxidation number (ii) half reaction method	C180 apply the concept of oxidation number to balance any redox reactions
	Application of redox reaction		CLO70learn the concept of redox reactions in terms of electrode processes.	C181 apply the concept of oxidation and reduction to explain electrode potential and reactions in an electrochemical cell; apply redox reactions in other walks/subjects such as understanding fermentation, food spoiling, burning of fossils, etc
8. Organic Chemistry: Basic	Shape, hybridisation and structural	(9) analyses and interprets graph/figure	CLO71 understand reasons for tetravalence of carbon and shapes of organic molecules	C182 interpret shape, hybridisation and structure representation of carbon compounds

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain-specific learning outcome	Indicators
principles and techniques	representation of carbon compounds			
	IUPAC nomenclature	(2) classifies materials/ phenomena/ processes, based on properties/characteristics	CLO72 name the compounds according to IUPAC system of nomenclature and also derive their structures from the given names	C183 classify and give the naming of organic compounds in trivial and IUPAC system
				C184 outline the names of compounds with functional groups using IUPAC system
8. Organic Chemistry: Basic principles and techniques	Isomerism	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO72 name the compounds according to IUPAC system of nomenclature and also derive their structures from the given names	C185 explain about different types of isomerism exhibited by organic compounds
	Electrophilic and nucleophilic reactions	(1) differentiates technical terms/ phenomena/ processes, based on properties/ characteristics	CLO73 recognise the types of organic reactions	C186 differentiate between electrophilic and nucleophilic reactions
	Resonance effect	(5) relates processes and phenomena with causes/ effects	CLO74 explain the influence of electronic displacements on structure and reactivity of organic compounds	C187 apply electron displacement effect to explain resonance structure and resonance effect
	Electromeric effect	(5) relates processes and phenomena with causes/ effects	CLO74 explain the influence of electronic displacements on structure and reactivity of organic compounds	C188 apply electron displacement effect to explain electrometric effect
	Hyperconjugation effect	(5) relates processes and phenomena with causes/ effects	CLO74 explain the influence of electronic displacements	C189 apply electron displacement effect to explain hyperconjugation

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain-specific learning outcome	Indicators
			on structure and reactivity of organic compounds	
8. Organic Chemistry: Basic principles and techniques	Purification of organic compounds	(3) plans and conducts investigations/ experiments/projects to arrive at and verify the facts/ principles/ phenomena or to seek answers to queries on their own	CLO75learn the techniques of purification of organic compounds	C190 define and conduct experiments based on the nature of organic compound to purify using different techniques with esp. focussing on types of chromatography and distillation and its types
	Qualitative analysis of organic compound	(3) plans and conducts investigations/ experiments/projects to arrive at and verify the facts/ principles/ phenomena or to seek answers to queries on their own	CLO75 learn the techniques of purification of organic compounds	C191 perform elemental detection test to detect carbon, hydrogen, sulphur, halogens etc in an organic compound
		(10) calculates using the data given		C192 calculate percentage of carbon, hydrogen, nitrogen and other elements in any organic compound
9. Hydrocarbons	IUPAC nomenclature	(2) classifies materials/ phenomena/ processes, based on, properties/characteristics	CLO75 name hydrocarbons according to IUPAC system of nomenclature	C193 List the different kinds of hydrocarbons according to common and IUPAC nomenclature
	Structure of hydrocarbons	(2) classifies materials/ phenomena/ processes, based on, properties/characteristics	CLO76 recognise and write structures of isomers of alkanes, alkenes, alkynes and aromatic hydrocarbons	C194 Identify and write the structures of isomers of aliphatic and aromatic hydrocarbons

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain-specific learning outcome	Indicators
9. Hydrocarbons	Preparation of hydrocarbon	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO77 learn about various methods of preparation of hydrocarbons	C195 explain reaction mechanism for the preparation of hydrocarbons using different chemical reactions
	Preparation of hydrocarbons	(1) differentiates technical terms/ phenomena/ processes, based on, properties/ characteristics	CLO78 distinguish between alkanes, alkenes, alkynes and aromatic hydrocarbons on the basis of physical and chemical properties	C196 discuss on the preparations and properties of alkanes, alkenes, alkynes and arenes
	Isomerism	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO79 predict the formation of the addition products of unsymmetrical alkenes and alkynes on the basis of electronic mechanism	C197 define Geometrical isomers(cis-trans) arising due to the restricted rotation along C=C
	Resonance and extra stability of benzene through resonance structure	(5) relates processes and phenomena with causes/ effects	CLO80 comprehend the structure of benzene, explain aromaticity and understand mechanism of electrophilic substitution reactions of benzene	C198 Explain resonance and extra stability of benzene through resonance structure
	Functional groups	(5) relates processes and phenomena with causes/ effects	CLO81 predict the directive influence of substituents in monosubstituted benzene ring	C199 predict the directive influence of functional groups on the aromatic ring system
	Carcinogenicity and toxicity in hydrocarbons	(6) explains scientific terms/factors/laws/theories governing processes and phenomena	CLO82 learn about carcinogenicity and toxicity.	C200 explain carcinogenicity and toxicity in aromatic hydrocarbons

CLASS 12 CONTENT DOMAIN SPECIFIC LEARNING OUTCOMES AND INDICATORS

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain specific learning outcome	Indicators
1. Solutions	Concentration units	(8) derives equations	CLO1 express concentration of solution in different units	C1 express the concentration of the solution in terms of mass percentage
				C2 express the concentration of the solution in terms of mole fraction
				C3 express the concentration of the solution in terms of molarity
				C4 express concentration of the solution in terms of molality
	Henry's and Raoult's law	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO2state and explain Raoult's law	C5 explain solubility of a solid in liquid and liquid in liquid and factors affecting them
				C6 Explain solubility of a gas in liquid and factors affecting them
	Ideal and non-ideal solution	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO3 distinguish between ideal and non-ideal solutions	C7 Apply Raoult's law to explain the conditions for ideal and non-ideal solutions; Differentiate between minimum and maximum boiling azetropic mixtures

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain specific learning outcome	Indicators
1. Solutions	Colligative properties of solution	(5) relates processes and phenomena with causes/ effects	CLO4 describe colligative properties of solutions and correlate these with molar masses of the solutes	C8 Explain colligative property and determine molar mass of solute using relative lowering of vapor pressure, depression of freezing point, elevation of boiling point, and osmotic pressure
	Osmosis and reverse osmosis	(3) plans and conducts projects/ investigations/ experiments/ to arrive at and verify the facts/ principles/ phenomena or to seek answers to queries on their own	CLO5 explain abnormal colligative properties exhibited by some solutes in solutions.	C9 Design an experimental setup to apply osmotic and reverse osmotic pressure to extract pure water to sugar solution inside a cut potato.
2. Electrochemistry	Electrochemical cell	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO6 Describe the formation of different type of cell	C10 describe an electrochemical cell and differentiate between Galvanic and electrolytic cells
	Nernst equation	(5) relates processes and phenomena with causes/ effects	CLO6 Describe the formation of different type of cell	C11 apply Nernst equation for calculating the emf of Galvanic cell and define standard potential of the cell
	Electrolytic conductivity and molar conductivity	(8) derives equations	CLO7 Find the cell potential of electrochemical cell using Nernst equation	C12 derive relation between standard potential of the cell, Gibbs energy of cell reaction and its equilibrium constant
		(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO8Understand conductivity and molar conductivity and effect of dilution	C13 explain resistivity (ρ), conductivity (κ) and molar conductivity (m) of ionic solutions

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain specific learning outcome	Indicators
2. Electrochemistry	Electrolytic conductivity and molar conductivity	(1) differentiates technical terms/ phenomena/ processes, based on, properties/ characteristics	CLO8Understand conductivity and molar conductivity and effect of dilution	C14 differentiate between ionic (electrolytic) and electronic conductivity
		(5) relates processes and phenomena with causes/ effects		C15 describe the method for measurement of conductivity of electrolytic solutions and calculation of their conductivity and molar conductivity
				C16 justify the variation of conductivity and molar conductivity of solutions with change in their concentration and define Λ°m (molar conductivity at zero concentration or infinite dilution)
	Kohlrausch law	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO8Understand conductivity and molar conductivity and effects of dilution on them	C17 enunciate Kohlrausch law and analyse the quantitative aspects of electrolysis
	Electrolysis	(19) communicates the findings and conclusions effectively	CLO8conduct an experiment to predict the outcome during electrolysis	C18 predict the identities of substances liberated during electrolysis from the state of electrolyte (molten or aqueous), position in the redox series (electrode potential) and concentration

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain specific learning outcome	Indicators
2. Electrochemistry	Fuel Cells and Batteries	(16) applies scientific concepts in daily life and solving problems	CLO9 examine fuel cells and batteries structure and working in daily life	C19 Examine the construction and functioning of some primary and secondary batteries and fuel cells
	Corrosion	(5) relates processes and phenomena with causes/ effects	CLO10 Explain the chemistry behind corrosion	C20 extrapolate the knowledge of the electrochemical process to explain corrosion.
3. Chemical kinetics	Types of reactions	(1) differentiates technical terms/ phenomena/ processes, based on, properties/ characteristics	CLO11 Define different types of reactions	C21 Distinguish between slow ,fast and moderate reaction
	Average rate of reaction	(1) differentiates technical terms/ phenomena/ processes, based on, properties/ characteristics	CLO12 define the average and instantaneous rate of reaction	C22 differentiate between the average and instantaneous rate of a reaction
	Rate equation	(8) derives equations	CLO13 deriverate equation	C23 express the rate of a reaction in terms of change in concentration of either of the reactants or products with time
	Types of reactions	(1) differentiates technical terms/ phenomena/ processes, based on, properties/ characteristics	CLO14 Define different types of reactions	C24 distinguish between elementary and complex reactions
	order of reaction	(1) differentiates technical terms/ phenomena/ processes, based on, properties/ characteristics	CLO15 Discuss the factors affecting the rate of reaction	C25 differentiate between the molecularity and order of a reaction

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain specific learning outcome	Indicators
3. Chemical kinetics	Rate constant	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO13 deriverate equation	C26 define rate constant on the basis of rate equation using reactants and products
	Rate of reaction	(3) plans and conducts projects/ investigations/ experiments/ to arrive at and verify the facts/ principles/ phenomena or to seek answers to queries on their own	CLO15 Discuss the factors affecting the rate of reaction	C27investigate a chemical reaction for the effect of temperature, catalyst and concentration on rate
	Rate equation for different orders of reactions	(8) derives equations	CLO13 deriverate equation	C28 derive integrated rate equations for the zero and first order reactions
	Rate constant and order of reaction	(8) derives equations	CLO12 define the average and instantaneous rate of reaction	C29 determine the rate constants for zero and first order reactions
	Collision theory	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO16 Understand the collision theory	C30 describe collision theory
4. d and f block elements	Position of transition elements	(5) relates processes and phenomena with causes/ effects	CLO17 learn the positions of the d– and f-block elements in the periodic table	C31 Justify the position of the d-and f-blocks of elements in the periodic table
	Electronic configuration of transition metals	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO18 know the electronic configurations of the transition (d-block) and the inner transition (f-block) elements	C32 write down the electronic configuration of transition elements

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain specific learning outcome	Indicators
4. d and f block elements	Physical and chemical characteristics of d block elements	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO19 understand the general characteristics of the d– and f–block elements and the general horizontal and group trends in them	C33 appreciate the trends in melting points and ionisation enthalpies of d block elements
		(5) relates processes and phenomena with causes/ effects		C34 predict the variation in the atomic and ionic sizes of transition metals
	Variable oxidation number	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO19 understand the general characteristics of the d– and f–block elements and the general horizontal and group trends in them	C35 elaborate the reason behind the variable oxidation states of most of the transition metals
	Electrode potential	(9) analyses and interprets graph/figure	CLO19 understand the general characteristics of the d– and f–block elements and the general horizontal and group trends in them	C36 interpret the graph showing standard electrode potential for transition metals
	Oxidation states	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO20appreciate the relative stability of various oxidation states in terms of electrode potential values describe the preparation, properties, structures and uses of some important compounds such as $K_2Cr_2O_7$ and $KMnO_4$	C37 deduce the reason why transition elements are stable in highest oxidation states
	Magnetic properties of transition metals	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO19 understand the general characteristics of the d– and f–block elements and the general horizontal and group trends in them	C38 identify the magnetic properties of transition metals

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain specific learning outcome	Indicators
4. d and f block elements	Complex compounds	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO19 understand the general characteristics of the d– and f–block elements and the general horizontal and group trends in them	C39 deduce the reason why transition elements suited for complex compounds and catalysts
	Preparation of metal oxides	(3) plans and conducts investigations/ experiments/projects to arrive at and verify the facts/ principles/ phenomena or to seek answers to queries on their own	CLO20appreciate the relative stability of various oxidation states in terms of electrode potential values describe the preparation, properties, structures and uses of some important compounds such as $K_2Cr_2O_7$ and $KMnO_4$	C40 know the different methods used to obtain chromium and Mn compounds
	Properties and trends of f-block elements	(2) classifies materials/ phenomena/ processes, based on, properties/characteristics	CLO19 understand the general characteristics of the d– and f–block elements and the general horizontal and group trends in them	C41 Describe the properties oflanthanoids and actinoids
		(1) differentiates technical terms/ phenomena/ processes, based on, properties/ characteristics	CLO21 describe the properties of the f-block elements and give a comparative account of the lanthanoids and actinoids with respect to their electronic configurations, oxidation states and chemical behaviour..	C42 distinguish between lanthanoids and actinoids
	Properties and trends of f-block elements	(6) explains scientific terms/factors/laws/theories governing processes and phenomena		C43 Describe the cause and consequence of lanthanoids contraction
	Werner's theory	(6) explains scientific terms/factors/laws/theories governing processes and phenomena	CLO22 appreciate the postulates of Werner's theory of coordination compounds	C44 describe different postulates of Werner's theory for the formation of coordination compounds

