National Curriculum of Pakistan
for

CHEMISTRY
(Grades IX-X and XI-XII)
2024

FOUR PARTS OF A CURRICULUM:

DIRECTORATE OF CURRICULUM & TEACHER EDUCATION

KHYBER PAKHTUNKHWA ABBOTTABAD

بسم الله الرحمن الرحيم

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Cross-Cutting Themes

Guidance for the Reader

The idea of Science, Technology, Engineering, The Arts and Mathematics (STEAM) is an overarching idea for how to break up the study of Chemistry into core disciplinary knowledge (that students need to learn in order to pass examination at each grade level) and cross-cutting themes (interdisciplinary connections and recurring ideas that are best reinforced in every chapter in order to promote student critical thinking and curiosity, but that is not expected to be assessed in standardized exams).

Cross-cutting themes must be appropriately included into every chapter of schools textbooks that are aligned with these standards. This does not mean that every subcomponent of every theme must be included in every chapter, rather that where connections are appropriate and would enhance the study of the core disciplinary knowledge these should be incorporated.

The themes presented below are adapted from the Next Generation Science Standards:

Science: theoretical understandings about science in general, experimental skills and their mutual overlaps in the methods of scientific inquiry.
Put Scientific Method in cross cutting themes

Engineering and Technology: applications of science to create solutions that improve standards of living, along with the design thinking approach of engineering applied to scientific problems and vice versa

Mathematics: the connections of mathematics with the natural world, and its interconnectedness with the methods of the natural sciences

The Arts: What can be understood about the nature of science from the fine arts, performing arts and the humanities?

Theme	Components	Elaboration and Guidance
Science	**A) Scientific Knowledge (these themes are applied across the conceptual SLOs)** **1. Patterns** i) Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. ii) Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus, requiring improved investigations and experiments. iii) Patterns of performance of designed systems can be analysed and interpreted to reengineer and improve the system. iv) Mathematical representations are needed to identify some patterns. v) Empirical evidence is needed to identify patterns. **2. Cause and Effect: Mechanism and Prediction** i) Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.	**Elaborations on (A) Scientific Knowledge):** 1. **Patterns:** Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them. 2. **Cause and Effect:** Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering. 3. **Scale, Proportion and Quantity:** In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change. 4. **Systems and System Models:** A system is an organized group of related objects or components; models can be used for understanding and predicting the behaviour of systems. 5. **Energy and Matter:** Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behaviour 6. **Structure and Function:** The way an object is shaped or structured determines many of its properties and functions.

	ii) Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. iii) Systems can be designed to cause a desired effect. iv) Changes in systems may have various causes that may not have equal effects. **3. Scale, Proportion, and Quantity** i) The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. ii) Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. iii) Patterns observable at one scale may not be observable or exist at other scales. iv) Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. v) Algebraic thinking is used to examine scientific data and predict the effect of a change in one	7. **Stability and Change:** For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand. **Elaborations on (B) Scientific Practices:** 1. **Asking Questions and Defining Problems:** A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world(s) works and which can be empirically tested. Engineering questions clarify problems to determine criteria for successful solutions and identify constraints to solve problems about the designed world. Both scientists and engineers also ask questions to clarify ideas. 2. **Developing and Using Models:** A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations. Modelling tools are used to develop questions, predictions and explanations; analyse and identify flaws in systems; and communicate ideas. Models are used to build and revise scientific explanations and proposed engineered systems. Measurements and observations are used to revise models and designs.

	variable on another (e.g., linear growth vs. exponential growth). **4. Systems and System Models** i) Systems can be designed to do specific tasks. ii) When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analysed and described using models. iii) Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. iv) Models can be used to predict the behaviour of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models. **5. Energy and Matter: Flows, Cycles, and Conservation** i) The total amount of energy and matter in closed systems is conserved. ii) Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.	**3. Planning and Carrying out Investigations:** Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters. Engineering investigations identify the effectiveness, efficiency, and durability of designs under different conditions. **4. Analysing and Interpreting Data:** Scientific investigations produce data that must be analysed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis. Engineering investigations include analysis of data collected in the tests of designs. This allows comparison of different solutions and determines how well each meets specific design criteria—that is, which design best solves the problem within given constraints. Like scientists, engineers require a range of tools to identify patterns within data and interpret the results. Advances in science make analysis of proposed solutions more efficient and effective.

	iii) Energy cannot be created or destroyed—only moves between one place and another place, between objects and/or fields, or between systems. iv) Energy drives the cycling of matter within and between systems. v) In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved. **6. Structure and Function** i) Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem. ii) The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. **7. Stability and Change** i) Much of science deals with constructing explanations of how things change and how they remain stable.	**5. Using Mathematics and Computational Thinking:** In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; solving equations exactly or approximately; and recognizing, expressing, and applying quantitative relationships. Mathematical and computational approaches enable scientists and engineers to predict the behaviour of systems and test the validity of such predictions. **6. Constructing Explanations and Designing Solutions:** The goal of science is the construction of theories that provide explanatory accounts of the world. A theory becomes accepted when it has multiple lines of empirical evidence and greater explanatory power of phenomena than previous theories. The goal of engineering design is to find a systematic solution to problems that is based on scientific knowledge and models of the material world. Each proposed solution results from a process of balancing competing criteria of desired functions, technical feasibility, cost, safety, aesthetics, and compliance with legal requirements. The optimal choice depends on how well the proposed solutions meet criteria and constraints. **7. Engaging in Argument from Evidence:** In science and engineering, reasoning and argument based on evidence are essential to identifying the best

	ii) Change and rates of change can be quantified and modelled over very short or very long periods of time. Some system changes are irreversible. iii) Feedback (negative or positive) can stabilize or destabilize a system. iv) Systems can be designed for greater or lesser stability. **B) Scientific Practices** **1. Asking Questions and Defining Problems** i) Ask questions: – that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information. – that arise from examining models or a theory, to clarify and/or seek additional information and relationships. – to determine relationships, including quantitative relationships, between independent and dependent variables. – to clarify and refine a model, an explanation, or an engineering problem. ii) Evaluate a question to determine if it is testable and relevant.	explanation for a natural phenomenon or the best solution to a design problem. Scientists and engineers use argumentation to listen to, compare, and evaluate competing ideas and methods based on merits. Scientists and engineers engage in argumentation when investigating a phenomenon, testing a design solution, resolving questions about measurements, building data models, and using evidence to evaluate claims. **8. Obtaining, Evaluating and Communicating Information:** Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity. Communicating information and ideas can be done in multiple ways: using tables, diagrams, graphs, models, and equations as well as orally, in writing, and through extended discussions. Scientists and engineers employ multiple sources to obtain information that is used to evaluate the merit and validity of claims, methods, and designs.

	iii) Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory. iv) Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design. v) Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical and/or environmental considerations. **2. Developing and Using Models** i) Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria. ii) Design a test of a model to ascertain its reliability. iii) Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.	

	iv) Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations. v) Develop a complex model that allows for manipulation and testing of a proposed process or system. vi) Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyse systems, and/or solve problems. **3. Planning and Carrying Out Investigations** i) Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled. ii) Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g.,	

	number of trials, cost, risk, time), and refine the design accordingly. iii) Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts. iv) Select appropriate tools to collect, record, analyse, and evaluate data. v) Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated. vi) Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables. **4. Analysing and Interpreting Data** i) Analyse data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. ii) Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear	

	fits) to scientific and engineering questions and problems, using digital tools when feasible. iii) Consider limitations of data analysis (e.g., measurement error, sample selection) when analysing and interpreting data. iv) Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations. v) Evaluate the impact of new data on a working explanation and/or model of a proposed process or system. vi) Analyse data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success. **5. Using Mathematics and Computational Thinking** i) Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. ii) Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.	

	iii) Apply techniques of algebra and functions to represent and solve scientific and engineering problems. iv) Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model "makes sense" by comparing the outcomes with what is known about the real world. v) Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m^3, acre-feet, etc.). **6. Constructing Explanations and Designing Solutions** i) Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. ii) Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.	

	iii) Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. iv) Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. v) Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade off considerations. **7. Engaging in Argument from Evidence** i) Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. ii) Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. iii) Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions,	

	responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions. iv) Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence. v) Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence. vi) Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations). **8. Obtaining, Evaluating and Communicating Information** i) Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.	

	ii) Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. iii) Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. iv) Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. v) Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).	
Technology & Engineering	**1. Analyse a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.** i) Analyse complex real-world problems by specifying criteria and constraints for successful solutions.	The Engineering Design cycle can be considered to consist of the below three iterative steps in a global problem solving context: **Define:** Attend to a broad range of considerations in criteria and constraints for problems of social and global significance.

	ii) Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. iii) Humanity faces major global challenges today, such as the need for supplies of clean water and food or for energy sources that minimize pollution, which can be addressed through engineering. These global challenges also may have manifestations in local communities. iv) All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment v) New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology. **2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.**	**Develop solutions:** Break a major problem into smaller problems that can be solved separately. **Optimize:** Prioritize criteria, consider trade-off, and assess social and environmental impacts as a complex solution is tested and refined.

	i) Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade off considerations. ii) Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. **3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.** i) Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade off considerations. ii) When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. **4. Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.**	

	i) Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. ii) Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. iii) Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales. **5. Interdependence of Science, Engineering, and Technology** i) Science and engineering complement each other in the cycle known as research and development (R&D). ii) Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise.	

	6. Influence of Engineering, Technology, and Science on Society and the Natural World i) Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications. ii) Engineers continuously modify these systems to increase benefits while decreasing costs and risks. iii) New technologies can have deep impacts on society and the environment, including some that were not anticipated. iv) Analysis of costs and benefits is a critical aspect of decisions about technology.	
The Arts and Mathematics	**A) Mathematical Knowledge in Science** (these are embedded in the conceptual SLOs, as well as is in the prerequisite mathematical knowledge requirements) **B) Nature of Science** 1. Scientific Investigations Use a Variety of Methods i) Science investigations use diverse methods and do not always use the same set of procedures to obtain data. ii) New technologies advance scientific knowledge.	

	iii) Scientific inquiry is characterized by a common set of values that include: logical thinking, precision, open-mindedness, objectivity, scepticism, replicability of results, and honest and ethical reporting of findings. iv) The discourse practices of science are organized around disciplinary domains that share examples for making decisions regarding the values, instruments, methods, models, and evidence to adopt and use. v) Scientific investigations use a variety of methods, tools, and techniques to revise and produce new knowledge. **2. Science knowledge is based on empirical evidence.** i) Science disciplines share common rules of evidence used to evaluate explanations about natural systems. ii) Science includes the process of coordinating patterns of evidence with current theory. iii) Science arguments are strengthened by multiple lines of evidence supporting a single explanation. **3. Scientific Knowledge is Open to Revision in Light of New Evidence** i) Scientific explanations can be probabilistic.	

	ii) Most scientific knowledge is quite durable but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence. iii) Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation. **4. Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** i) Theories and laws provide explanations in science, but theories do not with time become laws or facts. ii) A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that has been repeatedly confirmed through observation and experiment, and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence. iii) Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory.	

	iv) Laws are statements or descriptions of the relationships among observable phenomena. v) Scientists often use hypotheses to develop and test theories and explanations. **5. Science is a Way of Knowing** i) Science is both a body of knowledge that represents a current understanding of natural systems and the processes used to refine, elaborate, revise, and extend this knowledge. ii) Science is a unique way of knowing and there are other ways of knowing. iii) Science distinguishes itself from other ways of knowing through use of empirical standards, logical arguments, and sceptical review. iv) Science knowledge has a history that includes the refinement of, and changes to, theories, ideas, and beliefs over time. **6. Scientific Knowledge Assumes an Order and Consistency in Natural Systems** i) Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future.	

	ii) Science assumes the universe is a vast single system in which basic laws are consistent. **7. Science is a Human Endeavour** i) Scientific knowledge is a result of human endeavour, imagination, and creativity. ii) Individuals and teams from many nations and cultures have contributed to science and to advances in engineering. iii) Scientists' backgrounds, theoretical commitments, and fields of endeavour influence the nature of their findings. iv) Technological advances have influenced the progress of science and science has influenced advances in technology. v) Science and engineering are influenced by society and society is influenced by science and engineering. **8. Science Addresses Questions About the Natural and Material World** i) Not all questions can be answered by science.	

	ii) Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions. iii) Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge. iv) Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues.	

Cross Cutting Theme

Grade 9	Grade 10	Grade 11	Grade 12
1. State that people who study chemistry are called chemists. 2. Justify, with examples, that civilizations throughout history have systematically studied living things (Some examples include: • The ancient Egyptians experimented with metals, dyes, and medicines, while the ancient Greeks studied the properties of matter and proposed theories about composition. • The Indus Valley Civilization developed advanced metallurgy and pottery techniques, and Ayurvedic medicine utilized chemical compounds. • In China, alchemists experimented with chemical processes to create materials like	1. Suggest, with examples, the impact of social and political factors on the recognition of scientific contributions, using historical examples. (For example: – historically the contributions of women to scientific research have not been highlighted) – the effects of racism, colonialism and elitism on who gets credit for work – the influence (private, public, national, international) of funding sources and lobbying).		

porcelain, gunpowder, and paper, and discovered the principles of distillation and fermentation. • During the Islamic Golden Age, scholars like Jabir ibn Hayyan conducted experiments with metals and acids, paving the way for the discovery of many chemical reactions and compounds.) 3. Illustrate, with examples from the physical sciences, that scientists often work in areas, or produce findings, that have significant ethical and political implications. (Some examples include: – These areas include development of chemical weapons, drug research, disposal of chemical waste practices, mining of rare earth metals, development of chemical products that may have unforeseen side effects like causing cancer			

– There are also questions involving intellectual property rights and the free exchange of information that may impact significantly on a society. – Science is undertaken in universities, commercial companies, government organizations, defence agencies and international organizations. Questions of patents and intellectual property rights arise when work is done in a protected environment. – Science has been used to solve many problems and improve humankind's lot, but it has also been used in morally questionable ways and in ways that inadvertently caused problems. Advances in sanitation, clean water supplies and hygiene led to significant decreases in			

death rates but without compensating decreases in birth rates, this led to huge population increases with all the problems of resources, energy and food supplies that entails. – Ethical discussions, risk–benefit analyses, risk assessment and the precautionary principle are all parts of the scientific way of addressing the common good.)			

<u>Theoretical Concepts Progression Grid</u>

Guidance for the Reader

Assumption of Prior Knowledge: It is assumed that students will already have knowledge (and be able to apply it as needed in their current class) of what they learned in their previous grades, so SLOs from previous grades are not repeated in the higher grades. In practice, teachers may want to refresh concepts with their students as appropriate.

Organization of the SLOs in the Progression Grid: Inside a grade, teachers are free to teach the content in any order of preference. Textbook publishers are also free to organize the contents of their books in any manner that they consider most effective, as long as all the SLOs in the Progression Grid and Cross-Cutting themes are covered. The SLOs inside a grade do not need to be taught in the order presented in a grade in this PG. The Nature of Science domain would, for example, be best taught by being integrated into the teaching of all the chapters of the curriculum.

Nature of Science Domain A Guidance for the Reader: Nature of Science learning objectives have been added to the Progression Grids of Physics, Biology, Chemistry and Math. The purpose of studying science at the high school level is not only to prepare students for further study in the sciences. Many students will in fact not go on to study further science or STEM fields. The science that they learn in school may well remain their understanding of the subject for the rest of their lives. Hence these curricula must consider what citizens in a democratic society ought to know about the nature of science. "Nature of Science" (NOS) means teaching about science's underlying assumptions, and its methodologies. This involves some integrated study of the history of science, and some of the broad concepts from the philosophy of science. It is important to study NOS because it helps students become critical thinkers about the scientific information they consume from the world around them. Teaching NOS in the study of Physics, Biology, and Chemistry is a cutting-edge international trend.

- In the Nature of Science domain SLOs, unless explicitly stated, where the SLO begins with the phrase 'explain with examples' it is enough that students study 2-3 examples and can use them in their answers for examination questions.
- There is no need to extensively or comprehensively study the history of science or its applications in other fields.
- The purpose here is that students are able to develop an appreciation of these aspects of the field of chemistry with some rigor (hence these SLOs are expected to be assessed), but not to become so extensive that it takes a lot of time out from building competence in rest of the domains on chemistry skills and knowledge.

Assessment Criterion for Domain A

Assessment of Nature of Science Domain A in standardized board exams will be kept to objective knowledge; students will not be expected to write argumentative essays or express subjective perspectives. Rather assessment in the standardized exams will occur through multiple choice questions and/or through short answer questions that require two-three sentence responses. Sample questions are provided in the Curriculum Guidelines. In their regular classroom study, teachers *are* encouraged to teach these topics through learner-cantered activities that promote curiosity, inquiry, creativity, critical discussion and collaboration.

Optional SLOs: SLOs that are italicized are optional, as they may be advanced or too much to cover with the rest of the content in the grade.

Grade 9	Grade 10	Grade 11	Grade 12
Domain A: Nature of Science in Chemistry			
Standard: Students will demonstrate an understanding skill and attitude to deal in the areas of chemistry as an introduction. **Benchmark 1:** Students can describe the history of chemistry and key developments in the field.			
The Science of Chemistry: **[SLO: C-09-A-01]** Define chemistry as the study of matter, its properties, composition, structure and interactions with other matter and energy. Or Study of earth (solids), Air (gasses), Sea (liquids) and sky (plasma) and their interaction with each other.	**History of Chemistry** **[SLO: C-10-A-01]** Justify, with examples, that to do science is to be involved in a community of inquiry. (For context in Chemistry: – This community adheres to certain common principles, methodologies, and processes, such as the use of empirical evidence and logical reasoning to develop scientific theories.	**N/A**	

[SLO: C-09-A-02] Explain with examples that chemistry has many sub-fields and interdisciplinary fields. (Some examples include: ● Biochemistry ● Medicinal Chemistry ● Polymer Chemistry ● Geochemistry ● Environmental Chemistry ● Analytical Chemistry ● Physical Chemistry ● Organic Chemistry ● Inorganic Chemistry ● Nuclear Chemistry ● Astrochemistry) **[SLO: C-09-A-03]** Formulate examples of essential questions that are important for the branches of Chemistry. (e.g. for Analytical Chemistry a question would be 'how can we accurately determine the chemical composition of a sample?')	For example, chemists based their research on the assumptions of conservation of mass and energy and use this to verify whether their calculations and findings are sensible. – Scientists in different fields often share similar methodologies, such as the use of controlled experiments and the peer review process. The scientific community also values objectivity and scepticism, which are essential for ensuring the accuracy and validity of scientific findings.) **[SLO: C-10-A-02]** Explain, with examples, that 'scientific paradigm' is a theoretical model of how nature works. (Some examples include: – The belief that materials that burn do so because a material called ‘phlogiston’ was the paradigm in chemistry in the 18th century.		