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain specific learning outcome	Indicators
5. Coordination compounds	Werner's theory	(1) differentiates technical terms/ phenomena/ processes, based on, properties/ characteristics	CLO22 appreciate the postulates of Werner's theory of coordination compounds	C45 differentiate between double salt and complex compounds
	Coordination entity	(1) differentiates technical terms/ phenomena/ processes, based on, properties/ characteristics	CLO23 know the meaning of the terms: coordination entity, central atom/ ion, ligand, coordination number, coordination sphere, coordination polyhedron, oxidation number, homoleptic and heterolytic	C46 differentiate between coordination entity, central atom, and ligands of complex compounds
	Coordination number	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena		C47 identify coordination number of central atom
	Coordination polyhedron	(7) draws diagrams/ flow charts/ concept map/graphs		C48 draw the coordination polyhedron for different compounds
	Oxidation number of central atom	(10) calculates using the data given		C49 calculate the oxidation number of central atom
	Homolyptic and hetrolyptic complex compounds	(1) differentiates technical terms/ phenomena/ processes, based on, properties/ characteristics	CLO23 know the meaning of the terms: coordination entity, central atom/ ion, ligand, coordination number, coordination sphere, coordination polyhedron, oxidation number, homoleptic and heterolytic	C50 differentiate between homolyptic and hetrolyptic complex compounds

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain specific learning outcome	Indicators
5. Coordination compounds	IUPAC nomenclature	(11) uses scientific conventions, symbols, chemical formulae, chemical equations as per international standards	CLO24 learn the rules of nomenclature of coordination compounds	C51 write the IUPAC names of complex compounds
	Isomerism	(7) draws diagrams/ flow charts/ concept map/graphs	CLO25 define different types of isomerism in coordination compounds	C52 illustrate isomerism of complex compounds using their structure and identify their types
	Valance bond theory	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO26 understand the nature of bonding in coordination compounds in terms of the Valence Bond and Crystal Field theories	C53 apply valance bond theory to explain the formation of coordination compounds
	Magnetic properties of complexes	(5) relates processes and phenomena with causes/ effects		C54 predict the magnetic properties of coordination compounds
	Crystal field theory	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena		C55 appreciate the limitation of VBT theory and apply crystal field theory to explain coordination complexes
	Synergic bond	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO26 understand the nature of bonding in coordination compounds in terms of the Valence Bond and Crystal Field theories	C56 appreciate the significance of synergic bonding in certain carbonyl complexes
5. Coordination compounds	Application of complex compounds	(16) applies scientific concepts in daily life and solving problems	CLO27 apply and appreciate the importance and applications of coordination compounds in our day-to-day life	C57 demonstrate ligands exchange reactions and infer compounds through color change; list the importance of coordination compounds in

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain specific learning outcome	Indicators
				daily life such as colors in stained glass dragonfly, etc
6. Haloalkanes and haloarenes	IUPAC nomenclature of haloalkanes and arenes	(11) uses scientific conventions, symbols, chemical formulae, chemical equations as per international standards	CLO28 name haloalkanes and haloarenes according to the IUPAC system of nomenclature from their given structures	C58 write the trivial and IUPAC name of Haloalkanes and Haloarenes.
	Preparation of Haloalkanes	(6) explains scientific terms/factors/laws/theories governing processes and phenomena	CLO29 describe the reactions involved in the preparation of haloalkanes and haloarenes and understand various reactions that they undergo	C59 explain the reaction mechanism for the preparation of haloalkanes from alcohols and hydrocarbons
		(6) explains scientific terms/factors/laws/theories governing processes and phenomena	CLO30 correlate the structures of haloalkanes and haloarenes with various types of reactions	C60 apply electrophilic substitution and Sandmeyer's reaction for the preparation of haloarenes
	Preparation of Haloalkanes	(3) plans and conducts projects/ investigations/ experiments/ to arrive at and verify the facts/ principles/ phenomena or to seek answers to queries on their own	CLO30 correlate the structures of haloalkanes and haloarenes with various types of reactions	C61 carry out specific tests on three unknown compounds that contain halide ions, and use the results to identify the ions present
	Reaction mechanism for	(6) explains scientific terms/ factors / laws /		C62 apply nucleophilic substitution reaction to

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain specific learning outcome	Indicators
6. Haloalkanes and haloarenes	haloalkanes and arenes	theories governing processes and phenomena	CLO31 use stereochemistry as a tool for understanding the reaction mechanism	explain the reaction with haloalkanes
				C63 apply elimination reaction to explain the reaction with haloalkanes
				C64 identify chiral and achiral molecules
				C65 predict the product when haloalkanes and arenes react with a metal
				C66 apply nucleophilic substitution reaction to explain the reaction with haloarenes
	Application of haloalkanes and arenes	(16) applies scientific concepts in daily life and solving problems	CLO32 appreciate the applications of organo-metallic compounds	C67 appreciate the application of halogen compounds in real life
		(4) takes appropriate precautionary measures (do's and don'ts) while handling apparatus, chemicals during laboratory work	CLO33 highlight the environmental effects of polyhalogen compounds	C68 list out different environmental hazards and depletion of ozone layers owing to adverse effects of polyhalogen compounds
	IUPAC nomenclature of alcohols, phenols, ethers	(11) uses scientific conventions, symbols, chemical formulae, chemical equations as per international standards	CLO34 name alcohols, phenols and ethers according to the IUPAC system of nomenclature	C69 write the trivial and IUPAC name of alcohols, phenols,ethers

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain specific learning outcome	Indicators
7. Alcohols, phenols and ethers	Preparation of alcohol	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO35 discuss the reactions involved in the preparation of alcohols from alkenes, aldehydes, ketones and carboxylic acids	C70.explain the reactions involved in the preparationof alcohol using alkenes
				C71 explain the reactions involved in the preparationof alcohol using aldehydes
				C72 explain the reactions involved in the preparation of alcohol using ketones
				C73 explain the reactions involved in the Preparation of phenol using haloarenes
	Preparation of phenol	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO35 discuss the reactions involved in the preparation of phenols from haloarenes, benzene sulphonic acids, diazonium salts and cumene	C74 explain the reactions involved in the preparation of phenol using benzene sulphonic acids
				C75 explain the reactions involved in the preparation of phenol using diazonium salt
				C76 explain the reactions involved in the preparation of phenol using cumene
	Preparation of ether	(6) explains scientific terms/factors/laws / theories governing processes and phenomena	CLO35 discuss the reactions for preparation of ethers from (i) alcohols and (ii) alkyl halides and sodium alkoxides/aryloxides	C77 explain the reactions involved in the preparation of ethers using alcohols
				C78 explain the reactions involved in the preparation of ethers using alkyl halides

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain specific learning outcome	Indicators
7. Alcohols, phenols and ethers				C79 explain the reactions involved in the preparation of ethers using alkoxides/aryloxides
	Physical properties	(3) plans and conducts projects/ investigations/ experiments/ to arrive at and verify the facts/ principles/ phenomena or to seek answers to queries on their own	CLO36 correlate physical properties of alcohols, phenols and ethers with their structures to investigate the products	C80 investigate to identify the functional groups in four unknown organic compounds, P, Q, R and S, containing oxygen. Note that each of the four compounds contains three carbon atoms. (i) Test for hydroxyl groups using phosphorus pentachloride (ii) Investigating compounds that do contain a hydroxyl group
	Chemical reaction	(5) relates processes and phenomena with causes/ effects	CLO37 discuss chemical reactions of the three classes of compounds on the basis of their functional groups.	C81 elaborate electrophilic substitution and cleavage of C-O bond to describe the reaction mechanism for ethers and other compounds
	IUPAC nomenclature of aldehydes, ketones, and carboxylic acids	(11) uses scientific conventions, symbols, chemical formulae, chemical equations as per international standards	CLO38 write the common and IUPAC names of aldehydes, ketones and carboxylic acids	C82 write the trivial and IUPAC name of aldehydes, ketones and carboxylic acids

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain specific learning outcome	Indicators
8. Aldehydes, ketones and carboxylic acids	Structure of carboxyl groups	(7) draws diagrams/ flow charts/ concept map/graphs	CLO39 write the structures of the compounds containing functional groups namely carbonyl and carboxyl groups	C83 apply the orbital diagram to draw the structure of carbonyl and carboxyl groups compounds
	Preparation of aldehydes	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO40 describe the important methods of preparation and reactions of these classes of compounds correlate physical properties and chemical reactions of aldehydes, ketones and carboxylic acids, with their structures	C84 describe the reaction mechanism for the preparation of aldehydes using Etard reaction, Rosenmund reduction, Stephen reaction, Gatterman – Koch reaction
	Preparation of ketones	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena		C85 describe the reaction mechanism for the preparation of ketons using Friedel-Crafts acylation reaction and acyl chlorides
	Physical and chemical characteristics of aldehydes and ketones	(1) differentiates technical terms/ phenomena/ processes, based on, properties/ characteristics		C86 differentiate between physical and chemical properties of aldehydes and ketones
	Preparation of carboxylic acids	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO40 describe the important methods of preparation and reactions of these classes of compounds correlate physical properties and chemical reactions of aldehydes, ketones and carboxylic acids, with their structures	C87 describe the reaction mechanism for the preparation of carboxylic acids using alkyl benzenes, alcohols and aldehydes, Grignard reagents, nitriles and amides, esters, etc

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain specific learning outcome	Indicators
8. Aldehydes, ketones and carboxylic acids	Physical and chemical characteristics of Carboxylic acids	(2) classifies materials/ phenomena/ processes, based on, properties/characteristics	CLO41 understand various factors affecting the acidity of carboxylic acids and their reactions	C88 describe the physical and chemical properties of carboxylic acids
	Application of aldehydes, ketones, acids	(16) applies scientific concepts in daily life and solving problems	CLO42 describe the uses of aldehydes, ketones and carboxylic acids	C89 appreciate the usage of compounds of aldehydes, ketones, carboxyl acids in daily life
9. Amines	Structure of amines	(6) explains scientific terms/factors/laws/theories governing processes and phenomena	CLO43 describe amines as derivatives of ammonia having a pyramidal structure	C90 describe the structure of amine using orbital diagram
	Classification of amines	(2) classifies materials/ phenomena/ processes, based on, properties/characteristics	CLO44 classify amines as primary, secondary and tertiary	C91 classify amines as primary, secondary and tertiary depending upon the number of hydrogen atoms replaced by alkyl or aryl groups in ammonia molecule
	IUPAC nomenclature of amines	(11) uses scientific conventions, symbols, chemical formulae, chemical equations as per international standards	CLO45 name amines by common names and IUPAC system	C92 apply IUPAC nomenclature to write the names of amines
	preparation of amines	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO46 describe some of the important methods of preparation of amines	C93 describe the reaction mechanism to prepare amines using reduction of nitro compounds, nitriles, amiles,

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain specific learning outcome	Indicators
9. Amines				Gabriel phthalimide synthesis,ammonolysis of alkyl halides, and Hoffmann bromamide degradation reaction
	Physical and chemical properties of amines	(2) classifies materials/ phenomena/ processes, based on, properties/characteristics	CLO47explain the properties of amines	C94 describe the physical and chemical properties of amines
	Diazotisation	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena	CLO48 describe the method of preparation of diazonium salts and their importance in the synthesis of a series of aromatic compounds including azo dyes.	C95 elaborate on the reaction mechanism for diazotisation
	Preparation of diazonium salt	(6) explains scientific terms/factors/laws / theories governing processes and phenomena	CLO48 describe the method of preparation of diazonium salts and their importance in the synthesis of a series of aromatic compounds including azo dyes.	C96 describe different methods to prepare diazonium salts
	Importance of diazonium salts	(16) applies scientific concepts in daily life and solving problems	CLO48 describe the method of preparation of diazonium salts and their importance in the synthesis of a series of aromatic compounds including azo dyes.	C97 appreciate the importance of diazonium salts in the synthesis of aromatic compounds

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain specific learning outcome	Indicators
10. Biomolecules	Carbohydrates	(3) plans and conducts projects/ investigations/ experiments/ to arrive at and verify the facts/ principles/ phenomena or to seek answers to queries on their own	CLO49 explain the characteristics of biomolecules like carbohydrates, proteins and nucleic acids and hormones	C98 investigate the presence of carbohydrates/sugar/starch in a given food item using iodine test
	Classificationn of carbohydrates	(2).classifies materials/ phenomena/ processes, based on, properties/characteristics	CLO50.classify carbohydrates, proteins, nucleic acids and vitamins on the basis of their structures	C99 classify carbohydrates into different types and differentiate between them
	Fructose and glucose	(6) explains scientific terms/factors/laws / theories governing processes and phenomena	CLO50.classify carbohydrates, proteins, nucleic acids and vitamins on the basis of their structures	C100 explain the preparation of glucose and its structure
				C101 describe the preparation, structure and properties of fructose
		(1) differentiates technical terms/ phenomena/ processes, based on, properties/ characteristics		C102 differentiate between fructose and glucose
	Sources of protein	(7) draws diagrams/ flow charts/ concept map/graphs	CLO50classify carbohydrates, proteins, nucleic acids and vitamins on the basis of their structures	C103 identify different sources of protein and draw the structure of amines, zwitter ions; explain the isoelectric point and identify pH of different amines

Unit & Chapter	Key concept	NCERT Learning outcomes	Content domain specific learning outcome	Indicators
10. Biomolecules	Types of protein	(1) differentiates technical terms/ phenomena/ processes, based on, properties/ characteristics		C104 differentiate between fibrous and globular protein on the basis of their structure
	Denaturation of protein	(6) explains scientific terms/ factors / laws / theories governing processes and phenomena		C105 elaborate on the denaturation of protein
	Enzymes	(16) applies scientific concepts in daily life and solving problems	CLO51 describe the role of biomolecules in biosystem.	C106 explain the significance of enzymes in our life
	Vitamins	(1) differentiates technical terms/ phenomena/ processes, based on, properties/ characteristics	CLO50classify carbohydrates, proteins, nucleic acids and vitamins on the basis of their structures	C107 differentiate between fat soluble and water soluble vitamins
		(2) classifies materials/ phenomena/ processes, based on, properties/characteristics		C108 classify vitamins and identify their sources and deficiency diseases due to lack of each vitamins
	structure and chemical composition of nucleic acids	(6) explains scientific terms/factors/laws/theories governing processes and phenomena		C109 describe the structure and chemical composition of nucleic acids
	Role of biomolecules	(15) realizes and appreciates the interface of chemistry with other disciplines	CLO51 describe the role of biomolecules in biosystem.	C110 elaborates on the biological functions of hormones and nucleic acids

7. SAMPLE PEDAGOGICAL PROCESSES AND ASSESSMENT STRATEGIES

"The pedagogical practices should be learner centric. It is expected of a teacher to ensure an atmosphere for students to feel free to ask questions. They would promote active learning among students with a focus on reflections, connecting with the world around them, creating and constructing knowledge. The role of a teacher should be that of a facilitator who would encourage collaborative learning and development of multiple skills through the generous use of resources via diverse approaches for transacting the curriculum."

[CBSE Curriculum for classes 11-12]

NCERT higher secondary stage learning outcomes document provides a common set of pedagogical processes for each subject. Keeping these as guidelines, specific pedagogical processes and assessment strategies for a topic from one chapter each from classes 11 and 12 have been developed as suggestions and are shared in this section. These instances of pedagogical process and assessment strategies should enable teachers to derive principles for making the alignment between learning outcomes, pedagogical practices and assessment in their classrooms and to use these for creating their lesson plans. The key principles considered while designing the pedagogical processes and assessment strategies are the following:

1. **Keeping learner at the centre**
    - Since new knowledge is built over existing knowledge, both pedagogy and assessment should focus on students' pre-requisite knowledge, skills, attitudes, and beliefs that they bring in a classroom setting.
    - Constructivist approaches to learning with the student being at the centre of the learning process as an active constructor of knowledge must be emphasized.
    - Since students effectively learn by doing, classroom processes should involve activities, analysis and discussions. Systematic experimentation as a tool to discover/verify theoretical principles must be included.
2. **Focusing on learning outcomes**
    - Learning outcomes indicate what a student will be able to do at the end of an instruction unit by precisely breaking down broad goals of chemistry education (apply reasoning to develop conceptual understanding, develop process skills and experimental, observational, manipulative, decision-making and investigatory skills, etc.) to more measurable and observable behavior for each class.
    - Students learn better when the method of teaching, learning activities and assessment strategies are all aligned well with the learning outcomes. Pedagogical processes and assessment strategies should be aligned to both content domains and cognitive skills as mentioned in this document earlier.

3. **Making effective use of assessments**

- Assessment should be viewed as an integral part of pedagogy and it should focus on giving timely individualized feedback to students. Quality formative assessment should be designed as it helps to modulate students' understanding of their own learning and helps teachers adapt their pedagogy based on students' actual learning.
- Multiple modes of assessment including portfolios, project work, presentations, and written and oral assignments should be used to reflect the individual capacities of a student.

4. **Creating a social and inclusive learning environment**

- Cooperative and peer-supported teaching-learning activities should empower students to take charge of their own learning.
- Peer assessment involving students assessing the work of their peers against set assessment criteria should be used.
- Specific pedagogical processes should be used in the classroom that would help those students who may face learning difficulties including language, visual-spatial, or mixed processing problems.

Content Domain: Redox reaction

Chapter 8: Redox reaction

<table>
<tr><th>Learning outcomes</th><th>Competencies</th><th>Pedagogical processes</th><th>Assessment strategies</th></tr>
<tr>
<td>identify redox reactions as a class of reactions in which oxidation and reduction reactions occur simultaneously

define the terms oxidation, reduction, oxidant (oxidizing agent) and reductant (reducing agent)</td>
<td>C196 infer redox reaction in terms of electron transfer reactions

C197 analyse a reaction and identify which element goes through oxidation or reduction

C198 identify oxidising and reducing agent in any reaction

C199 calculate oxidation number of an element in terms of electron transfer</td>
<td>The lesson plan to teach these competencies should have 4 major parts: Part 1 is recall information from the last class, setting up the expectations for this class and dividing the students into three groups. Allow them to discuss and engage for 2 mins. This shall act as icebreaking. Part 2 is the INM (introduction to new material through role-play or activity). Here the students will be exposed to the concepts of redox reaction and various concepts related to it. Part 3 is called GP(Guided practice). Based on what they understood in part 2, they shall consolidate their knowledge in group activity, and part 4 is the IP (independent practice).

Organize the class into 3 groups and hand over a worksheet with key terminology, and examples, related to redox reaction, oxidation number, oxidizing agent and reducing agent.

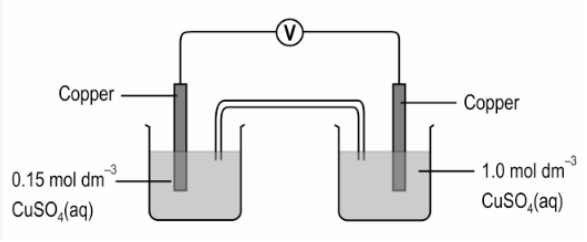
Explain one example for each section in the worksheet: Oxidation, reduction, oxidizing agent, reducing agent and oxidation number.</td>
<td>Assess what the students have learned during share time after group discussions. If there are misconceptions about the material, change your approach to a more informative, lecture–based class.

Following reactions can be used for assignment questions (as exit slip)

First give Instruction: Add columns as: element oxidised, element reduced, oxidising agent, reducing agent, and if this is a redox reaction. For each reaction, fill the columns.
<table>
<tr><th>Reaction</th></tr>
<tr><td>$Cu + 2AgNO_3 \rightarrow Cu(NO_3)_2 + 2 Ag$</td></tr>
<tr><td>$PbCl_2 + Li_2S \rightarrow PbS + 2LiCl$</td></tr>
<tr><td>$2Fe + 3ZnS \rightarrow Fe_2S_3 + 2 Zn$</td></tr>
<tr><td>$2NH_3 \rightarrow 3H_2 + N_2$</td></tr>
</table>
</td>
</tr>
</table>

		Once explained, ask each group to take one section, for example, group 1 will fill the oxidizing agent column for all the reactions mentioned in the worksheet, group 2 shall fill the column named oxidation for all the reactions and so on. Once this is completed ask them to come back in large groups and consolidate everything. For the GP (guided practice), divide the class into 5 groups and set expectation for the game called Redox relay and say like this: The goal of the game is to solve all six puzzles and put your winning cards in the right column of this chart – point to a parchment paper with a differences T-chart. First, you need to assign one person to communicate with the mediator and one person to put the card on the chart. All the rest of your team will stay at the assigned lab bench at all times. (rephrase in a simpler way if possible). This is where the relay part comes in Got it? The communicator will come to the mediator (show myself walking hastily from the lab bench to the front of the room) and the mediator (standing here) will hand them an envelope with a card in it (act like the mediator). The card contains three or four compounds on it. Assign oxidation numbers to each element in the boxes below them." (put example on board as shown below)	

		<table><tr><th>Reaction</th></tr><tr><td>$\overset{0}{F_2} + \overset{+1\ 2}{K_2S} \rightarrow \overset{+1\ -1}{2KF} + \overset{0}{S}$</td></tr><tr><td>$ZnCl_2 + Li_2SO_4 \rightarrow ZnSO_4 + 2LiCl$</td></tr><tr><td>$2H_2 + O_2 \rightarrow 2H_2O$</td></tr></table> "Once you fill that out, you bring it back to the mediator who checks if they're right. If they're right, he gives you another envelope with the same number. In that envelope is another card you'll have to fill out and bring to the moderator to check. The cards won't take long to answer but you're competing against each other so you have to be fast and work together. Also, you have two charts on your lab table that will help you solve the puzzles. If you complete both envelopes with the same number, you get a card with a clue on it. The clue tells you which side of the chart you put it under (demonstrate). Once all six cards are in place on the chart, you win!! I know it sounds like a lot but it will be very fast-paced and organized, like a RELAY!"	
learn the concept of redox reactions in terms of electrode processes.	C202 apply the concept of oxidation and reduction to explain electrode potential and reactions in an electrochemical cell	Demonstrate oxidation and reduction half reaction for each electrode using copper and iron. This Daniel cell could be set in a laboratory and the flow of electrons can be demonstrated using a multimeter. Students should be then provided with 2-3 cases with different metals as electrodes and should discuss and complete oxidation and reduction half-reaction for each case.	Ask students to draw schematic diagrams of the galvanic cells, including labels to identify the metals of the cathode and anode and metal ions in the cathodic and anodic beakers, and circling the correct direction of electron flow. Question: In the chemistry lab, Zoya set up an electrochemical cell as shown below:

			 At room temperature, she found that the initial voltmeter reading was +0.16v. (i) The standard electrode potential for the Cu^{2+}/Cu electrode is given by $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$; $E^o = +0.34$ V Calculate the electrode potential of the electrode on the left-hand side of the above electrochemical cell.

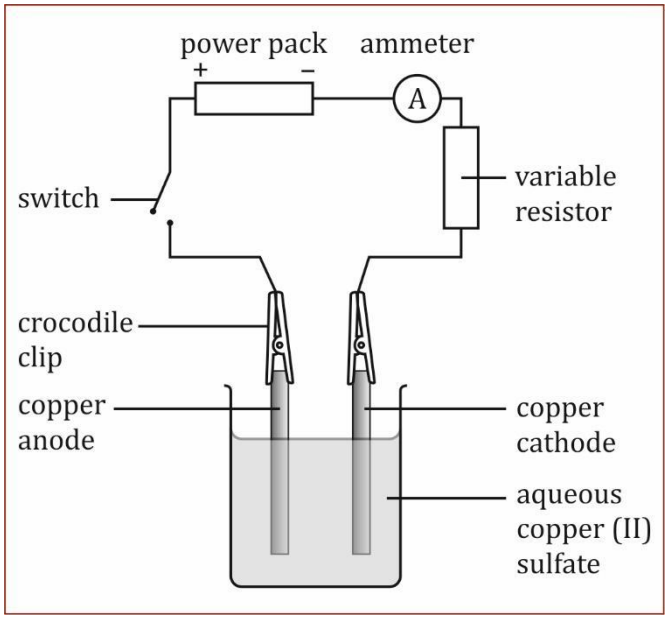
Content Domain: Electrochemistry

Learning outcomes	Competencies	Pedagogical processes	Assessment strategies
plans and conducts projects/investigations/ experiments / to arrive at and verify the facts/ principles/ phenomena or to seek answers to queries on their own	To experimentally determine the value of Faraday constant by measuring the gain in mass of a copper cathode when passing an electric current for a known time interval during the electrolysis of aqueous copper(II) sulphate.	Use the existing definition of the Faraday constant: The amount of electrical charge carried by one mole of electrons is called the Faraday constant to determine it experimentally. **YOU WILL NEED** **Equipment:** • 0-1 A ammeter • 100 ohms variable resistor • 6 V power pack or battery pack • electrical on-off switch • five connecting wires • 150 cm^3 glass beaker • cardboard electrode holder. • 100 cm^3 0.5 mol dm-3 copper(II) sulfate solution • two copper foils 6 cm × 2 cm (for use as electrodes) • two crocodile clips • clock or watch to record to 45 minutes • plastic gloves **Access to:** • distilled water in wash bottle. • 2 mol dm^{-3} nitric acid • ethanol • tweezers or clean tongs. • drying oven set at 100 °C • balance to weigh to at least two decimal places Methods to be followed: 1. Using tongs or tweezers, dip each copper electrode into 2 mol dm−3 nitric acid for about 20 s. 2. Rinse each electrode with distilled water. 3. Rinse each electrode with ethanol. 4. Dry each electrode in a drying oven at 100 °C.	First, ask the students to fill in their results and observations Mass of cathode at the start of the experiment . . . g Mass of cathode at the end of the experiment . . . . g Gain in mass of the cathode . . . . . g Average current passed . . . . . A Time . . . . . S Other observations: Some probing questions: 1. Why do we need to rinse electrodes with distilled water and ethanol in steps 2 and 3? 2. Suggest why it is better to measure the mass loss of the anode, rather than the gain in mass of the cathode. 3. Suppose a weighing error was made-the mass of the cathode at the start of the experiment was higher than the actual mass. What effect would this have on the value of the Faraday constant? Explain your reasoning. 4. Compare your result with the actual value of the Faraday constant and explain why there is a difference in actual value and experimental value.

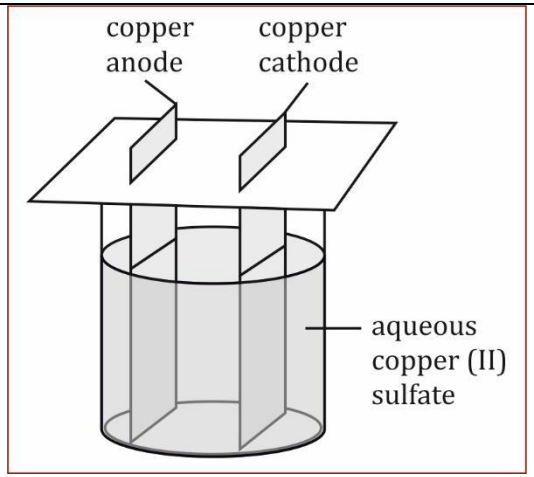
5. Allow the electrodes to cool.

6. Accurately weigh the electrode that is to be the cathode (to two decimal places). Record this mass in the Results section.

7. Arrange the apparatus as shown in the image below, leaving the switch open and the variable resistor at maximum resistance



8. Pour 100 cm^3 of aqueous copper(II) sulfate into the beaker and arrange the copper electrodes as shown in the image below. Make sure that you know which electrode is the cathode.



9. When everything is ready, note the exact time and close the electrical switch and quickly adjust the variable resistor so that the reading on the ammeter is 0.2 A.

10. Keep the electric current at 0.2 A throughout the experiment by adjusting the variable resistor.

11. Record any observations in the Results section.

12. After exactly 45 minutes, switch off the current. Carefully remove the cathode and rinse it with distilled water and then ethanol. Dry the cathode as before. Allow it to cool and then reweigh it. Record your results

8. TEST PAPER DESIGN

TEST PAPER BLUEPRINTS FOR CLASS 12 FINAL EXAMINATION

The test papers for the final examination for class 12 should be balanced in terms of their coverage of content domains, cognitive domains and types of questions. However, the blueprint governing the design of the test papers should not be very rigid and should provide sufficient latitude to the paper setter so that the focus while setting the paper remains on the quality of questions and the overall balance of the test paper.