[SLO: C-09-A-04] Differentiate between 'science', 'technology' and 'engineering' by making reference to examples from the physical sciences. (Science is a process of exploring new knowledge methodically through observation and experiments, technology refers to the process of applying scientific knowledge in practical applications for various purposes. Engineering is the application of knowledge in order to design, build and maintain a product or a process that solves a problem and fulfils a need. Science provides the foundational knowledge and understanding while engineering applies that knowledge to develop practical solutions.)	– Historical models of the atom are paradigms, such as the ‘plum-pudding' and the Rutherford models of the atom. – The Periodic Table of elements and belief in the ‘periodicity’ of atoms based on the arrangements of their electrons is a paradigm. Scientific paradigms in chemistry provide a framework for understanding the properties of materials and developing new materials with specific properties. Overall, scientific paradigms in chemistry guide research and development in the field, and help scientists to better understand the behaviour of chemicals and their interactions.)		

Standard: Students should be able to explain and evaluate, with examples, what philosophical assumptions underpin the practice of science

Benchmark I: Students should able to: Describe how scientists argue with level of confidence or uncertainty based on the experimental results.	**Benchmark I**: Students should be able to: Explain the role of thought experiments in chemical theory Consider the ethical aspects of developing and using chemical substances

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<td>Philosophy of Science:

[SLO: C-10-A-03]
Explain, with examples, how scientists speak of “levels of confidence” (or uncertainty) when discussing experimental outcomes.

[SLO: C-10-A-04]
Explain the difference between repeatability and reproducibility in chemistry.

(For context:
– Repeatability as the idea that scientific results from experiments should be possible to verify by conducting the experiment again under the same physical conditions.

– Reproducibility as the idea that the same or similar result is obtained when the measurement is made under either different conditions or by a different method or in a different experiment.)</td>
<td>Thought Experiments

[SLO: C-11-A-01]
Explain that a thought experiment is a hypothetical situation in which a hypothesis, theory or principle is laid out for the purpose of thinking through its consequences.</td>
<td>Ethics and Values in Chemistry

[SLO: C-12-A-01]
Identify common cognitive biases/fallacies that can hinder sound scientific reasoning in physical sciences (Add few examples from the following:

● the confirmation biases
● hasty generalizations
● post hoc ergo propter hoc (false cause)
● the straw man fallacy
● redefinition (moving the goalposts)
● the appeal to tradition
● false authority
● failing Occam's Razor
● argument from non-testable hypothesis
● begging the question
● fallacy of exclusion
● faulty analogy)

[SLO: C-12-A-02]
Explain the pros and cons of ethical considerations involved in the production and use of chemical substances and processes</td>
</tr>
</table>

			(Some examples include: the impact on human health and the environment; the responsibility of scientists and companies; the role of regulations and laws.) **[SLO: C-12-A-03]** Explain and apply the following terms to deconstruct the structure of a scientific argument in a variety of formats such as speeches, written articles and advertisement brochures: ● claims ● counterclaims ● rebuttals ● premises ● conclusions ● assumptions

Domain B: Physical Chemistry			
Standard: (Matter) **Students should be able to:** **Define matter and describe its physical and chemical properties.** **Classify matter as elements, compounds, or mixtures, and explain the characteristics that define each type.** **Discuss the behaviour of matter at the macroscopic and microscopic levels, including the kinetic molecular theory and phase changes.**			
Benchmark 1: Students can explain the nature of matter. and its composition including atoms, elements, (including allotropic forms) and molecules		**N/A**	
[SLO: C-09-B-01] Define matter as a substance having mass and occupying space. **[SLO: C-09-B-02]** State the distinguishing macroscopic properties of commonly observed states of solids, liquids and gasses in particular density, compressibility, and fluidity. **[SLO: C-09-B-03]** Identify that state is a distinct form of matter (examples could include familiarity with plasma, intermediate states and exotic states e.g. BEC or liquid crystals.)			N/A

[SLO: C-09-B-04] Explain the allotropic forms of solids (some examples may include diamond, graphite, and fullerenes.) **[SLO: C-09-B-05]** Explain the differences between elements, compounds and mixtures. **[SLO: C-09-B-06]** Identify solutions, colloids, and suspensions as mixtures and give an example of each. **[SLO: C-09-B-07]** Explain the effect of temperature on solubility and formation of unsaturated and saturated solutions.			
Benchmark 2: Students can understand the states of matter and phase changes, and can explain the impact of temperature and pressure on matter.		**N/A**	
N/A	**[SLO: C-10-B-01]** Explain changes of state and internal energy without change in temperature (melting, boiling, freezing, condensation, sublimation and deposition) in terms of kinetic particle theory.	N/A	N/A

	[SLO: C-10-B-02] Distinguish between evaporation and boiling. **[SLO: C-10-B-03]** Interpret heating and cooling curves in terms of kinetic particle theory. **[SLO: C-10-B-04]** Interpret in terms of kinetic particle theory the effects of changing pressure, temperature and volume of a gas on the other two with regards to Boyle's law, Charles' Law, and Avogadro's Law. ***[SLO: C-10-B-05]*** Explain qualitatively the effect of external pressure on rate of boiling and evaporation. **[SLO: C-10-B-06]** Explain diffusion of gases in terms of kinetic particle theory. **[SLO: C-10-B-07]** Examine qualitatively the effect of molecular mass and temperature on the rate of diffusion.		

<table>
<tr><td></td><td>[SLO:C-10-B-08]
Discuss applications of sublimation around us, (Examples may include: solid air fresheners and 3D printing.)

[SLO:C-10-B-09]
Explain, with the help of kinetic particle theory, the importance of rates of diffusion of medicines in the body.</td><td></td><td></td></tr>
<tr><td colspan="4">Standard: (Atomic Structure)
Students should be able to:
Describe the structure of atoms, including the nucleus and electron shells.
Explain the concept of atomic number and its relationship to the number of protons in an atom.
Describe the arrangement of electrons in the electron shells and explain how this arrangement affects the chemical properties of an atom.
Discuss the principles of isotopes, including atomic mass and isotopic abundance.
Explain the concept of ionization and describe the formation of ions.
Discuss ionization energy, factors affecting ionization energy and its trends in the Periodic Table.</td></tr>
<tr><td colspan="2">Benchmark 1: Students can describe the structure of atoms, including the protons, neutrons, and electrons and using these concepts to discuss Isotopes.</td><td colspan="2">Benchmark 1: The student will be able to explain the energy levels and use these levels to predict and interpret trends in the Periodic Table, such as atomic radius.</td></tr>
<tr><td>[SLO: C-09-B-08]
Explain the structure of the atom as a central nucleus containing neutrons and protons surrounded by electrons in shells.

[SLO: C-09-B-09]
State that, orbits (shells) are energy levels of electrons and a larger shell implies higher</td><td>N/A</td><td>[SLO: C-11-B-01]
Describe that, each atomic shell and sub-shell are further divided into degenerate orbitals having the same energy.

[SLO: C-11-B-02]
Describe protons, neutrons and electrons in terms of their relative charges and relative masses.</td><td>N/A</td></tr>
</table>

energy and greater average distance from nucleus. ***[SLO: C-09-B-10]*** *State that electrons are quantum particles with probabilistic paths whose exact paths and locations cannot be mapped (with reference to the uncertainty principle).* **[SLO: C-09-B-11]** Explain that a nucleus is made up of protons and neutrons held together by strong nuclear force. **[SLO: C-09-B-12]** Explain that an atomic model is an aid to understand the structure of an atom. **[SLO: C-09-B-13]** State the relative charges and relative masses of subatomic particles (an electron, proton and neutron). **[SLO: C-09-B-14]** Interpret the relationship of masses and charges of subatomic particles.		**[SLO: C-11-B-03]** Recognize that the terms atomic and proton number represent the same concept. **[SLO: C-11-B-04]** Recognize the terms mass number and nucleon number represent the same concept. **[SLO: C-11-B-05]** Describe the behaviour of beams of protons, neutrons and electrons moving at the same velocity in an electric field. **[SLO: C-11-B-06]** Determine the numbers of protons, neutrons and electrons present in both atoms and ions given atomic or proton number, mass/or nucleon number and charge. **[SLO: C-11-B-07]** Explain the change in atomic and ionic radius across a period and down a group.	

[SLO: C-09-B-15] Illustrate the path that positively and negatively charged particles would take under the influence of a uniform electric field. **[SLO: C-09-B-16]** Define proton number/atomic number as the number of protons in the nucleus of an atom. **[SLO: C-09-B-17]** Explain that the proton number is unique to each element and used to arrange elements in Periodic Table. ***[SLO: C-09-B-18]*** *State that radioactivity can change the proton number and alter an atom's identity.* **[SLO: C-09-B-19]** Define nucleon number/ mass number as sum of number of protons and neutrons in the nucleus of an atom.			

[SLO: C-09-B-20] Define isotopes as different atoms of the same element that have same number of protons but different neutrons. **[SLO: C-09-B-21]** State that isotopes can affect molecular mass but not chemical properties of an atom. **[SLO: C-09-B-22]** Determine the number of protons and neutrons of different isotopes. **[SLO: C-09-B-23]** Define relative atomic mass as the average mass of isotopes of an element compared to $\frac{1}{12}^{th}$ of mass of an atom of Carbon-12. ***[SLO: C-09-B-24]*** *State that isotopes can exhibit radioactivity.* **[SLO: *C-09-B-25*]** Discuss the importance of isotopes using carbon dating			

and medical imaging as examples. **[SLO: *C-09-B-26*]** Describe the formation of positive (cation) and negative (anion) ions from atoms. **[SLO: *C-09-B-27*]** Interpret and use the symbols for atoms and ions. **[SLO: *C-09-B-28*]** Calculate relative atomic mass of an element from relative masses and abundance of isotopes. **[SLO: *C-09-B-29*]** Calculate the relative mass of an isotope given relative atomic mass and abundance of all stable isotopes.			
N/A		**Benchmark 2: Students can describe the electronic configuration of atomic shells and subshells in detail, relate electronic configuration to patterns in ionization energy and calculate the relative atomic mass.**	
N/A	N/A	**[SLO: C-11-B-08]** Define terms related to electronic configuration (Some examples include shells, subshells, orbitals, principal quantum number (n), ground state.)	N/A

		[SLO:C-11-B-09] Relate Quantum Numbers to Electronic distribution of elements. **[SLO: C-11-B-10]** Describe the number of orbitals making up s, p, d and f sub-shells, and the number of electrons that can fill s, p, d and f sub-shells. **[SLO:C-11-B-11]** Apply Aufbau principle, Pauli exclusion principle and Hund's rule to write the electronic configuration of elements. **[SLO: C-11-B-12]** Describe the order of increasing energy of the subshells (s, p, d and f). **[SLO: C-11-B-13]** Describe the electronic configuration to include the number of electrons in each shell, subshell and orbital.	