Table 8.1. Distribution of marks across content domains

Content domains	Marks Distribution
Solutions	23
Electrochemistry	
Chemical kinetics	
d and f block elements	14
Coordination compounds	
Organic chemistry	33
Biomolecules	
Total	**70**

Table 8.2. Distribution of marks across cognitive domains

Cognitive domain	Marks distribution
Remember and understand	28
Apply	21
Analyse, Evaluate and Create	21
Total	**70**

Table 8.3. Distribution of marks across types of questions

Question type	Marks distribution
MCQs with single option or multiple options as correct answer	12-15
Very short answer questions with 1 mark	8-10
Short answer questions with 2 or 3 marks	25-30
Long answer questions (including structured questions with sub-questions) with 5 or 6 marks	20-25
Total	**70**

Other details of the test paper

- Maximum marks: 70
- Duration of the test (writing time): 3 hours
- Time given for reading the test paper: 15 minutes
- Total word count of the questions: 1600-2200 words

9. ASSESSMENT OF PRACTICAL WORK

A key component of the chemistry curriculum for classes 11-12 is practical work related to the concepts and principles covered in the content domains. Along with discovering or verifying results covered in the curriculum, students are also expected to acquire and practice process skills related to science. The learning outcomes for the curriculum as listed in chapter 5, include the following 3 learning outcomes which are especially relevant for practical work in chemistry.

LO3.Plans and conducts projects/ investigations/ experiments/ to arrive at and verify the facts/ principles/ phenomena or to seek answers to questions on their own

LO4. Takes appropriate precautionary measures (do's and don'ts) while handling apparatus, and chemicals during laboratory work

LO12. Measures physical quantities using appropriate apparatus

DESIGN OF THE PRACTICAL EXAMINATION

Students are expected to conduct experiments, do practical activities and investigative projects throughout the course of 2 years, and are also required to take a practical examination at the end of each year.

Table 9.1. Distribution of marks for the practical examination

Evaluation scheme for examination	Distribution of marks
Volumetric analysis	8
Salt analysis	8
Content-based experiment	6
Project work	4
Class record and viva	4
Total	**30**

The lists of suggested experiments, practical activities and investigative projects that students are expected to work on throughout the course are given below for both classes 11 and 12.

SUGGESTED EXPERIMENTS, PRACTICAL ACTIVITIES AND INVESTIGATIVE PROJECTS – CLASS 11

EXPERIMENTS

A. Basic Laboratory Techniques

1. Cutting glass tube and glass rod
2. Bending a glass tube
3. Drawing out a glass jet
4. Boring a cork

B. Characterization and Purification of Chemical Substances

1. Determination of the melting point of an organic compound.
2. Determination of the boiling point of an organic compound.
3. Crystallization of impure sample of any one of the following: Alum, Copper Sulphate, Benzoic Acid.

C. Experiments based on pH

a) Any one of the following experiments:

Determination of pH of some solutions obtained from fruit juices, solution of known and varied concentrations of acids, bases and salts using pH paper or universal indicator.

- Comparing the pH of solutions of strong and weak acids of the same concentration.

Study the pH change in the titration of a strong base using a universal indicator.

b) Study the pH change by common-ion in case of weak acids and weak bases.

D. Chemical Equilibrium One of the following experiments:

a) Study the shift in equilibrium between ferric ions and thiocyanate ions by increasing/decreasing the concentration of either of the ions.

b) Study the shift in equilibrium between [Co(H2O)6] 2+ and chloride ions by changing the concentration of either of the ions

E. Quantitative Estimation

i. Using a mechanical balance/electronic balance.

ii. Preparation of standard solution of Oxalic acid.

iii. Determination of strength of a given solution of Sodium hydroxide by titrating it against a standard solution of Oxalic acid.

iv. Preparation of standard solution of Sodium carbonate.

v. Determination of strength of a given solution of hydrochloric acid by titrating it against standard Sodium Carbonate solution.

F. Qualitative Analysis

a) Determination of one anion and one cation in a given salt

Cations- Pb^{2+}, Cu^{2+}, As^{3+}, Al^{3+}, Fe^{3+}, Mn^{2+}, Ni^{2+}, Zn^{2+}, Co^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Mg^{2+}, NH_4^+

Anions – $(CO_3)^{2-}$, S^{2-}, NO_2^-, SO_3^{2-}, SO_2^{4-}, NO_3^-, Cl^-, Br^-, I^-, PO_4^{3-}, CH_3COO^- (Note: Insoluble salts excluded)

PROJECTS

Scientific investigations involving laboratory testing and collecting information from other sources.

A few suggested Projects

- Checking the bacterial contamination in drinking water by testing sulphide ion
- Study of the methods of purification of water
- Testing the hardness, presence of Iron, Fluoride, Chloride, etc., depending upon the regional variation in drinking water and study of causes of presence of these ions above permissible limit (if any).
- Investigation of the foaming capacity of different washing soaps and the effect of addition of Sodium carbonate on it
- Study the acidity of different samples of tea leaves.
- Determination of the rate of evaporation of different liquids
- Study the effect of acids and bases on the tensile strength of fibres.
- Study of acidity of fruit and vegetable juices. Note: Any other investigatory project, which involves about 10 periods of work, can be chosen with the approval of the teacher

SUGGESTED EXPERIMENTS, PRACTICAL ACTIVITIES AND INVESTIGATIVE PROJECTS – CLASS 12

EXPERIMENTS

A. Surface Chemistry

(a) Preparation of one lyophilic and one lyophobic sol Lyophilic sol - starch, egg albumin and gum

Lyophobic sol - aluminium hydroxide, ferric hydroxide, arsenous sulphide.

(b) Dialysis of sol-prepared in (a) above.

(c) Study of the role of emulsifying agents in stabilizing the emulsion of different oils.

B. Chemical Kinetics

(a) Effect of concentration and temperature on the rate of reaction between Sodium Thiosulphate and Hydrochloric acid.

(b) Study of reaction rates of any one of the following:

(i) Reaction of Iodide ion with Hydrogen Peroxide at room temperature using different concentrations of Iodide ions.

(ii) Reaction between Potassium Iodate, (KIO_3) and Sodium Sulphite: (Na_2SO_3) using starch solution as an indicator (clock reaction).

C. Thermochemistry (Any one of the following experiments)

i) Enthalpy of dissolution of Copper Sulphate or Potassium Nitrate.

ii) Enthalpy of neutralization of strong acid (HCI) and strong base (NaOH).

iii) Determination of enthalpy change during interaction (Hydrogen bond formation) between Acetone and Chloroform.

D. Electrochemistry Variation of cell potential in Zn/Zn^{2+}|| Cu^{2+}/Cu with change in concentration of electrolytes ($CuSO_4$ or $ZnSO_4$) at room temperature.

E. Chromatography

i) Separation of pigments from extracts of leaves and flowers by paper chromatography and determination of R_f values.

ii) Separation of constituents present in an inorganic mixture containing two cations only (constituents having large differences in R_f values to be provided).

F. Preparation of Inorganic Compounds Preparation of double salt of Ferrous Ammonium Sulphate or Potash Alum. Preparation of Potassium Ferric Oxalate.

G. Preparation of Organic Compounds Preparation of any one of the following compounds

i) Acetanilide

ii) Di -benzalacetone

iii) p-Nitroacetanilide

iv) Aniline yellow or 2 - Naphthol Anilinedye.

H. Tests for the functional groups present in organic compounds: Unsaturation, alcoholic, phenolic, aldehydic, ketonic, carboxylic and amino (Primary) groups.

I. Characteristic tests of carbohydrates, fats and proteins in pure samples and their detection in given foodstuffs.

J. Determination of concentration/ molarity of $KMnO_4$ solution by titrating it against a standard solution of:

i) Oxalic acid,

ii) Ferrous Ammonium Sulphate (Students will be required to prepare standard solutions by weighing themselves).

K. Qualitative analysis

Determination of one cation and one anion in a given salt.

Cation : Pb^{2+}, Cu^{2+} As^{3+}, $A\ell^{3+}$, Fe^{3+}, Mn^{2+}, Zn^{2+}, Cu^{2+}, Ni^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Mg^{2+} , NH^{4+}

Anions: $(CO_3)^{2-}$, S^{2-} , $(SO_3)^{2-}$, $(NO_2)^-$, $(SO_4)^{2-}$, $C\ell^-$, Br^- , I^- , PO_3^{4-}, $(C_2O_4)^{2-}$, CH_3COO^- ,NO_3^- (Note: Insoluble salts excluded)

PROJECTS

Scientific investigations involving laboratory testing and collecting information from other sources

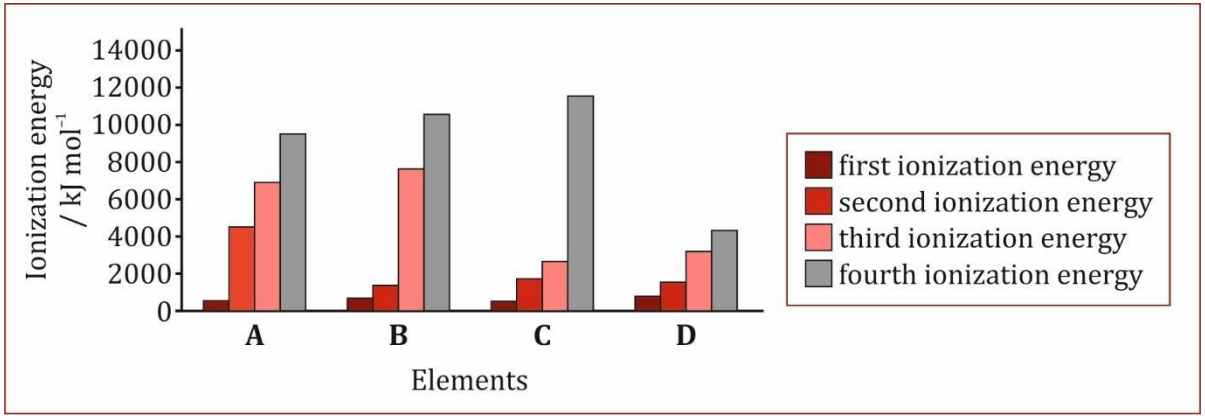
A few suggested Projects.

- Study of the presence of oxalate ions in guava fruit at different stages of ripening.
- Study of quantity of casein present in different samples of milk.
- Preparation of soybean milk and its comparison with the natural milk with respect to curd formation, effect of temperature, etc.
- Study of the effect of Potassium Bisulphate as food preservative under various conditions (temperature, concentration, time, etc.)
- Study of digestion of starch by salivary amylase and effect of pH and temperature on it.
- Comparative study of the rate of fermentation of following materials: wheat flour, gram flour, potato juice, carrot juice, etc.
- Extraction of essential oils present in Saunf (aniseed), Ajwain (carum), Illaichi (cardamom).
- Study of common food adulterants in fat, oil, butter, sugar, turmeric powder, chilli powder and pepper. Note: Any other investigatory project, which involves about 10 periods of work, can be chosen with the approval of the teacher.

10. SAMPLE ASSESSMENT ITEMS WITH MARKING SCHEMES

1. Multiple Choice Question (MCQ)

Content Domain (Chapter name)	**Structure of atom**	
Content Domain Learning outcome	Describe Bohr's atomic model	
Competency	Apply Bohr's model of hydrogen energy levels to calculate the energy of electrons in excited state	
Cognitive level	Application	
Thinking Process	Understanding and problem-solving	
Difficulty level	Low	
Marks	1	
Time	2 mins	
Item Stem	In a hydrogen atom, if energy of an electron in the ground state is 13.6 eV, then what will be the energy of the same electron in the 2nd excited state?	
Correct answer	1.51 eV	As per the energy equation, $E_n = 13.6/n^2$; n= 3 for 2^{nd} excited state. So, $E_n = 13.6/9 = 1/51$eV
Distractor 1	13.6 eV	Assume that n in the formula refers to atomic number. Since the atomic no of hydrogen is 1, so $E_n = 13.6/1 = 13.6$
Distractor 2	3.4 eV	Would consider n = 2 as the stem mentions 2^{nd} excited state. so $E_n = 13.6/4 = 3.4$eV
Distractor 3	4.53 eV	Would consider the energy formula as $E_n = 13.6/n$ and solve by applying n = 3 in it

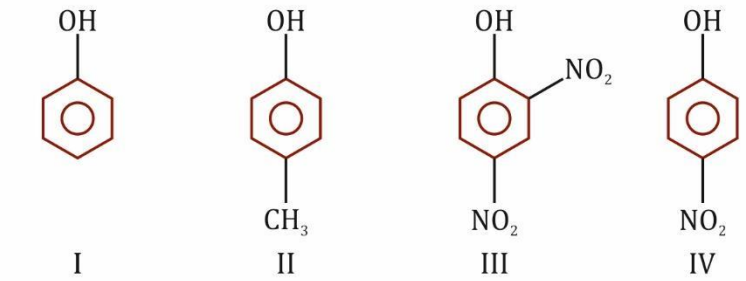
Content Domain (Chapter name)	Classification of elements and periodicity in properties	
Content Domain Learning outcome	Use scientific vocabulary appropriately to communicate ideas related to certain important properties of atoms e.g., atomic/ ionic radii, ionization enthalpy, electron gain enthalpy, electronegativity, valence of elements.	
Competency	Apply shielding/screening effect to understand different levels of ionisation enthalpy in an element	
Cognitive level	Analyse	
Thinking Process	Apply	
Difficulty level	High	
Marks	1	
Time	2 mins	
Item Stem	The graph below shows the first four ionization energies of four elements A, B, C and D (the letters are not their chemical symbols). Which element is magnesium? 	
Correct answer	B	Look for the first big jump in ionisation energy. This will occur when the electron is removed from an inner level. The number of electrons removed before the jump is the same as the group number.