		[SLO: C-11-B-14] Explain the electronic configuration in terms of energy of the electrons and inter-electron repulsion. **[SLO: C-11-B-15]** Determine the electronic configuration of atoms and ions given the proton or electron number and charge. (Some examples include: a. simple configuration e.g. 2, 8, b. subshells e.g. $1s^2$, $2s^2$, $2p^6$, $3s^2$ c. students should be able to determine both of these from Periodic Table and are not required to memorize d. students should understand that chemical properties of an atom are governed by valence electrons). **[SLO: C-11-B-16]** *Illustrate the importance of electronic configuration in development of new materials for electronic devices.*	

		(For example, semiconductors such as silicon have a specific electronic configuration that makes them ideal for use in electronic devices.) **[SLO: C-11-B-17]** Describe the shapes of s, p and d orbitals. **[SLO: C-11-B-18]** Describe a free radical as a species with one or more unpaired electrons. ***[SLO: C-11-B-19]*** Explain that ionization energy is due to the attraction between the nucleus and the outer electron. ***[SLO: C-11-B-20]*** Explain the trends of ionization energy across a period and down a group of the Periodic Table. ***[SLO: C-11-B-21]*** Account for the variation in successive ionization energies of an element.	

		[SLO: C-11-B-22] Explain the factors influencing the ionization energies of elements in terms of nuclear charge, atomic/ionic radius, shielding by inner shells and subshells and spin-pair repulsion. **[SLO: C-11-B-23]** Deduce the electronic configurations of elements using successive ionization energies data. **[SLO: C-11-B-24]** Deduce the position of an element in the Periodic Table using successive ionization energies data. **[SLO: C-11-B-25]** Explain how a mass spectrometer can be used to determine the relative atomic mass of an element from its isotopic composition. **[SLO: C-11-B-26]** Perform calculations involving non-integer relative atomic masses and abundance of	

<table>
<tr><td></td><td></td><td>isotopes from given data, including mass spectra.

[SLO: C-11-B-27]
Explain the concept of emission spectra, use the concept of emission spectra to deduce the electronic configuration of elements.</td><td></td></tr>
<tr><td colspan="4">Standard: (Chemical Bonding)
Students should be able to:
Explain the concept of chemical bonding and describe the different types of bonds, including ionic, covalent, and metallic bonds.
Discuss the factors that affect bond strength, including bond length and bond energy.
Describe the properties of molecular compounds and how they are affected by the type of bond they contain.
Apply the principles of chemical bonding to explain the physical properties of materials.
Describe electronegativity and its trends in the Periodic Table.</td></tr>
<tr><td colspan="2">Benchmark 1: Students can describe the types of chemical bonds, including ionic, covalent coordinate covalent, and metallic bonds. Discuss the structure and uses of ionic and covalent compounds.</td><td colspan="2">Benchmark 1: Students can apply the concepts of chemical bonding and bond theories to predict the structure and properties of molecules, including molecular geometry, and polarity</td></tr>
<tr><td>[SLO: C-09-B-30]
Describe that noble gas electronic configuration, octet and duplet rules help predict chemical properties of main group elements.

[SLO: C-09-B-31]
Compare between the formation of cations and anions.</td><td>N/A</td><td>[SLO: C-11-B-28]
Define electronegativity as the power of an atom to attract shared electrons to itself.

[SLO: C-11-B-29]
Explain the factors influencing the electronegativities of elements in terms of nuclear charge, atomic radius, shielding by inner shells electrons.</td><td>N/A</td></tr>
</table>

[SLO: C-09-B-32]Account for the electropositive and electronegative nature of metals and non-metals. **[SLO: C-09-B-33]** Define ionic, covalent, coordinate covalent and metallic bonds. **[SLO: C-09-B-34]** Differentiate between ionic compounds and covalent compounds. (The following points need to be included in the respective definitions: a. Ionic Bond as strong electrostatic attraction between oppositely charged ions b. Covalent bond as strong electrostatic attraction between shared electrons and two nuclei c. Metallic bond as strong electrostatic attraction between cloud/sea of delocalized electrons and positively charged cations.)		**[SLO: C-11-B-30]**Explain the trends in electronegativity across a period and down a group of the Periodic Table. **[SLO: C-11-B-31]** Use the differences in Pauling electronegativity values to predict the formation of ionic and covalent bonds. **[SLO: C-11-B-32]** Use bond energy values and the concept of bond length to compare the reactivity of covalent molecules. **[SLO: C-11-B-33]** Describe the shapes and bond angles in molecules using VSEPR theory (including describing by sketching). **[SLO: C-11-B-34]** Predict the shapes, and bond angles in molecules and ions. ***[SLO: C-11-B-35]*** *Explain the importance of VSEPR theory in the field of drug design by discussing how the shape and bond angles of the molecules helps*	

[SLO: C-09-B-35] Explain the properties of compounds in terms of bonding and structure. **[SLO: C-09-B-36]** Compare uses and properties of materials such as strength and conductivity as determined by the type of chemical bond present between their atoms. **[SLO: C-09-B-37]** Interpret the strength of forces of attraction and their impact on melting and boiling points of ionic and covalent compounds. **[SLO: C-09-B-38]** Justify the availability of free charged particles (electrons or ions) for conduction of electricity in Ionic compounds (solid and molten) covalent compounds and metallic bonds. **[SLO: C-09-B-39]** Recognize that some substances can ionize when dissolved in water (e.g., acids dissolve in water and conduct electricity).		*chemists predict their interactions in the body.* **[SLO: C-11-B-36]** Describe covalent bonding in molecules using the concept of hybridization to describe sp, sp^2 and sp^3 orbitals. **[SLO:C-11-B-37]** Explain hybridization and types of hybridization. **[SLO: C-11-B-38]** Explain valence bond theory. **[SLO:C-11-B-39]** Explain the salient features of molecular orbital theory. **[SLO:C-11-B-40]** Explain the paramagnetic nature of Oxygen molecule in the light of MOT. **[SLO:C-11-B-41]** Calculate Bond order of N_2, O_2, F_2 and He_2.	

[SLO: C-09-B-40] Justify the suitability of usage of graphite, diamond and metals for industrial purposes, (Some examples may include: a. graphite as lubricant or an electrode b. diamond in cutting tools c. metals for wires, and sheets) **[SLO: C-09-B-41]** Draw the structure of ionic and covalent compounds along with their formation. (Some examples can include: a. Ionic bonds in binary compounds such as NaBr, NaF, $CaCl_2$using dot-and-cross diagrams and Lewis-dot structures. b. covalent bonds in simple molecules including H_2, Cl_2, O_2, N_2, H_2O, CH_4, NH_3, HCl, CH_3OH, C_2H_4, CO_2, HCN, and similar molecules using dot-and-cross diagrams and Lewis-dot structures.)		**[SLO: C-11-B-42]** Describe the types of Van der Waals' forces(Including: a. instantaneous dipole – induced dipole (id-id) force, also called London dispersion forces b. permanent dipole – permanent dipole (pd-pd) force, including hydrogen bonding c. Hydrogen bonding as a special case of permanent dipole – permanent dipole force between molecules where hydrogen is bonded to a highly electronegative atom.) **[SLO: C-11-B-43]** Explain the strength and applications of Van der Waals' forces. **[SLO: C-11-B-44]** Describe hydrogen bonding, limited to molecules containing N–H, O–H and H–F groups, (including ammonia, water and H–F as simple examples). **[SLO: C-11-B-45]** Use the concept of hydrogen bonding to explain the anomalous properties of H_2O (ice and water).	

		[SLO: C-11-B-46] Use the concept of electronegativity to explain bond polarity and dipole moments of molecules. **[SLO: C-11-B-47]** State that, in general, ionic, covalent and metallic bonding are stronger than intermolecular forces. **[SLO: C-11-B-48]** Recognize that molecular ions/polyatomic ions can have expanded octets e.g. sulphate and nitrate. **[SLO: C-11-B-49]** Analyse the formation of dative bond in CO, ozone and H_3O^+ ion (resonance structure not required).	

Standard: (Stoichiometry)
Students should be able to:
Explain the mole concept and its application in chemical calculations, including stoichiometry.
Apply the law of conservation of mass to predict the quantities of reactants and products in chemical reactions.
Constructing chemical equations and understanding the balancing of these chemical equations.
Use stoichiometry to calculate the amount of reactants and products in a chemical reaction.
Describe the relationship between moles, mass, and volume, and apply this relationship to stoichiometric calculations.