Distractor 1	A	Would consider that Mg has 2 electrons in the outermost shell and that is why the difference between the first and second ionisation energy will be the highest.
Distractor 2	C	Would consider that the big jump in ionisation energy happens for the last electron that goes through ionisation
Distractor 3	D	Would consider that there is no drastic jump in ionisation energy from one electron to another

Content Domain (Chapter name)	**Thermodynamics**
Content Domain Learning outcome	Explain entropy as a thermodynamic state function and apply it for spontaneity
Competency	Predict the entropy of a reaction and compare it with other reactions
Cognitive level	Understand
Thinking Process	Explain
Difficulty level	Medium
Marks	1
Time	2 mins
Item Stem	Which reaction has the largest increase in entropy? A. $H_2(g) + Cl_2(g) \rightarrow 2HCl\ (g)$ B. $Al(OH)_3(s) + NaOH(aq) \rightarrow Al(OH)_4^-(aq) + Na^+(aq)$ C. $Na_2CO_3\ (s) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2\ (g) + H_2O(l)$ D. $BaCl_2(aq) + Na_2SO_4\ (aq) \rightarrow BaSO_4(s) + 2NaCl\ (aq)$

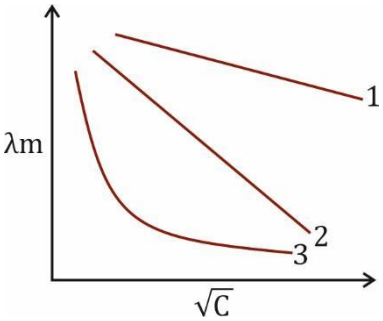
Correct answer	C	The products so formed are in gas and liquid from solid and aq (reactant). Furthermore, 3 moles of reactants gave 4 moles of products giving the largest increase in entropy among others.
Distractor 1	A	Would consider that both products and reactants are gases; since gas has the highest entropy so its correct
Distractor 2	B	Would consider that products so formed are ions (opposite charged) and need more energy to be stable.
Distractor 3	D	Would consider that both the compounds in the reactant is ionic in nature so the entropy change will be the largest.

Content Domain (Chapter name)	**Alcohols, phenols and ethers**
Content Domain Learning outcome	Estimate the chemical characteristics of phenols.
Competency	Apply the properties of functional groups to distinguish between the acidic strength of compounds
Cognitive level	Analyse
Thinking Process	Apply
Difficulty level	Medium
Marks	1
Time	2 mins
Item Stem	Which of the following will show the highest acidic strength?

		
Correct answer	III	Presence of electron withdrawing groups such as the nitro group enhances the acidic strength of phenol. Since it has nitro groups as both ortho and para position, it's highest acidic strength
Distractor 1	I	Would consider that since there are no other functional groups, it's easier to release H+ ion.
Distractor 2	II	Would consider that electron-releasing groups such as the alkyl group increase the acidic strength of phenol.
Distractor 3	IV	Would consider that the less the number of electron-withdrawing groups, the higher the acidic strength.

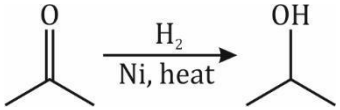
2. Constructed Response Questions

Content domain (Chapter name)	**Chemical bonding and molecular structure**
Content Domain Learning outcome	Understands the relationship between molar conductivity and concentration for different compounds
Competency	Analyse the trends in molar conductivity vs concentration graph for NaCl, HCl, and NH_4OH
Cognitive level	Analyse
Thinking Process	Explain
Difficulty level	Medium

Marks	3 marks
Time	3-4 minutes
Item stem	The molar conductivity vs √c curve for NaCl, HCl, and NH_4OH are shown below in random order.  Identify which graph corresponds to HCl, NaCl, and NH_4OH. (ii) Give reasons to justify your answer in (i).

Marking Scheme

Part	Mark	Answer
1	**1**	(i) From the above graph, 1 corresponds to HCl 2 corresponds to NaCl 3 corresponds to NH_4OH
2	**2**	- When the above compounds dissociate, H+ has the highest mobility in comparison with Na, because the Molar mass of H+ is less than Na+ ion. - HCl and NaCl are strong electrolytes compared to NH_4OH which is a weak base. [1 mark] - Strong electrolytes are already completely dissociated and there is a small increase (change) in dissociation on dilution. For weak electrolytes, the degree of dissociation increases to a greater extent/abruptly and follows the non-linear curve. so at a given concentration, molar conductivities of HCl>NaCl>NH_4OH [1 mark]

Content domain (Chapter name)	Chemical Kinetics
Content Domain Learning outcome	Discuss the dependence of rate of reactions on concentration, temperature and catalyst;
Competency	Investigate the effect of Nickel as a catalyst during the hydrogenation of a ketone.
Cognitive level	Analyse
Thinking Process	Explain
Difficulty level	High
Marks	6 marks
Time	6-8 minutes
Item stem	Nickel catalyses the conversion of propanone to propan-2-ol  (a) Outline how a catalyst increases the rate of reaction. (b) Explain why an increase in temperature increases the rate of reaction? (c) Discuss, referring to intermolecular forces present, the relative volatility of propanone and propan-2-ol.

Marking Scheme			
Part	**Mark**	**Answer**	**Further Information**

A	**1**	provides an alternative pathway/mechanism AND lower E_a ✓	Accept description of how catalyst lowers E_a (e.g. "reactants adsorb on the surface of catalyst", "reactant bonds weaken when adsorbed").
b	**2**	more/greater proportion of molecules with $E \geq E_a$ ✓ greater frequency/probability/chance of collisions between the molecules OR more collision per unit of time/second ✓	
C	**3**	hydrogen bonding/bonds and dipole–dipole and London/dispersion forces are present in» propan-2-ol ✓ dipole–dipole «and London/dispersion are present in propanone ✓ propan-2-ol less volatile AND hydrogen bonding/bonds stronger than dipole–dipole OR propan-2-ol less volatile AND sum of all intermolecular forces stronger ✓	

Content domain (Chapter name)	**Basic concepts of chemistry**
Content Domain Learning outcome	Appreciate the significance of mole fraction, limiting reagent, mass percent in an equation
Competency	apply stoichiometric coefficients to understand the limiting reagent in an equation
Cognitive level	Application

Thinking Process	Calculate
Difficulty level	Medium
Marks	4 marks
Time	4-5minutes
Item stem	3.26g of iron powder are added to 80.0cm^3 of 0.200moldm^{-3} copper(II) sulphate solution. The following reaction occurs: Fe(s) + $CuSO_4$ (aq) → $FeSO_4$ (aq) + Cu(s) (a) Determine the limiting reactant showing your working. (b) The mass of copper obtained experimentally was 0.872g. Calculate the percentage yield of copper.

Marking Scheme

Part	Mark	Answer	Further Information
A	2	$nCuSO_4$ = 0.0800 dm^3 × 0.200 mol dm^{-3}= 0.0160 mol AND nFe=3.26 g /55.85 gmol^{-1}= 0.0584 mol ✓ $CuSO_4$ is the limiting reactant ✓	Do not award 2 marks if mole calculation is not shown
B	2	***ALTERNATIVE 1:*** «<0.0160 mol x 63.55 g mol-1 => 1.02 «g» ✓ $\frac{0.872\ g}{1.02\ g}$ × 100 =» 85.5 «%» ✓ 1.02g ***ALTERNATIVE 2:*** $\frac{0.872g.}{63.55\ gmol^{-1}}$ => 0.0137 «mol»> ✓ $\frac{0.0137\ mol}{0.0160\ mol}$ × 100 => 85.6 «%»✓	Accept answers in the range 85–86 %. Award [2] for the correct final answer.

Content domain (Chapter name)	Basic concepts of chemistry		
Content Domain Learning outcome	Calculate the mass per cent of component elements constituting a compound		
Competency	Derive the empirical and molecular formula using the mass percentage of elements		
Cognitive level	Apply		
Thinking Process	derive		
Difficulty level	Medium		
Marks	3 marks		
Time	4 minutes		
Item stem	An organic compound containing carbon, hydrogen and oxygen has 62.1 % carbon and 10.5 % hydrogen by mass. (a) Determine the empirical formula of the compound, showing your working.		
Marking Scheme			
Part	**Mark**	**Answer**	**Further Information**
A	3	In a 100g sample, the amount of carbon will be 62.1 g, hydrogen will be 10.5 g and oxygen will be 27.4 g	Do not award 3 marks if all the three steps are not there

Now, use the **molar masses** of the three elements to determine how many moles of each you have in this sample.

$$\text{For C: } 62.1\,\cancel{g} \cdot \frac{1 \text{ mole C}}{12.011\,\cancel{g}} = 5.1703 \text{ moles C}$$

$$\text{For H: } 10.5\,\cancel{g} \cdot \frac{1 \text{ mole H}}{1.00794\,\cancel{g}} = 10.417 \text{ moles H}$$

$$\text{For O: } 27.4\,\cancel{g} \cdot \frac{1 \text{ mole O}}{15.9994\,\cancel{g}} = 1.7126 \text{ moles O}$$

To get the **mole ratio** that exists between the elements in the compound, divide all values by the smallest one. This will get you

$$\text{For C: } \frac{5.1703\,\cancel{\text{moles}}}{1.7126\,\cancel{\text{moles}}} = 3.019 \approx 3$$

$$\text{For H: } \frac{10.417\,\cancel{\text{moles}}}{1.7126\,\cancel{\text{moles}}} = 6.083 \approx 6$$

$$\text{For O: } \frac{1.7126\,\cancel{\text{moles}}}{1.7126\,\cancel{\text{moles}}} = 1$$

Since **3:6:1** represents the smallest **whole number ratio** that can exist between the three elements, the empirical formula of the unknown compound will be

Now, use the molar masses of the three elements to determine how many moles of each you have in this sample.

C_3H_6O

11. ESSENTIAL IDEAS

This section contains the 1-2 essential ideas (core idea encapsulating the entire chapter or critical concepts) per chapter for class 11 and 12 textbook chapters.Furthermore, the ideas are conveyed through a high-quality understanding-based question.

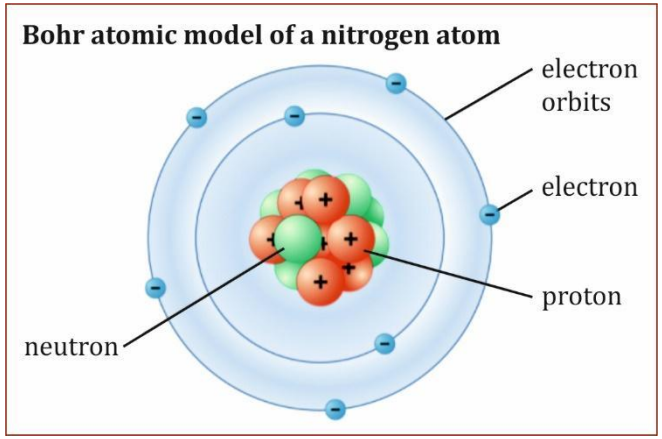
CLASS 11 ESSENTIAL IDEAS

<table>
<tr><th>Chapter name</th><th colspan="2">Basic Concepts of Chemistry</th></tr>
<tr><td>Essential Idea</td><td colspan="2">Atoms of a given element have identical mass and compounds are formed when atoms of different elements combine in a fixed ratio. [Note that isotopes are not considered in the above case]</td></tr>
<tr><td>Item stem</td><td colspan="2">A group of geologists during an expedition came across an unknown black solid compound “U” which looks similar to a known substance “A”.
The table below summarizes the hydrogen and oxygen content of these compounds.
<table>
<tr><th>Compound</th><th>Hydrogen content</th><th>Carbon Content</th></tr>
<tr><td>U</td><td>15 g</td><td>105 g</td></tr>
<tr><td>A</td><td>2 g</td><td>30 g</td></tr>
</table>
Are these substances the same? Justify.</td></tr>
<tr><th colspan="3">Marking Rubric</th></tr>
<tr><th>Description</th><th>Marks</th></tr>
<tr><td>A possible complete answer:
As per the law of constant proportion, for two different compounds, if the proportion of all elements by weight in one compound is equal to that in another compound, the compounds will be the same.
For unknown compound:</td><td>3</td></tr>
</table>

% of Hydrogen = 15/120 x 100% = 12.5% % of Carbon = 105/120 x 100 % = 87.5 % For Known compound: % of Hydrogen = 2/32 x 100% = 6.25% % of Carbon = 30/32 x 100 % = 93.75 % Since the proportion of elements is not the same, they are different compounds.	
As per the law of constant proportion, if the proportion of all elements by weight is the same, the compounds will be the same.	1
For unknown compound: % of Hydrogen = 15/120 x 100% = 12.5% % of Carbon = 105/120 x 100 % = 87.5 %	1
For Known compound: % of Hydrogen = 2/32 x 100% = 6.25% % of Carbon = 30/32 x 100 % = 93.75 % Since the proportion of elements is not the same, they are different compounds.	1

Chapter Name	**Basic concepts of chemistry**	
Essential Idea	Chemical reactions involve reorganisation of atoms. These are neither created nor destroyed in a chemical reaction. The stoichiometric coefficient in a balanced chemical reaction can provide information on the amount of reactants required to produce a certain amount of product.	
Item Stem	A student performs a neutralisation reaction in a laboratory. The below reaction shows the same: H_3PO_3 (aq) + 2KOH (aq) $\rightarrow K_2HPO_3 + 2H_20$ What will be the amount of 0.1M KOH required to neutralise 20 ml of 0.1M H_3PO_3 aqueous solution?	
Correct answer	40 mL	Reason: M1 x V1/1 = M2 x V2 /2. So 20 x 0.1/1 = 0.1 x V2/2 = 40 ml

Distractor 1	20 mL	Explanation: Students did not consider the stoichiometric coefficient as 2 in the RHS of the formula (for KOH). They assume it as 1.
Distractor 2	10 mL	Explanation: They assume that only half the amount of H3PO3 volume should be enough as the no of moles of KOH is 2.
Distractor 3	60 mL	Explanation: Students consider the stoichiometric coefficient as 3 for KOH (by adding 2 and 1 in LHS of reaction) and get this value.

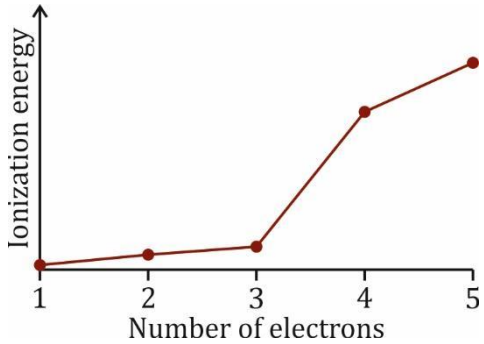
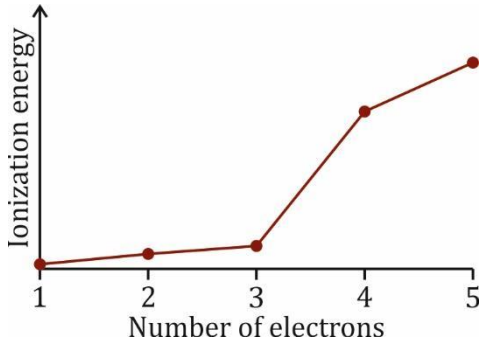
Chapter name	**Structure of atom**
Essential Idea	Contrary to Dalton's atomic model, atoms are divisible and are made up of subatomic particles- electrons, protons and neutrons. The center of the atom (consists of protons and neutrons) is positively charged and the electron revolves around this centre in circular orbits (with specific energies).
Item stem	The below diagram shows the rough 2D Bohr's model for nitrogen atom.  (i) Protons are arranged in very concentrated space inside the center of the atom. However, the centre is stable despite the fact that more than one protons with the same charge are packed together. Why is there no electrostatic repulsion leading to the break up of the nucleus and making an atom unstable? (ii) As per the electrostatics force, all the electrons should be attracted towards the positively charged nucleus. Why do the electrons not attracted towards the nucleus?