Benchmark 1: Students should be able to balance chemical equations and perform stoichiometry calculations using the mole concept.	**Benchmark 1: Students can use stoichiometry to predict the quantities of reactants and products in chemical reactions, identify the limiting reagents and write balanced chemical equations.**

[SLO: C-09-B-42] State the formulae of compounds. **[SLO: C-09-B-43]** Define molecular formula of a compound as the number and type of different atoms in one molecule. **[SLO: C-09-B-44]** Define empirical formula of a compound as the simplest whole number ratio of different atoms in a molecule. **[SLO: C-09-B-45]** Deduce the formula and name of binary ionic compounds from ions given relevant information. **[SLO: *C-09-B-46*]** Deduce the formula of a molecular substance from the given structure of molecule. **[SLO: C-09-B-47]** Define mole as amount of substance containing Avogadro's number ($6.02x10^{23}$) of particles.	**[SLO: C-10-B-10]** Use the molar gas volume, 24 dm^3 at room temperature and pressure (RTP), in calculations involving gases. **[SLO: C-10-B-11]** Define concentration, use both g/dm^3 and mol/dm^3, and interconvert them. **[SLO: C-10-B-12]** Calculate stoichiometric relationships between substances. (Specifically: ● reacting masses, limiting reactants, ● volume of gasses at RTP, ● volumes of solution and concentrations of solutions in g/dm^3 or mol/dm^3, including conversion between cm^3 and dm^3.) **[SLO: C-10-B-13]** Calculate concentration of a solution in a titration using empirical data. **[SLO: C-10-B-14]** Calculate empirical formula and molecular formula from appropriate data.	**[SLO: C-11-B-50]** Express balanced chemical equations in terms of moles, representative particles, masses, and volumes of gases (at STP). **[SLO: C-11-B-51]** Explain the concept of limiting reagents. **[SLO: C-11-B-52]** Calculate the maximum amount of product and amount of any unreacted excess reagent. **[SLO: C-11-B-53]** Calculate theoretical yield, actual yield, and percentage yield when given appropriate information. **[SLO: C-11-B-54]** State the volume of one mole of a gas at STP. **[SLO: C-11-B-55]** Use the volume of one mole of gas at STP to solve mole-volume problems. **[SLO: C-11-B-56]** Calculate the mole of a gas from density measurements at STP.	N/A

[SLO: C-09-B-48] Explain the relationship between a mole and Avogadro's number. **[SLO: C-09-B-49]** Use the relationship amount of substance = mass / molar mass to calculate number of moles, mass, molar mass, relative mass (atomic/molecular/formula) and number of particles. **[SLO: C-09-B-50]** Construct chemical equations and ionic equations to show reactants forming products, including state symbols. **[SLO: C-09-B-51]** Deduce the symbol equation with state symbols for a chemical reaction given relevant information.	**[SLO: C-10-B-15]** Calculate percentage yield, percentage composition by mass and percentage purity from appropriate data.	**[SLO: C-11-B-57]** Derive measurements of mass, volume, and number of particles using moles. **[SLO: C-11-B-58]** Calculate the quantities of reactants and products involved in a chemical reaction using stoichiometric principles, (Some examples include calculations involving reacting masses, volumes of gasses, volumes, and concentrations of solutions, limiting reagent and excess reagent, percentage yield calculations.) ***[SLO: C-11-B-59]*** *Explain, with examples, the importance of stoichiometry in the production and dosage of medicine.*	
Standard: (Electrochemistry) **Students should be able to:** **Describe the principles of electrochemistry, including the movement of electrons in terms of oxidation and reduction in a chemical reaction.** **Explain the concept of oxidation and reduction, including the role of electrons in these processes.** **Describe the process of electrolysis and its applications.** **Discuss the relationship between electricity and chemical reactions, including the use of electrodes and electrolytes.** **Apply the principles of electrochemistry to explain the behaviour of batteries, fuel cells, and other electrochemical devices.**			

Benchmark 1: Students should be able to describe the principles of electrochemistry, including redox reactions, and the behaviour of electrolytes.			
[SLO: C-09-B-52] Define redox reactions as simultaneous oxidation and reduction in terms of oxygen, hydrogen, electrons and changes in oxidation state. **[SLO: C-09-B-53]** Use Roman numerals to indicate oxidation number of an element in a compound. **[SLO: C-09-B-54]** Identify oxidizing and reducing agents in a redox reaction in term of electron (s). **[SLO: C-09-B-55]** Recognize that the oxidation number of elements in their free state is zero. **[SLO: C-09-B-56]** Derive the formula of ionic compounds from ionic charges and oxidation numbers. **[SLO:C-09-B-57]** Identify that the oxidation number of a monoatomic ion is	**[SLO: C-10-B-16]** Define electrolysis as decomposition of ionic compound, in molten or aqueous solution, by passage of electric current. **[SLO: C-10-B-17]** Define Electrochemical cell and describe its types. **[SLO: C-10-B-18]** Identify and label in simple electrolytic cell, the anode (+), cathode (-), electrolyte and direction of flow of electrons in external circuit. **[SLO: C-10-B-19]** Describe the transfer of charge in external circuit, movement of ions in the electrolyte and transfer of electrons at electrodes. **[SLO: C-10-B-20]** Identify the products formed at electrodes and describe the observations made during the electrolysis of molten lead (II) chloride, concentrated aqueous sodium chloride, dilute sulphuric acid using inert electrodes (platinum or carbon/graphite).	N/A	**[SLO: C-12-B-01]** Apply the concept of oxidation numbers in identifying oxidation and reduction reactions. **[SLO: C-12-B-02]** Apply the concept of changes in oxidation numbers to balance chemical equations. **[SLO: C-12-B-03]** Define the terms redox, oxidation, reduction, and disproportionation (in terms of electron transfer and changes in oxidation number.) **[SLO: C-12-B-04]** Identify the oxidizing and reducing agents in a redox reaction. **[SLO: C-12-B-05]** Describe the role of oxidizing and reducing agents in the redox reaction. **[SLO: C-12-B-06]** Explain the concept of the activity series of metals and how it relates to the ease of oxidation.

the same as the charge on the ion. **[SLO:C-09-B-58**] Explain that the sum of the oxidation numbers in a neutral compound is zero. **[SLO:C-09-B-59**] Explain that the sum of the oxidation numbers in an ion is equal to the charge on the ion. **[SLO: C-09-B-60]** Identify redox reactions by the colour changes involved when using acidified aqueous Potassium manganate (VII) to (II) and aqueous potassium iodide.	**[SLO: C-10-B-21]** State that hydrogen-oxygen fuel cell uses hydrogen and oxygen to produce electricity with water as the only chemical product. **[SLO: C-10-B-22]** Describe the advantages and disadvantages of using hydrogen–oxygen fuel cell in comparison with gasoline /petrol engines in vehicles.		**[SLO: C-12-B-07]** Deduce the feasibility of redox reactions from activity series or reaction data. **[*SLO: C-12-B-08]*** *Explain the use of the Winkler Method to measure biochemical oxygen demand (BOD) and its use as a measure of water pollution.* **[SLO: C-12-B-09]** Explain how electrolytic cells convert electrical energy to chemical energy, with oxidation at the anode and reduction at the cathode. **[SLO: C-12-B-10]** Predict the identities of substances liberated during electrolysis based on the state of the electrolyte, position in the redox series, and concentration. **[SLO: C-12-B-11]** Apply the relationship between the Faraday constant, Avogadro constant, and the charge on the electron to solve problems. **[SLO: C-12-B-12]** Calculate the quantity of charge passed during electrolysis and the mass or

			volume of substance liberated during electrolysis. **[SLO: C-12-B-13]** Deduce the Avogadro constant by an electrolytic method. **[SLO: C-12-B-14]** Define the terms standard electrode potential and standard cell potential. **[SLO: C-12-B-15]** Describe the standard hydrogen electrode and methods used to measure standard electrode potentials. **[SLO: C-12-B-16]** Calculate the standard cell potentials by combining the potentials of two standard electrodes and then use these to predict the feasibility of a reaction and the direction of electron flow in a simple cell. **[SLO: C-12-B-17]** Deduce the relative reactivity of elements as oxidizing agents or reducing agents from their electrode potential values.

			[SLO: C-12-B-18] Construct redox equations using relevant half-equations. **[SLO: C-12-B-19]** Explain how electrode potentials vary with the concentrations of aqueous ions and use the Nernst equation to predict this quantitatively.
Benchmark 2: Students can apply the concepts of electrochemistry to explain and predict the behaviour of electrochemical cells and the transfer of electrons in chemical reactions. They also understand the role of electrochemistry in real-world applications, such as batteries, corrosion, and electroplating.		**Benchmark 2: Students should be able to explain how voltaic or galvanic cells convert chemical energy into electrical energy.**	
[SLO: C-09-B-61] Define corrosion and discuss methods to prevent it. (some examples may include barrier method such as using paint, galvanizing, electroplating; sacrificial protection such as using magnesium blocks in ships.)	**[SLO: C-10-B-23]** Identify the products formed at electrodes and describe the observations made during the electrolysis of dilute copper (II) sulphate using inert electrode or copper electrode. **[SLO: C-10-B-24]** Predict the products of electrolysis of a halide compound in dilute or concentrated solution. **[SLO: C-10-B-25]** Construct ionic half-equations for reaction at either electrode.		**[SLO: C-12-B-20]** Explain how voltaic (galvanic) cells convert energy from spontaneous, exothermic chemical processes to electrical energy, with oxidation at the anode and reduction at the cathode. **[SLO: C-12-B-21]** Explain how voltaic cells convert chemical energy from redox reactions to electrical energy using Cu-Zn galvanic cell as an example. **[SLO: C-12-B-22]** Explain the merits of photovoltaic cells as sustainable ways of meeting energy