Marking Rubric		
Part	**Description**	**Marks**
	A possible complete answer: (i) Inside the nucleus, there are two types of forces that come into action. One is the strong attractive nuclear force (which has short-range order) between proton and neutrons and neutron and neutrons and the second is the electrostatic force between proton and proton. Inside the nucleus, the strong nuclear force overpowers the electrostatic force and the resultant force is attractive in nature. That's why, although there is repulsion between protons and protons, they are together inside the nucleus. (ii) As per quantum mechanics, electrons are not little balls that can fall into the nucleus under electrostatic attraction. Rather, electrons are quantized wavefunctions that spread out in space and can sometimes act like particles in limited ways. An electron in an atom spreads out according to its energy. The states with more energy are more spread out. All electron states overlap with the nucleus, so the concept of an electron "falling into" or "entering" the nucleus does not really make sense. Electrons are always partially in the nucleus but are not captured by protons.	
(i)	Describes two types of forces that are present inside the nucleus: Electrostatic and strong nuclear forces.	1
	Describe why the magnitude of the resultant force is attractive in nature.	1
(ii)	-Apply quantum mechanics to describe the position of electrons (wave functions) in orbitals. [1 mark] - Inability of proton for electron capture, when electrons are localised near the nucleus. [1 mark]	2

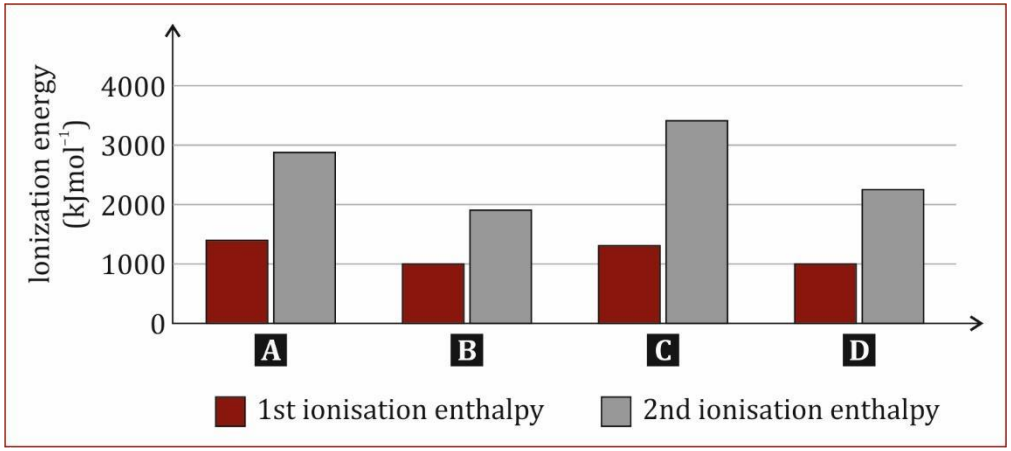
Chapter Name	**Structure of Atom**
Essential Idea	The electronic configuration of an atom can be deduced from its atomic number. Furthermore, the energy of electron and the shape of orbitals where they reside is determined by the quantum numbers.
Item Stem	The electrons identified by quantum numbers n and l as (a) n = 4, l= 1 (b) n=4, l=0

	(c)n=3, l=2 (d) n=3, l=1 Arrange the electrons with the above set of n and l in order of increasing energy.	
Correct answer	d<b<c<a	Reason: a, b, c, d corresponds to 4p, 4s, 3d, and 3p consecutively. According to Bohr's (n+l) rule, the energy order of the subshell is 3p<4s<3d<4p
Distractor 1	c<d<b<a	Explanation: assumes that 4s would have higher energy than 3d owing to 4 as a quantum number.
Distractor 2	b<d<a<c	Explanation: assumes that 3d would have the higher energy than 4p and 4s both due to screening effect.
Distractor 3	b<a<d<c	Explanation: assumes that electrons with quantum no 3 would have higher energy than that of 4.

Chapter name	**Classification of elements**	
Essential Idea	Deduction of electron arrangement and Vertical and horizontal trends in the periodic table exist for atomic radius, ionic radius, ionization energy, electron affinity and electronegativity.	
Item stem	Properties of elements and their compounds can be related to the position of the elements in the periodic table. (a) Explain the decrease in atomic radius from Na to Cl. (b) Sketch a graph to show the relative values of the successive ionization energies of boron.	
Marking Rubric		
Part	**Description**	**Marks**
	A possible complete answer: (i) Since Na and cl belong to the same period and in a period, the effective nuclear charge increases as electron shielding remains constant. A higher effective nuclear charge causes greater attraction to the electrons, pulling the electron cloud closer to the nucleus which results in a smaller atomic radius.	

	(ii) B-$1S^2 2S^2 2p^1$  	
(i)	nuclear charge/the number of protons/Z_{eff} increases causing a stronger pull on the outer electrons [1 mark]	1
	Na and cl belong to the same period, thereby having the same number of shells, each next element has one more proton with same no of valance electron, leading to increase nuclear charge.	1
(ii)	 Sketch showing: largest increase between third and fourth ionization energies $IE_1 < IE_2 < IE_3 < IE_4 < IE_5$	2

Chapter Name	**Classification of elements**
Essential Idea	Deduction of electron arrangement and vertical and horizontal trends in the periodic table exist for atomic radius, ionic radius, ionization energy, electron affinity and electronegativity.

Item Stem	The graph below shows the first two ionization energies of four elements A, B, C, and D (the letters are not their chemical symbols). These elements are the first two elements of groups 15 and 16. Which element is Oxygen? 	
Correct answer	C	Reason: In a group, ionisation enthalpy decreases as we move down and, in the period,, it increases. Furthermore, the second ionisation enthalpy for group 16 is higher than that of group 15 as the second electron needs to be removed from perfectly half-filled orbitals.
Distractor 1	A	Explanation: They might just look at the curve for the second ionisation enthalpy and assume C as sulphur thinking IE increases down the group.
Distractor 2	B	Explanation: They assume that IE decreases across the period and increases down the group
Distractor 3	D	Explanation: They assume that IE decreases across the period and decreases down the group.

Chapter name	**Chemical Bonding**
Essential Idea	As per electron pair repulsion theory, the shape of molecules and ions are dictated by the number of regions of negative charge in the outermost shell of their central atoms and that these regions of negative charge will repel each other and get as far apart as possible. The regions of negative charge may be lone pairs as well as single, double, and triple bonds.
Item stem	Explain the difference in the structure of CO_2 and SO_2

Marking Rubric	
Description	**Marks**
A possible complete answer: CO_2 has only two negative centres (two double bonds) around the central atom C whereas SO_2 has three centres of negative charge (two double bonds and one lone pair) around the S atom. The presence of a lone pair on S atom brings lone pair-bond pair repulsion into the play in case of SO_2 . Hence, the double bonds bent to avoid repulsion.	
In CO_2 , Carbon has two negative centres (double bond counts as one centre). Having just two negative centres around the central atom makes CO_2 linear.	1
In SO_2 , sulphur has three negative centres (two double bonds and one lone pair). To avoid the repulsion between these centres, the shape can't be linear but rather V-shaped.	1

Chapter Name	**Chemical bonding**	
Essential Idea	Due to the wave nature of electrons, molecular orbitals are formed due to constructive and destructive interference of wave functions (electrons)	
Item Stem	Which of the following is/are true? (i) In an anti-bonding molecular orbital, the electron density is maximum between the two nuclei of the molecule. (ii) When two atoms combine to form a molecule, energy is released. (iii) The bond order of NO > 0_2^-	
Correct answer	ii and iii	Reason: In order to gain stability, energy is released. The higher the amount of released energy, the higher the stability. The bond order of NO is 2.5 and that of $0_2^-$is 1.5.
Distractor 1	ii only	Explanation: They might got the value of bond order0_2^-greater than or equal to NO.

Distractor 2	iii only	Explanation: They assume that energy will be required to form a molecule.
Distractor 3	i and iii	Explanation: They assume that the possibility of finding an electron could be maximum at the centre of the nucleus.

Chapter name	**Thermodynamics**
Essential Idea	(i) The change in the internal energy of a system is equal to the difference between the heat added to the system and the work done by the system. (ii) The total entropy of the system and surroundings will never decrease.
Item stem	The equation for the reaction between ammonia and oxygen is shown. $4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$; $\Delta H = -905$ kJ mol^{-1} Gas / S^θ / J K^{-1} mol^{-1}: **$NH_3(g)$** 193 **$O_2(g)$** 205 **$NO(g)$** 211 **$H_2O(g)$** 189 (i) Calculate a value for the Gibbs free-energy change (ΔG), in kJ mol^{-1}, for the reaction between ammonia and oxygen at 600 °C (ii) The reaction between ammonia and oxygen was carried out at a higher temperature. Explain how this change affects the value of ΔG for the reaction.

Marking Rubric		
Part	**Description**	**Marks**
(i)	$\Delta S = \Sigma S_p - \Sigma S_R$ ⇨ $\otimes S = 181\ JK^{-1}\ mol^{-1}$ $(\Delta G = \Delta H - T\Delta S) = - 905 - (600 + 273) \times 181 \times 10^{-3}$ $\Delta G = - 1063 / -1060$ (kJ mol-1) If the alternative value of $\Delta S = 211$ used, answer = -1089 (kJ mol^{-1})	1
(ii)	ΔG becomes more negative/less positive. The entropy change ΔS is positive, $T\Delta S$ gets bigger, $-T\Delta S$ gets more negative.	1

Chapter Name	**Thermodynamics**	
Essential Idea	(i) The change in the internal energy of a system is equal to the difference between the heat added to the system and the work done by the system. (ii) The total entropy of the system and surroundings will never decrease.	
Item Stem	For the below equation, P(g)+ Q(g)→R(g) + S(g) Which of the following is correct at T= 300K?	
Correct answer	$\Delta H = \Delta E$	Reason: From the equation, $\Delta n = 0$, so $\Delta H = \Delta E$
Distractor 1	$\Delta H > \Delta E$	Explanation: They might just think that since $\Delta H = \Delta E + \Delta nRT$, so ΔH will always be greater.
Distractor 2	$\Delta H < \Delta E$	Explanation: They assume that ΔnRT is negative.
Distractor 3	Insufficient information	Explanation: They assume that the values of heat and energy is required to make any inference.

Chapter name	Equilibrium
Essential Idea	The state of equilibrium is attained when the rate of forward reaction is the same of the rate of backward reaction. And at constant temperature and pressure, the equilibrium constant is the ratio of the total concentration of products to the total concentration of reactants.
Item stem	The ionic product of water, $K_w = 2.93 \times 10^{-15}$ mol^2 dm^{-6} at 10 °C. (i) What is the correct expression for K_w? Calculate the pH of pure water at 10 °C. (ii) Suggest why this pure water at 10 °C is not alkaline.

Marking Rubric

Part	Description	Marks
(i)	correct expression for $K_w = [H^+]\,[OH^-]$ $[H_+] = \sqrt{K_w} = \sqrt{2.93 \times 10^{-15}}$ $(= 5.41 \times 10^{-8})$ $pH = (-\log (5.41 \times 10^{-8}) = 7.27$	2
(ii)	Since $[H^+] = [OH^-]$, it's not alkaline	1

Chapter Name	Equilibrium
Essential Idea	The state of equilibrium is attained when the rate of forward reaction is the same of the rate of backward reaction. And at constant temperature and pressure, the equilibrium constant is the ratio of the total concentration of products to the total concentration of reactants.
Item Stem	Ice and water attain equilibrium at a particular temperature and pressure. Ice ⇌ Water

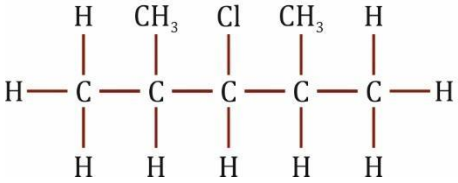
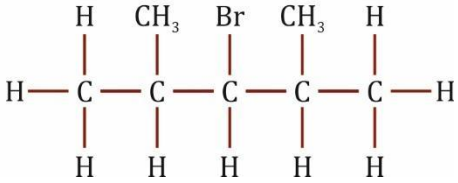
	What will happen when external pressure is applied to this equilibrium condition?	
Correct answer	More water will be formed	Reason: Since melting of ice is accompanied by absorption of heat and a decrease in volume, both the increase in pressure or temperature will favour the forward reaction.
Distractor 1	More ice will be formed	Explanation: They might assume that by applying pressure water will condense and become ice
Distractor 2	No change in the equilibrium	Explanation: They assume that the equilibrium state does not depend on pressure.
Distractor 3	Water will evaporate	Explanation: They assume that the extra pressure would do the phase change for water as the internal energy will increase.

Chapter Name	**Redox reaction**	
Essential Idea	Redox reactions involve change in oxidation number (increase in oxidation no= oxidation, decrease in oxidation no = reduction) of the interacting species and the same atoms could have different oxidation numbers.	
Item Stem	Which of the following correctly depicts the oxidation number of sulfur in the substances below?	

	SO_3^{2-}	**$NaHSO_4$**	**H_2S**
A	+4	+6	+2
B	+6	+4	+2
C	+4	+6	-2
D	+6	+2	-2

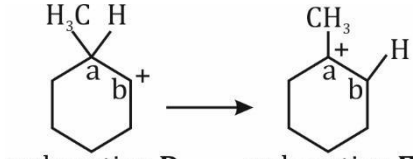
Correct answer	C	Reason: Sulphur can take any oxidation no from -2 to +6. Here in the first case sulphur is an electron donor.
Distractor 1	A	Explanation: They might assume hydrogen as more electronegative than sulphur

Distractor 2	B	Explanation: They might assume hydrogen as more electronegative than sulphur and assume that -2 electron is also due to sulphur.
Distractor 3	D	Explanation: They might assume that -2 electron is also due to sulphur.