	[SLO: C-10-B-26] Describe electroplating and its applications. **[SLO: C-10-B-27]** Sketch a schematic diagram for a voltaic cell e.g. Daniel cell. **[SLO: C-10-B-28]**Use the voltage data given for voltaic cells to determine order of reactivity of any two metals.		demands by making reference to the photovoltaic principle.
Standard: (States and Phases of Matter) The students should be able to: Identify and explain the physical properties of solids, liquids, and gasses. Describe and interpret molar heat capacity, heat of fusion, and heat of vaporization for different substances. Describe the properties and uses of liquid crystals and identify the different types of solids based on their structures.			
N/A		**Benchmark 1: Explain and apply the kinetic molecular theory to predict the properties of liquids and gases based on molecular motion and intermolecular forces.**	
N/A	N/A	**[SLO: C-11-B-61]** Describe simple properties of liquids e.g., diffusion, compression, expansion, motion of molecules, spaces between them, intermolecular forces and kinetic energy based on kinetic molecular theory. **[SLO: C-11-B-62]** Describe physical properties of liquids such as evaporation,	N/A

		vapour pressure, boiling point, viscosity and surface tension. **[SLO: C-11-B-63]** Apply the concept of hydrogen bonding to explain the properties of water (specifically high surface tension, high specific heat, low vapour pressure, high heat of vaporization, and high boiling point.) **[SLO: C-11-B-64]** Define molar heat of fusion, molar heat of vaporization and molar heat capacity. **[SLO: C-11-B-65]** Describe how heat of fusion and heat of vaporization are affected by force of attraction between particles that make up matter. **[SLO: C-11-B-66]** Outline the importance of heat of fusion in the study of glaciers and ice sheets (particularly while studying polar ice caps). **[SLO: C-11-B-67]** Describe the physical properties of gasses (including	

		compressibility, expandability and pressure exerted by gases.) **[SLO: C-11-B-68]** Describe liquid crystals and give their uses in daily life. **[SLO: C-11-B-69]** Differentiate liquid crystals from pure liquids and crystalline solids.	
N/A		**Benchmark 2: Explain the properties of solids depending on the type of solid in context.**	
N/A	N/A	**[SLO: C-11-B-70]** Describe simple properties of solids e.g. compression, expansion, motion of molecules, inter particle space, intermolecular forces and kinetic energy based on kinetic molecular theory. **[SLO: C-11-B-71]** Differentiate between amorphous and crystalline solids. **[SLO: C-11-B-72]** Describe properties of crystalline solids like geometrical shape, melting point, cleavage plane, habit of a crystal, crystal growth.	N/A

Standard: (Energetics) **Students should be able to:** **Describe the nature of energy, including energy profile diagrams.** **Explain the relationship between energy and chemical reactions, including exothermic and endothermic reactions.** **Apply the principles of thermochemistry to calculate heat transfer and changes in enthalpy.**			
Benchmark 1: Students should define and use thermal energy concepts, including energy change, enthalpy change, and activation energy in chemical reactions.		**Benchmark 1: Students should understand the concepts of thermodynamics to analyse and predict energy changes in chemical systems, including exothermic and endothermic reactions, enthalpy and entropy changes**	
[SLO: C-09-B-62] Explain the idea of a chemical system and its connection with its surroundings influences energy transfer during a chemical reaction. **[SLO: C-09-B-63]** Differentiate between exothermic and endothermic reactions by giving examples. **[SLO: C-09-B-64]** State that thermal energy is called enthalpy change at constant pressure and recognize its sign as negative for exothermic and positive for endothermic reactions.	N/A	**[SLO: C-11-B-73]** Describe that chemical reactions are accompanied by enthalpy changes and these changes can be negative for exothermic reactions or positive for endothermic reactions. **[SLO: C-11-B-74]** Interpret a reaction pathway diagram, in terms of the enthalpy change of the reaction and activation energy. **[SLO: C-11-B-75]** Define terms such as standard conditions, enthalpy changes of reaction (formation, combustion, neutralization).	N/A

[SLO: C-09-B-65] Define activation energy as the minimum energy that colliding particles must have for a successful collision. **[SLO:C-09-B-66]** Explain that activation energy depends on reaction pathway which can be changed using catalysts or enzyme (detailed pathways not required). **[SLO: C-09-B-67]** Draw, label and interpret reaction pathway diagram for exothermic and endothermic reaction which includes enthalpy change, activation energy (uncatalyzed and catalysed), reactants and products. **SLO: C-09-B-68** Recognize that bond breaking is endothermic and bond making is exothermic processes. **[SLO: C-09-B-69]** Explain that enthalpy change is sum of energies absorbed and		**[SLO: C-11-B-76]** Explain that energy transfer occurs during chemical reactions because of the breaking and making of bonds. **[SLO: C-11-B-77]** Calculate the bond energies from the enthalpy change of reaction, ΔH. **[SLO: C-11-B-78]**Describe that some bond energies are exact and some bond energies are approximate. **[SLO: C-11-B-79]** Calculate enthalpy changes from appropriate experimental results, including the use of the relationships $q = mc\Delta T$ and $\Delta H = -mc\Delta T/n$. **[SLO: C-11-B-80]** Define terms such as enthalpy change of atomization, lattice energy, first electron affinity. **[SLO: C-11-B-81]** Explain the factors affecting the electron affinities of elements.	

released in bond breaking and bond forming. **[SLO: C-09-B-70]** Calculate enthalpy change of a reaction given bond energy values. ***[SLO:*****C-09-B-71*****]*** *Explain how respiration (aerobic and anaerobic), an exothermic process, provides energy for biological systems and lipids as reserve stores of energy.*		**[SLO: C-11-B-82]** State and explain Hess's Law. **[SLO: C-11-B-83]** Apply Hess's Law to calculate enthalpy changes in a reaction carried out in multiple steps. **[SLO: C-11-B-84]** Construct Born–Haber cycles for ionic solids. **[SLO: C-11-B-85]** Perform calculations involving Born–Haber cycles. ***[SLO: C-11-B-86]*** *Explain the effect of ionic charge and ionic radius on the numerical magnitude of lattice energy.* **[SLO: C-11-B-87]** Apply enthalpy change with reference to hydration, and solution. ***[SLO: C-11-B-88]*** *Construct an energy cycle involving enthalpy change of solution, lattice energy and enthalpy change of hydration.*	

		[SLO: C-11-B-89] *Perform calculations involving the energy cycles.* **[SLO: C-11-B-90]** Explain the effect of ionic charge and ionic radius on the numerical magnitude of an enthalpy change of hydration. **[SLO: C-11-B-91]** Define the term entropy, S, as the number of possible arrangements of the particles and their energy in a given system. **[SLO: C-11-B-92]** Explain the sign of the entropy changes that occur during a change in state, temperature change and a reaction in which there is a change in the number of gaseous molecules. **[SLO: C-11-B-93]** Calculate the entropy change for a reaction, ΔS, given the standard entropies, S, of the reactants and products.	

		[SLO: C-11-B-94] Explain the concept of heat as a form of energy. **[SLO: C-11-B-95]** Explain the relationship between temperature and kinetic energy of particles. **[SLO: C-11-B-96]** State that total energy is conserved in chemical reactions. **[SLO: C-11-B-97]** Explain the concept of standard conditions and standard states in measuring energy changes. **[SLO: C-11-B-98]** Explain the relationship between bond formation energy, and bond breaking energy. **[SLO: C-12-B-99]** Explain Gibbs free energy. **[SLO: C-12-B-100]** Apply the concept of Gibbs free energy to solve problems.	

		[SLO: C-12-B-101] *Outline how enthalpy change relates to the calorie content of the food we eat.*	
Standard: (Reaction Kinetics) Students should be able to: **Describe the nature of chemical reactions, including the activation energy and rate of reaction.** **Explain the factors that affect the rate of reaction, including temperature, concentration, surface area, and catalyst.** **Discuss the mathematical models used to describe reaction kinetics, including rate laws and rate constants.**			
Benchmark 1: Students should apply the principles of reaction kinetics to analyse and predict the rate of chemical reactions, including the effect of changing conditions on reaction rate.		**Benchmark 1: The student should calculate the rate of reaction and rate constant using the rate law equation and be able to interpret the meaning of the rate constant in terms of reaction rate.**	
N/A	**[SLO: C-10-B-29]** Describe collision theory in terms of number of particles per unit volume, frequency of collisions of particles, kinetic energy of particles and activation energy. **[SLO: C-10-B-30]** State that catalyst changes the rate of reaction, provides alternate pathway with lower/higher activation energy, and remains unchanged at the end of a reaction. **[SLO: C-10-B-31]** Describe the physical parameters that may affect the rate of reaction including change in concentration, temperature, pressure and surface area.	**[SLO: C-11-B-102]**Explain the rate of reaction, rate constant and rate law. **[SLO: C-11-B-103]** Use experimental data to calculate the rate of a reaction. **[SLO: C-11-B-104]** Explain the concept of activation energy and its role in chemical reactions. **[SLO: C-11-B-105]** Use the Boltzmann distribution curve to explain the effect of temperature on the rate of a reaction.	N/A

	[SLO: C-10-B-32] Interpret data, including graphs, for investigating rate of reaction.	**[SLO: C-11-B-106]** Explain the concept of catalyst and how they increase the rate of a reaction by lowering the activation energy. **[SLO: C-11-B-107]** Interpret reaction pathway diagrams, including the presence and absence of catalyst. **[SLO: C-11-B-108]** Explain the relationship between Gibbs free energy change, ΔG, and the feasibility of a reaction. **[SLO: C-11-B-109]** Use rate equations to explain order of reaction. **[SLO: C-11-B-110]** Calculate the numerical value of a rate constant using the initial concentration and half-life. **[SLO: C-11-B-111]** Suggest a reaction mechanism that is consistent with a given rate equation and rate-determining step.	

		[SLO: C-11-B-112] Describe the effect of temperature change on the rate constant and rate of a reaction.	
Benchmark 2: Students should describe the factors that influence the rate of chemical reaction, including concentration, temperature, and catalyst, and how these factors affect the activation energy.		**N/A**	
N/A	**[SLO: C-10-B-33]** Explain the effect on rate of reaction of changing concentration of a reactant, pressure of gases, surface area of solids, temperature, and presence of catalyst (including enzymes). ***[SLO: C-10-B-34]*** *Justify the importance of chemical kinetics in the food industry to determine ideal harvesting and transportation times for product.*	N/A	N/A
Standard: (Equilibria) **Students should be able to:** **Describe the concept of chemical equilibrium and the dynamic nature of chemical reaction.** **Explain the relationship between concentration of reactants or products and the position of equilibrium.** **Apply the law of mass action to predict the position of chemical equilibrium.** **Discuss the effect of temperature and pressure on chemical equilibria.** **Describe the concept of Le Chatelier's principle and its application in predicting the effect of changes on chemical equilibria.**			
Benchmark 1: Students should describe the concept of chemical equilibrium and how reversible reactions can be influenced by the adjustment of physical parameters		**Benchmark 1: Students should apply the principles of chemical equilibrium to analyse and predict the position and extent of chemical reactions, and to gauge the extent of dissociation of solutes into solvents based on adjustment of physical parameters**	

[SLO: C-09-B-72] Recognize that reversible reactions are shown by symbol ⇌ and may not go to completion. **[SLO: C-09-B-73]** Describe how changing the physical conditions of a chemical equilibrium system can redirect reversible reactions (Some examples can include: a. effect of heat on hydrated compounds b. addition of water to anhydrous substances in particular copper (II) sulphate and cobalt (II) chloride.) **[SLO: C-09-B-74]** State that reversible reactions can achieve equilibrium in a closed system when rate of forward and reverse reactions are equal.	N/A	**[SLO: C-11-B-113]** Describe what is meant by a reversible reaction and dynamic equilibrium in terms of the rate of forward and reverse reactions being equal and the concentration of reactants and products remaining constant. **[SLO: C-11-B-114]** Define dynamic equilibrium between two physical states. **[SLO: C-11-B-115]** State the necessary conditions for equilibrium and the ways that equilibrium can be recognized. **[SLO: C-11-B-116]** Describe the microscopic events that occur when a chemical system is in equilibrium, explain with examples. **[SLO: C-11-B-117]** Deduce the equilibrium constant expression [Kc] from an equation for homogeneous reaction. **[SLO: C-11-B-118]** Write the equilibrium expression for a given chemical reaction in terms of concentration, Kc,	**[SLO: C-12-B-23]** Use the extent of ionization and the acid dissociation constant, Ka, to distinguish between strong and weak acids. **[SLO: C-12-B-24]** Use the extent of ionization and the base dissociation constant, Kb, to distinguish between strong and weak bases. **[SLO: C-12-B-25]** Explain what is meant by a chemical buffer and how a buffer system works. (For context this should include: a. defining what is a buffer solution b. explaining how a buffer solution can be made c. explaining how buffer solutions control pH; use chemical equations in these explanations d. describe and explain the uses of buffer solutions,

		partial pressure Kp, number of moles Kn and mole fraction, Kx. **[SLO: C-11-B-119]** Determine the relationship between different equilibrium constants for the same reaction at the same temperature. **C-11-B-120** Describe the applications of Equilibrium constant. **[SLO: C-11-B-121]** Differentiate between Microscopic and Macroscopic events in a chemical reaction, at equilibrium. **[SLO: C-11-B-122]** Propose microscopic events that account for observed macroscopic changes that take place during a shift in equilibrium. **[SLO: C-11-B-123]** Determine if the equilibrium constant will increase or decrease when temperature is changed,	including the role of HCO_3^- in controlling pH in blood) **[SLO: C-12-B-26]** Calculate concentrations of ions of slightly soluble salts. **[SLO: C-12-B-27]** State what is meant by the term partition coefficient, Kpc. **[SLO: C-12-B-28]** Calculate a partition coefficient for a system in which the solute is in the same physical state in the two solvents. **[SLO: C-12-B-29]** Explain the factors affecting the numerical value of a partition coefficient in terms of the polarities of the solute and the solvents used.

		given the equation for the reaction. **[SLO: C-11-B-124]** State Le Chatelier's Principle and apply it to systems in equilibrium with changes in concentration, pressure, temperature, or the addition of catalyst. **[SLO: C-11-B-125]** Explain industrial applications of Le Chatelier's Principle using Haber's process and the Contact Process as an example. **[SLO: C-11-B-126]** Discuss the industrial applications of chemical equilibria and how it can be used to optimize chemical reactions to maximize yields and minimize waste products. **[SLO: C-11-B-127]** Use the concept of hydrolysis to explain why aqueous solutions of some salts are acidic or basic.	
Standard: (Acid-Base Chemistry and pH) **Students should be able to:** **Define acids and bases and describe their properties.** **Explain the concept of pH and describe the relationship between pH and the concentration of hydrogen ions in a solution.**			

Describe the different types of acid-base reactions, including neutralization and proton transfer. Discuss the use of buffers to control pH, including the relationship between buffer capacity and the concentration of buffer components.			
Benchmark 1: Students will be able to identify and distinguish between acids and bases based on their properties, chemical behaviour, and their definition using Bronsted-Lowry theory.		**Benchmark 1: Students will be able to calculate pH values for dissolved acids and Bases (alkalis), also interpret the pH of a solution and understand the relationship between pH, concentration, and the strength of acids and bases.**	
[SLO: C-09-B-75] Define Bronsted-Lowry acids as proton donors and Bronsted-Lowry bases as proton acceptors. **[SLO: C-09-B-76]** Recognizethat aqueous solutions of acids contain H^+ ions and aqueous solutions of alkalis contain OH^- ions. **[SLO: C-09-B-77]** Define a strong acid and base as an acid or base that completely dissociates in aqueous solution and weak acid and base that partially dissociates in aqueous solution. (Some examples include: Student writing symbol equations to show these for hydrochloric acid, sulphuric acid, nitric acid, and ethanoic acid.)	N/A	**Acid-Base Theory** **[SLO: C-11-B-128]** Define conjugate acid–base pairs. **[SLO: C-11-B-129]** Identify conjugate acid-base pairsin reactions. **[SLO: C-11-B-130]** Apply the concept of conjugate acid and conjugate base on salt hydrolysis. **[SLO: C-11-B-131]** Define mathematically the terms pH, Ka, pKa and Kw and use them in calculations (Kb and the equation $Kw = Ka \times Kb$ will not be tested). **[SLO: C-11-B-132]** Calculate $[H^+_{(aq)}]$ and pH values for: (a) strong acids	**The pH scale** **[SLO: C-12-B-30]** State that pH = $-\log[H^+_{(aq)}]$ and $[H^+] = 10^{-pH}$. **SLO-C-12-B-31** Interpret Acidity and basicity of solution from pH scale. **[SLO: C-12-B-32]** State that change of one pH unit represents a 10-fold change in the hydrogen ion concentration $[H^+]$. **[SLO: C-12-B-33]** Use the ionic product constant, $K_w = [H^+][OH^-] = 10^{-14}$ at 298 K to solve problems. **SLO: C-12-B-34]** Sketch the pH titration curves of titrations using combinations of strong

[SLO: C-09-B-78] Formulate dissociation equation for an acid or base in aqueous solution. **[SLO: C-09-B-79]** Recognize that bases are oxides or hydroxides of metals and that alkalis are water-soluble bases. **[SLO: C-09-B-80]** Describe the characteristic properties of acids in terms of their reactions with metals, bases and carbonates. **[SLO: C-09-B-81]** Identify the characteristic properties of bases in terms of their reactions with acids and ammonium salts.		(b) strong bases(alkalis) (c) weak acids (d) weak bases (alkalis). **[SLO: C-11-B-133]** Distinguish that Lewis acids accept lone pair, and Lewis bases donate lone pair to make a coordinate covalent bond. **[SLO: C-11-B-134]** Calculate the pH of buffer solutions from given appropriate data. **[SLO: C-11-B-135]** Demonstrate the ability to comprehend and effectively apply the concept of solubility product. (Ksp). **[SLO: C-11-B-136]** Construct an expression for K_{sp}. **[SLO: C-11-B-137]** Calculate K_{sp} from concentrations and vice versa. **[SLO: C-11-B-138]** Explain common ion effect giving suitable examples.	and weak acids with strong and weak Base (alkalis).

		[SLO: C-11-B-139] Apply the concept of the common ion effect to describe why the solubility of a substance changes when it is dissolved in a solution containing a common ion. **[SLO: C-11-B-140]** Calculate the $[H_3O^+]$ given the Ka and molar concentration of weak acid. **[SLO: C-11-B-141]** Calculate molarity and strength of given sample solutions in acid-base titration using empirical data. **[SLO: C-11-B-142]** Select suitable indicators for acid-base titrations, given appropriate data (pKa values will not be used).	
Standard: (Salts) **Students should be able to:** **Describe the nature of salts, including their formation from the reaction of acids and bases.** **Discuss the properties of salts, including solubility, conductivity, and melting point.** **Apply the principles of chemical bonding to explain the behaviour of salts in different physical states.**			
Benchmark 1: Students will be able to differentiate between different types of salts based on their solubility.		**N/A**	

N/A	**[SLO: C-10-B-35]** Explain that salts are ionic compounds formed due to electrostatic attraction between oppositely charged ions (in which the positive ions come from bases and negative ions come from acids). **[SLO: C-10-B-36]** Explain why at STP salts are solids with high melting points. **[SLO: C-10-B-37]** Describe that under normal conditions, ionic compounds are usually solids with lattice structures. **[SLO: C-10-B-38]** Explain why the molten and aqueous solutions of salts are good conductors of electricity by making reference to the idea of mobile ions. **[SLO: C-10-B-39]** Describe the general solubility rules for salts. (These are: a. sodium, potassium and ammonium salts are soluble b. chlorides are soluble except lead and silver	N/A	N/A

	c. carbonates are insoluble except sodium, potassium and ammonium d. hydroxides are insoluble except sodium, potassium, ammonium and calcium (partially).) **[SLO: C-10-B-40]** Describe the preparation, separation and purification of soluble salts by reactions of acids with alkali (titration), excess metal, excess insoluble base, and excess insoluble carbonate.		