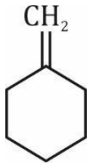
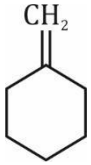
Chapter name	**Organic chemistry**
Essential Idea	By understanding different types of organic reaction intermediates (such as nucleophilic substitution, electrophilic addition, electrophilic substitution and redox reaction) and their mechanisms, it is possible to synthesize new compounds with novel properties which can be used in several applications.
Item stem	Compound D reacts with dilute aqueous sodium hydroxide in a similar way to A to form alcohol B. **Compound A**  **Compound D**  Explain why D reacts more quickly than A with dilute aqueous sodium hydroxide at the same temperature.

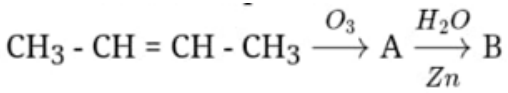
Marking Rubric	
Description	**Marks**
A possible correct answer: The C-Br bond in compound D is weaker than the C-Cl bond in compound A. So it's easier to break the compound D bond and hence it reacts quickly.	
C–Br is weaker than C–Cl or C–Br has lower bond enthalpy than C–Cl or C–Br breaks more easily C–Cl	2

Chapter Name	Organic Chemistry	
Essential Idea	By understanding different types of organic reactions (such as nucleophilic substitution, electrophilic addition, electrophilic substitution and redox reaction) and their mechanisms, it is possible to synthesize new compounds with novel properties which can be used in several applications.	
Item Stem	Which of the following is the most stable compound?	
Correct answer	Ph_3C^+	Reason: The tertiary carbocation is more stable than secondary, and primary. Furthermore, the cation is stabilised by the resonance.
Distractor 1	Ph_2C^+H	Explanation: They assume that secondary carbocation is more stable as there won't be the bulky effect.
Distractor 2	$Ph_3CC^+H_2$	Explanation: They assume that resonance is only possible in this compound.
Distractor 3	PhC^+H_2	Explanation: They assume that primary carbocation is the highest stable.

Chapter name	Hydrocarbons
Essential Idea	Alkanes mainly undergo free radical substitution, combustion, oxidation and aromatization. Alkenes and alkynes undergo mainly electrophilic additions. Aromatic hydrocarbons, despite having unsaturation, undergo mainly electrophilic substitution reactions.
Item stem	Carbocation D can undergo a type of reaction called a rearrangement to form carbocation E. In this reaction, a hydrogen atom and its bonding pair of electrons move from carbon a to carbon b as shown in Figure:  carbocation **D** carbocation **E** (i) Use your knowledge of carbocations to explain why this rearrangement takes place.

	(ii) As a result of this rearrangement, an alkene is formed. Draw the structure of the formed alkene.

Marking Rubric		
Part	**Description**	**Marks**
	A possible correct answer: (i) The rearrangement changed the secondary carbocation to tertiary carbocation which is more stable. (ii) 	
i	more stable (carbocation formed). changes from secondary to tertiary (carbocation)	1
ii		1

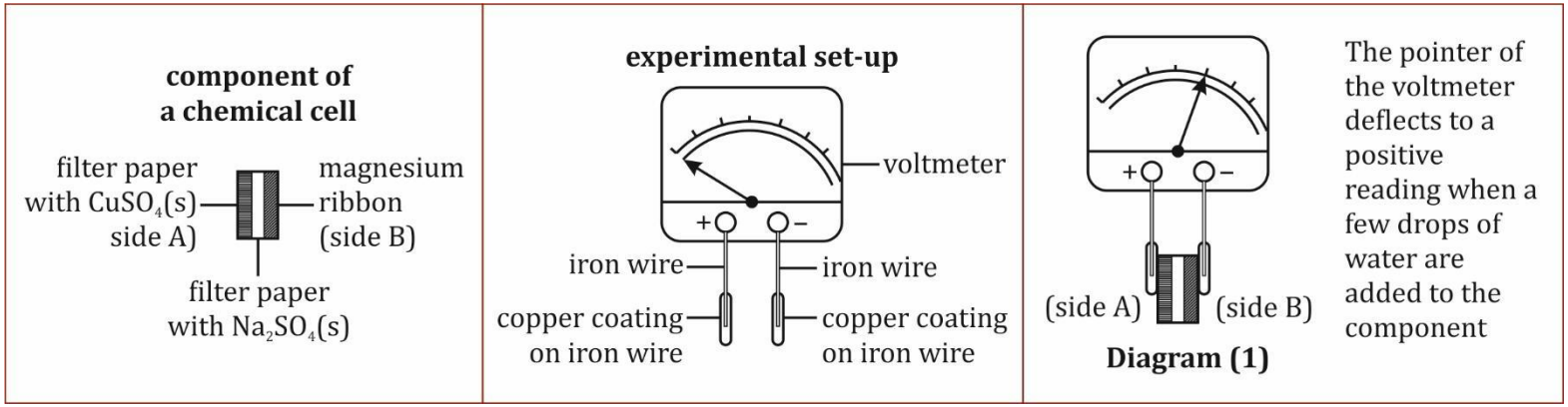
Chapter Name	Hydrocarbons	
Essential Idea	Alkanes mainly undergo free radical substitution, combustion, oxidation and aromatization. Alkenes and alkynes undergo mainly electrophilic additions. Aromatic hydrocarbons, despite having unsaturation, undergo mainly electrophilic substitution reactions.	
Item Stem	Identify product B in the following reaction: 	
Correct answer	CH_3CHO	Reason: When alkene undergoes ozonolysis, ozonide (A) is formed. When ozonide is reacted with zinc in the presence of moisture, an acetaldehyde (B) is formed.
Distractor 1	CH_3 CH_2CHO	Explanation: They assume that one carbon will be consumed in the reaction but an aldehyde will be formed.
Distractor 2	CH_3CO CH_3	Explanation: They assume that since the compound looks symmetric with a double bond, a similar-looking symmetric compound i.e. ketone is formed.
Distractor 3	CH_3 CH_2CO CH_3	Explanation: They assume that the number of carbon atoms remains the same.

Chapter name	Solutions
Essential Idea	The boiling point or freezing point of a pure substance is absolute but when the substance is adulterated by adding some other non-volatile substances, its boiling point and freezing point could change.
Item stem	Radiators with water are used in car engines to transfer the excess heat from the engine to the air outside. In a cold winter, the temperature suddenly dips down to -2 °C. If the water in a car's radiator would freeze down, the engine will not function properly after some time. To avoid the freezing of water, a certain amount of ethylene glycol should be used to lower the freezing point of water in the radiator. If the capacity of a car's radiator to hold water is 1 kg, how many grams of ethylene glycol must be added to lower the freezing point of water from 0 ° to -2 °C? (molecular weight of ethylene glycol= 62 g/mol)

Marking Rubric

Description	Marks
Calculation of the amount of ethylene glycol: - $\Delta T_f = i \times K_f \times m$.....equation (i) - Given that $\Delta T_f = 2$ °C, K_f of water = 1.86 K kg/mol , i =1 as ethylene glycol is a non-electrolyte, weight of solvent = 1kg, molecular weight of solute = 62	1.5
Let the weight of solute= X grams ∴from equation (i) 2 = 1 x 1.86 x X/62 or X = 66.67 g So, the amount of ethylene glycol to be used = 66.67 g	1.5

Chapter Name	Solutions	
Essential Idea	The solubility of a gas in a liquid depends upon the partial pressure and temperature.	
Item Stem	As per Henry's law $K_H = p/x$; where p is the partial pressure, x is the mole fraction of the gas, and K_H is the Henry law constant. If, the concentration of N_2 gas in water at constant pressure increases quadratically, how will the value of K_H change?	
Correct answer	Remains the same	Reason: The value of K_H only depends on temperature.
Distractor 1	Increases linearly	Explanation: They assume that since the equation is linear, K_H would increase linearly.
Distractor 2	Decreases linearly	Explanation: They assume that since the equation is linear, K_H would decrease linearly.
Distractor 3	Decreases quadratically	Explanation: They assume that the K_H is inversely proportional to concentration.

Chapter name	Electrochemistry
Essential Idea	The chemical reactions in an electrochemical cell generate mobile ions to produce electrical energy.
Item stem	The diagrams below show the component of a chemical cell, an experimental set-up and how the pointer of the voltmeter deflects when the set-up is connected to the component.  Why does the pointer of the voltmeter deflect as shown when a few drops of water are added to the component?

Marking Rubric

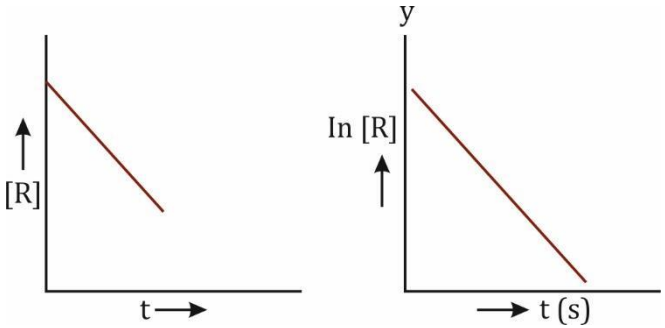
Part	Description	Marks
Correct answer	A possible answer: When a few drops of water are added, it acts as an electrolyte solution to form an electrochemical cell $CuSO_4$ ionises to form Cu^{2+} and SO_4^{2-} ions and mg releases electrons and hence there is movement of electrons in the cell giving rise to emf.	
	Water helps $CuSO_4$ and Mg to ionise and release electrons.	1
	Writes half-cell reaction for $CuSO_4$ and Mg and infers emf potential is created.	1

Chapter Name	Electrochemistry	
Essential Idea	The chemical reactions in an electrochemical cell generate mobile ions to produce electrical energy.	
Item Stem	Which of the following statements is/are correct? Given that $E^0_{Ag+/Ag}$ = 0.80 V, $E^0_{Mg2+/Mg}$ = -2.37 V, $E^0_{Cu2+/Cu}$ = +0.34 V (i) $AgNO_3$ can be stored in a copper vessel (ii) $Mg(NO_3)_2$ can be stored in a copper vessel (iii) $CuCl_2$ can be stored in silver vessel	
Correct answer	ii and iii	Reason: Cu is less reactive than Mg, so it can't replace Mg from its nitrates. Ag is less reactive than Cu, so it can't replace Cu from $CuCl_2$
Distractor 1	i and ii	Explanation: They assume that copper is less reactive than silver and hence it can't displace $AgNO_3$
Distractor 2	iii only	Explanation: They assume that copper will displace Mg also
Distractor 3	I, ii, iii	Explanation: They assume that copper can displace Mg but not Ag. .

<table>
<tr><th>Chapter name</th><th>Chemical Kinetics</th></tr>
<tr><td>Essential Idea</td><td>Rate of reactions can only be determined empirically and these limit possible reaction mechanisms. In particular cases, such as a linear chain of elementary reactions, the rate equation is equivalent to the slowest step of the reaction.</td></tr>
<tr><td>Item stem</td><td>The data in Table were obtained in a series of experiments on the rate of the reaction between compounds A and B at a constant temperature.
<table>
<tr><th>Experiment</th><th>Initial concentration of A/mol dm-3</th><th>Initial concentration of B/mol dm-3</th><th>Initial rate/mol dm-3s-1</th></tr>
<tr><td>1</td><td>0.12</td><td>0.26</td><td>2.10×10^{-4}</td></tr>
<tr><td>2</td><td>0.36</td><td>0.26</td><td>1.89×10^{-3}</td></tr>
<tr><td>3</td><td>0.72</td><td>0.13</td><td>3.78×10^{-3}</td></tr>
</table>
Show how these data can be used to deduce the rate expression for the reaction between A and B.</td></tr>
</table>

Marking Rubric

Description	Marks
Consider experiments 1 and 2: [B constant]; [A] increases × 3; rate increases by 9 times, therefore 2nd order with respect to A	1
From experiments 2 and 3: ⇨ $K[0.36]^a [0.26]^b / K[0.72]^a [0.13]^b = 1.89 \times 10^{-3} / 3.78 \times 10^{-3}$ ⇨ $2^b/2^a = 1/2^1$ Since a =2 ⇨ $2^b = 2^1$ ⇨ b =1 So, Rate = $K[A]^2 [B]^1$	2

Chapter Name	Chemical Kinetics	
Essential Idea	Rate reactions can only be determined empirically and these limit possible reaction mechanisms. In particular cases, such as, linear chain of elementary reactions, the rate equation is equivalent to the slowest step of the reaction	
Item Stem	The graphs below show the variation in concentration of reactants vs time for two different reactions. What are the orders of the reactions respectively? 	
Correct answer	0,1	Reason: For Zero order reaction, $R(t) = R_0 - k(t)$ and for first order, $\ln R(t) = -k(t) + \ln R_0$
Distractor 1	1,0	Explanation: They assume that for 1st order log is not involved.
Distractor 2	1,1	Explanation: They assume that both are the same and adding log values does not matter. Issue with basic step to derive the equation.
Distractor 3	0,2	Explanation: The basic step to derive the first order could be missing.

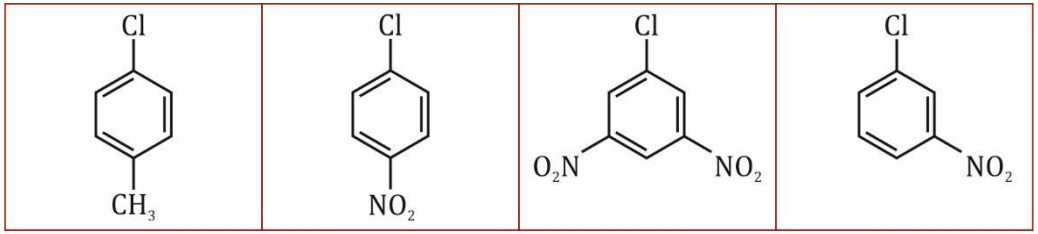
Chapter Name	d and f block elements
Essential Idea	The involvement of (n–1) d electrons in the behaviour of transition elements impart variable oxidation states, paramagnetic behaviour, catalytic properties, tendency for the formation of coloured ions, interstitial compounds and complexes.
Item Stem	Which of the following statements is false regarding the transition elements?

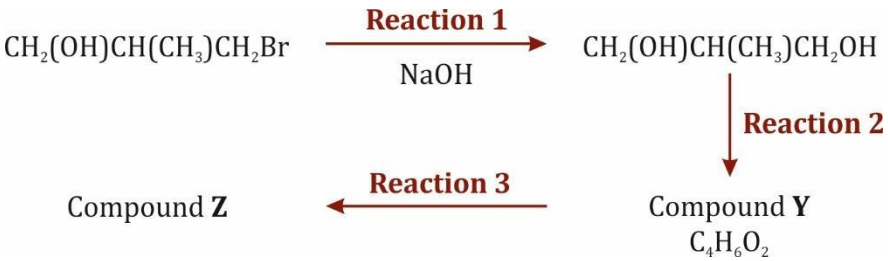
Correct answer	Atomic radii of transition metals increase rapidly with an increase in atomic number because of poor shielding of nuclear attraction by (n-1)d electrons.	Reason: Due to the shielding effect, although the atomic radii of transition metals increase with the increase in atomic number, it does not increase rapidly.
Distractor 1	4s electron penetrates towards the nucleus more than 3d electrons.	Explanation: They assume that the higher the value of n, the lower will be the penetration.
Distractor 2	Second and third transition series elements are nearly the same size.	Explanation: They assume that due to effective nuclear charge, the sizes would vary drastically.
Distractor 3	Their densities are higher and the densities of 5d series elements is greater than that of 4d series elements.	Explanation: They assume that since some of the d and f orbitals are empty, they are not dense.

Chapter name	**d and f block elements**	
Essential Idea	The involvement of (n–1) d electrons in the behaviour of transition elements impart variable oxidation states, paramagnetic behaviour, catalytic properties, tendency for the formation of coloured ions, interstitial compounds and complexes.	
Item stem	Explain the reason for the following: (i) Transition metals and many of their compounds are paramagnetic in nature. (ii) Transition metals generally form coloured compounds. (iii) The enthalpies of atomisation of transition metals are high.	
Marking Rubric		
Part	**Description**	**Marks**
(i)	As metal ions generally contain one or more unpaired electrons in them & hence their complexes are generally paramagnetic.	1
(ii)	This is attributed to the presence of unpaired electrons leading to (d-d transition in most of the compounds)	1

Iii	Because of having a larger number of unpaired electrons in their atoms, they have stronger interatomic interaction and hence stronger bonding between the atoms	1

Chapter Name	**Coordination Compounds**	
Essential Idea	The metal atom or ion under the influence of ligands can use its (n-1)d, ns, np or ns, np, nd orbitals for hybridisation to yield a set of equivalent orbitals (overlapping with ligands orbitals that donates electrons)	
Item Stem	Which of the following molecule is not tetrahedral? (Atomic number of Pt= 78; Zn = 30; Ni = 28)	
Correct answer	$[Pt(en)_2)]^{2+}$	Reason: It has dsp^2 hybridisation and hence square planar geometry.
Distractor 1	$[Ni(Co)_4]$	Explanation: They assume that it has dsp^2 hybridisation.
Distractor 2	$[Zn(NH_3)_4]^{2+}$	Explanation: They assume that it has sp^3d or dsp^2 hybridisation.
Distractor 3	$[NiCl_4]^{2-}$	Explanation: They assume that They assume that it has dsp^2 hybridisation.

Chapter Name	Haloalkanes and Haloarenes	
Essential Idea	Owing to the high electronegative value of halogens (Cl, F) in the C-X bond, there is polarity giving rise to reactions such as nucleophilic substitution, elimination, etc reactions.	
Item Stem	When chlorobenzene undergoes nucleophilic substitution reaction by heating it with sodium hydroxide at high temperature and pressure, the substitution of the Cl atom takes place very slowly. The substitution of the chlorine atom proceeds more easily when certain substituents are present on the benzene ring. In which of these compounds will the substitution of the chlorine atom be the easiest?  **P** **Q** **R** **S**	
Correct answer	Q	Reason: Due to resonance, the electron-withdrawing Nitro group at the para position creates a nucleophilic site at the ortho position.
Distractor 1	P	Explanation: They assume that CH_3 is an electron-donating group and create a nucleophilic site at the ortho position.
Distractor 2	R	Explanation: They assume that a greater number of electron-donating groups matters not their position.
Distractor 3	S	Explanation: They assume that NO_2 at the meta position would create the nucleophilic site.

Chapter name	Haloalkanes and haloarenes
Essential Idea	Owing to the high electronegative value of halogens (Cl, F) in the C-X bond, there is polarity giving rise to reactions such as nucleophilic substitution, elimination, etc.
Item stem	Haloalkanes are useful compounds in synthesis. A reaction pathway is shown:  (i) Reaction 1 occurs via a nucleophilic substitution mechanism. Explain why the halogenoalkane is attacked by the nucleophile in this reaction. (ii) Write the IUPAC name for $CH_2(OH)CH(CH_3)CH_2Br$

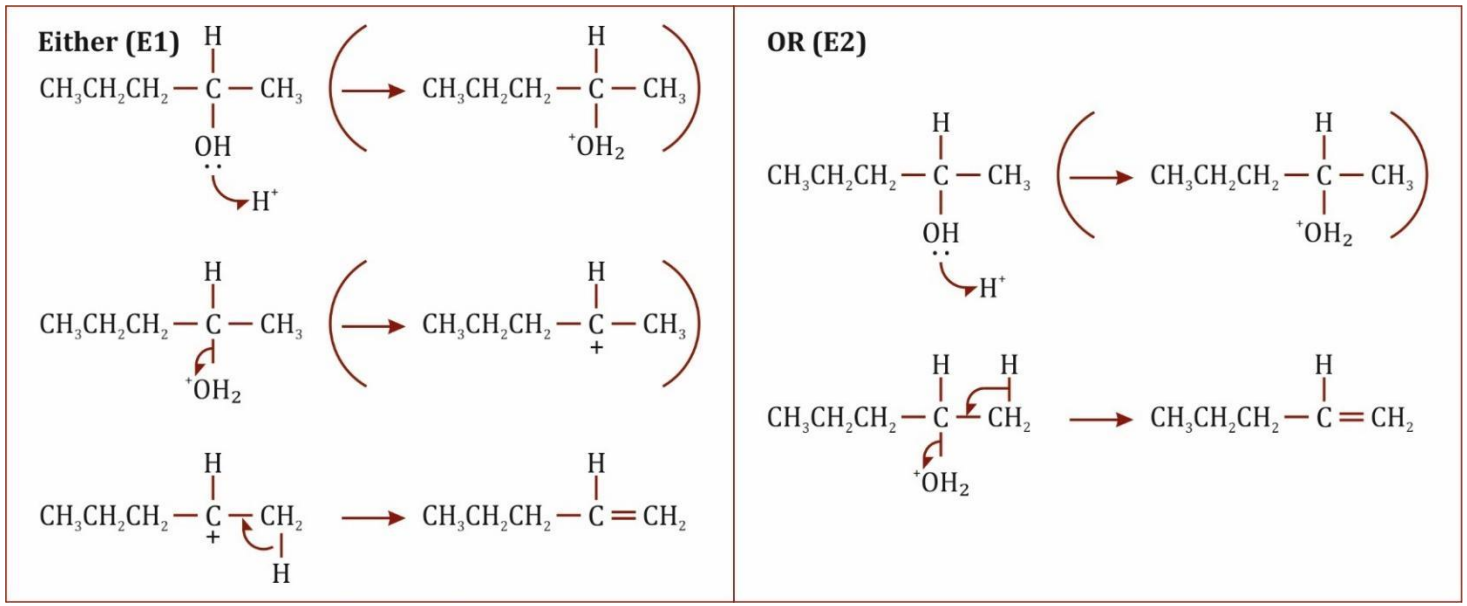
Marking Rubric

Part	Description	Marks
(i)	Bromine is more electronegative than carbon. C is partially positive / electron deficient. The lone/electron pair (on the nucleophile) donated to the partially positive carbon.	1
(ii)	3-bromo-2-methylpropan-1-ol	1

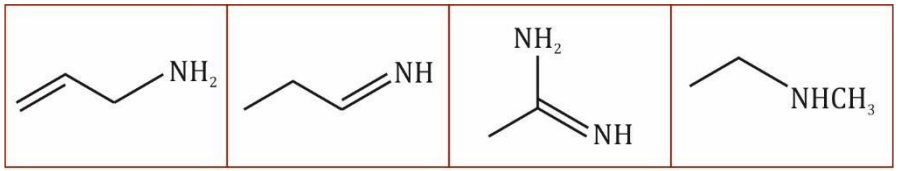
Chapter Name	Alcohols, Phenols, and ethers	
Essential Idea	Alcohols and phenols are versatile in nature due to the presence of C-O bond (which when broken it's an electrophile) and O-H bond (which when breaks make them nucleophile).	
Item Stem	At room temperature, which of the following will be formed when Phenol first reacts with conc. sulphuric acid and then conc. nitric acid.	
Correct answer	o-nitrophenol	Reason: Phenol on reaction with H2SO4 gives ortho and para products, but ortho is more stable at room temperature which on treatment with con HNO3 gives o-nitrophenol.
Distractor 1	p-nitrophenol	Explanation: They assume that para product is stable after the first step.
Distractor 2	Picric acid	Explanation: They assume that phenols will be transformed to picric acid as it reacts with acids.
Distractor 3	nitrobenzeneee	Explanation: They assume that OH group is replaced by NO2

Chapter name	Alcohols, phenols and ethers
Essential Idea	Alcohols and phenols are versatile in nature due to the presence of C-O bond (which when broken it's an electrophile) and 0-H bond (which when breaks make them nucleophile).
Item stem	A mixture of isomeric alkenes is produced when pentan-2-ol is dehydrated in the presence of hot concentrated sulfuric acid. Pent-1-ene is one of the isomers produced. Name and outline a mechanism for the reaction producing pent-1-ene.

Marking Rubric

Description	Marks
Name of reaction: Elimination	**1**
Mechanism:  	3

Chapter Name	Aldehydes, Ketones and Carboxylic acids	
Essential Idea	Both the aldehydes and ketones have similar carbonyl groups and hence they undergo similar kinds of reactions. the carbonyl carbon is an electrophilic (Lewis acid), and the carbonyl oxygen, a nucleophilic (Lewis base) centre.	
Item Stem	Given below are two statements: (i) In the electrophilic substitution of both aldehydes and ketones, the carbonyl group acts as an ortho-directing group. (ii) Both Benzaldehyde and ethanal can undergo aldol condensation. Choose the most appropriate alternatives.	
Correct answer	Both I and ii are false	Reason: In the electrophilic substitution of both aldehydes and ketones, the carbonyl group acts as a meta-directing group. Benzaldehyde does not have alpha hydrogen so it can't undergo an aldol reaction.
Distractor 1	Both I and ii are true	Explanation: They assume that Benzaldehyde has also alpha hydrogen. Also, they assume the carbonyl group is meta-directing
Distractor 2	I is true but ii is false	Explanation: they assume the carbonyl group is meta directing
Distractor 3	I is false but ii is true	Explanation: They assume that Benzaldehyde has also alpha hydrogen.

Chapter Name	Amines	
Essential Idea	Amines are a derivative of ammonia (NH3) in that one H is replaced by an alkyl group and makes it more basic than ammonia. The unshared electrons on Nitrogen is responsible for reactions, making it a Lewis base.	
Item Stem	Identify the correct order of basicity of the following compounds:  (a) (b) (c) (d)	
Correct answer	b<a<d<c	Reason: The basic nature depends on the ability to donate lone pairs. Because of +M effect, the electron density at NH would increase. In other compounds there is no +M effect
Distractor 1	b<a<c<d	Explanation: They assume that the effect of +I effect in d is more than +M effect in C
Distractor 2	a<b<c<d	Explanation: They assume that the effect of +I effect in d is more than +M effect in C.
Distractor 3	d<b<a<c	Explanation: They assume that -I effect in a is more powerful for making NH as electron donation than that of +I effect in d

Chapter name	Biomolecules
Essential Idea	Metabolic reactions in the human body are dependent on the supply of nutrients such as carbs, proteins, fats, vitamins through a regular balanced diet. Globally there are significant differences in the availability of nutritious food, which have major and diverse impacts on human health.
Item stem	Glucose and other dietary monosaccharides like fructose and galactose are very soluble in water at neutral pH. For example, over 150 g of glucose can be dissolved in 100 ml water at 25°C. (a) What features of the chemical structure of glucose make it so soluble in water?
Marking Rubric	

Part	Description	Marks
a	- Glucose and other hexose monosaccharides have five hydroxyl groups and an oxygen in the heterocyclic ring that can all form hydrogen bonds with water. - The ability to form these hydrogen bonds with water and other polar molecules enables hexoses and other carbohydrates to dissolve easily in aqueous solution.	1

Chapter Name	Biomolecules	
Essential Idea	Proteins are polymers of 2-amino acids, joined by amide links also known as peptide bonds.	
Item Stem	Which of the following hold(s) two peptide chains together in the β - -pleated sheet structure of proteins? P) peptide bonds Q) intermolecular hydrogen bonds R) intramolecular hydrogen	
Correct answer	Only Q	Reason: in the β - pleated sheet, intermolecular hydrogen bonding is present between oxygen and hydrogen of two different sheets.
Distractor 1	Only P	Explanation: They assume that since it involves protein and peptide chains, so its peptide bonds.
Distractor 2	P and Q	Explanation: They assume that peptide bonds can't be ignored for joining polymers of amino acids in the protein.
Distractor 3	P and R	Explanation: They assume that O-H in the same sheet are joined by hydrogen bonds.

12. REFERENCE DOCUMENTS

1. NCERT Draft LO document
   https://ncert.nic.in/pdf/publication/otherpublications/Draft_LO.pdf

2 NCERT Curriculum document
   http://cbseacademic.nic.in/curriculum_2022.html

3. NCERT textbooks
   https://ncert.nic.in/textbook.php?keip1=0-8

4. IB Past papers
   https://ibresources.org/ib-past-papers/

5. HKDSE Past papers
   https://www.hkeaa.edu.hk/en/hkdse/hkdse_subj.html?A1&1&4_25

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