<table>
<tr><td colspan="4">Domain C: Inorganic Chemistry</td></tr>
<tr><td colspan="4">Standard: (Periodic Table and Periodicity)
Students should be able to:
Describe the organization of the Periodic Table, including the arrangement of elements by atomic number, electronic configuration, and chemical properties.
Explain the concept of periodicity, including the repeating patterns of physical and chemical properties of elements.
Discuss the trends in the Periodic Table, including ionization energy, electron affinity, and electronegativity.
Apply the principles of periodicity to predict the properties and reactivity of elements.
Describe the role of the Periodic Table in the study of chemistry and its importance in the prediction of chemical behaviour.</td></tr>
<tr><td colspan="2">Benchmark 1: The students will be able to explain the similarities and differences in properties of elements within the same group (vertical column) and across the period (horizontal row) of the Periodic Table, including the demarcation of elements into “s” and “p” blocks based on their electronic configurations.</td><td colspan="2">Benchmark 1: The student will be able to interpret and explain the periodic trends of electronic configuration, ionization energy, electron affinity, electro negativity and atomic radius, predict the properties and reactivity of elements based on their position in the Periodic Table and use periodic properties to classify elements and compounds into groups and identify relationships between them.</td></tr>
<tr><td>[SLO: C-09-C-01]
Define the Periodic Table as an arrangement of elements in periods and groups, in order of increasing proton number/atomic number
(Note: Use and explain in the Periodic Table group numbers 1-18 and I-VIII).

[SLO: C-09-C-02]
Identify the group, period, or block of an element using its electronic configuration (only</td><td>N/A</td><td>[SLO: C-11-C-01]
Explain the arrangement of elements in the Periodic Table.

[SLO: C-11-C-02]
Explain that the Periodic Table is arranged into four blocks associated with the four sub energy levels—s, p, d, and f.

[SLO: C-11-C-03]
Recognize that the period number (n) is the outer energy</td><td>N/A</td></tr>
</table>

the idea of subshells related to the blocks can be introduced). **[SLO: C-09-C-03]** Explain the relationship between group number and the charge of ions formed from elements in the group in terms of their outermost shells. **[SLO: C-09-C-04]** Explain similarities in the chemical properties of elements in the same group in terms of their electronic configuration. **[SLO: C-09-C-05]** Identify trends in group and period, given information about the elements, including trends for atomic radius, electron affinity, electronegativity, ionization energy, metallic character, reactivity and density. **[SLO: C-09-C-06]** Use terms alkali metals, alkaline earth metals, halogens, noble gases, transition metals, lanthanides and actinides in reference to the Periodic Table.		level that is occupied by electrons. **[SLO: C-11-C-04]** State that the number of the principal energy level and the number of the valence electrons in an atom can be deduced from its position on the Periodic Table. **[SLO: C-11-C-05]** Identify the positions of metals, non-metals and metalloids in the Periodic Table. **[SLO: C-11-C-06]** Explain that vertical and horizontal trends in the Periodic Table exist for atomic radius, ionic radius, ionization energy, electron affinity and electronegativity. **[SLO: C-11-C-07]** Recognize that trends in metallic and non-metallic behaviour are due to the trends in valence electrons. **[SLO: C-11-C-08]** Deduce the electronic configuration of an atom from	

[SLO: C-09-C-07] Predict the characteristic properties of an element in a given group by using knowledge of chemical periodicity. **[SLO: C-09-C-08]** Deduce the nature, possible position in the Periodic Table and the identity of unknown elements from given information about their physical and chemical properties.		the element's position in the Periodic Table, and vice versa (based on s, p, d and f sub-shells). **[SLO: C-11-C-09]** Write equations for, the reactions of Na and Mg with oxygen, chlorine and water. **[SLO: C-11-C-10]** Explain the variation in the oxidation number of the oxides and chlorides (NaCl, $MgCl_2$) in terms of their outer shell (valence shell) electrons. **[SLO: C-11-C-11]** Describe (including writing equations for) the reactions, if any, of the oxides (acidic and basic) with water (including the likely pHs of the solutions obtained). **[SLO: C-11-C-12]** Explain with the help of equations for the acid / base behaviour of the oxides and the hydroxides (NaOH, $Mg(OH)_2$) including, where relevant, amphoteric behaviour in	

		reactions with acids and bases (aluminium hydroxide only). **[SLO: C-11-C-13]** Explain with equations for, the reactions of the chlorides with water including the likely pHs of the solutions obtained (NaCl, $AlCl_3$, PCl_3). **[SLO: C-11-C-14]** Explain the variations and trends in terms of bonding and electronegativity. **[SLO: C-11-C-15]** Suggest the types of chemical bonding present in the chlorides and oxides from observations of their chemical and physical properties. **[SLO: C-11-C-16]** Predict the characteristic properties of an element in a given group by using knowledge of chemical periodicity. **[SLO: C-11-C-17]** Deduce the nature, possible position in the Periodic Table and identity of unknown elements from given	

		information about physical and chemical properties. **[SLO: C-11-C-18]** Explain the trends in the ionization energies and electron affinities of the Group-IA and Group-VIIA elements.	
Standard: (Group Properties and Elements) **Students should be able to:** **Describe the group properties of elements, including their electronic configurations and reactivity.** **Explain the trends in reactivity, size, melting point and density of elements within a group.** **Discuss the chemical behaviour of elements in different oxidation states and their role in chemical reactions.** **Apply the concepts of electronic configuration and electron transfer to explain the reactivity of elements.** **Describe the properties of elements in different groups, including the alkali metals, alkaline earth metals, halogens, and noble gases.**			
Benchmark 1: Students should describe the physical and chemical properties of elements in different groups of the Periodic Table, including their reactivity and their tendency to form compounds.		**N/A**	
Group I Properties **[SLO: C-09-C-09]** Define Group-IA Alkali metals as relatively soft metals with general trends down the group limited to decreasing melting point, increasing density and increasing reactivity. **[SLO: C-09-C-10]**Predict properties of other elements in	**Nitrogen and Sulphur** ***[SLO: C-10-C-01]*** *Recognize that atmospheric oxides of nitrogen (NO and NO_2) can react with unburned hydrocarbons to form peroxyacetyl nitrate, PAN, which is a component of photochemical smog.* ***[SLO: C-10-C-02]*** *Describe the role of NO and NO_2 in the formation of acid rain both directly and in their catalytic role in*		

group IA, given information about the elements. **[SLO: C-09-C-11]** Predict properties of elements in group-IA in order of reactivity, given relevant information. **Group VIIA Properties** **[SLO: C-09-C-12]** Define group VIIA halogens as diatomic non-metals with general trends limited to increasing density, and decreasing reactivity. **[SLO: C-09-C-13]** Identify the appearance of halogens at RTP as fluorine as pale-yellow gas, chlorine as yellow-green gas, bromine as red-brown liquid, iodine as grey-black solid. **[SLO C-09-C-14]** Explain the displacement reactions of halogens with other	*the oxidation of atmospheric sulphur dioxide.* **[SLO: C-10-C-03]** State the symbol equation for the production of ammonia in the Haber process, $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$ **[SLO: C-10-C-04]** State the sources of the hydrogen (methane) and nitrogen (air) in the Haber process. **[SLO: C-10-C-05]** State the typical conditions in the Haber process as 450°C, 20000kPa /200 atm and an iron catalyst. **[SLO: C-10-C-06]** State the symbol equation for the conversion of sulphur dioxide to sulphur trioxide in the Contact process, $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$. **[SLO: C-10-C-07]** State the sources of the sulphur dioxide (burning sulphur or roasting sulphide ores) and oxygen (air) in the Contact process.		

halide ions and also as reducing agents. **[SLO: C-09-C-15]** Predict the properties of elements in group-VIIA, given information about the elements. **[SLO: C-09-C-16]** Analyse the relative thermal stabilities of the hydrogen halides and explain these in terms of bond strengths. **Transition elements** **[SLO: C-09-C-17]** Describe the transition elements as metals that: have high densities, high melting points, variable oxidation numbers, form coloured compounds and act as catalysts for industrial purposes. (Some examples include catalysts being used in the Haber process, catalytic converters, Contact process and manufacturing of vegetable ghee.)	**[SLO: C-10-C-08]** State the typical conditions for the conversion of sulphur dioxide to sulphur trioxide in the Contact process as 450°C, 200kPa /2atm and a Vanadium (V) oxide catalyst. **Oxides** **[SLO: C-10-C-09]** Describe amphoteric oxides as oxides that react with acids and bases to produce salt and water. **[SLO: C-10-C-10]** Classify oxides as acidic, including SO_2 and CO_2, basic, including CuO and CaO, or amphoteric, limited to Al_2O_3 and ZnO, related to metallic and non-metallic character. **Properties of metals** **[SLO: C-10-C-11]** Identify the general chemical properties of metals, limited to their reactions with dilute acids, cold water, steam and oxygen. **[SLO: C-10-C-12]** Arrange metals in order of reactivity given relevant information.		

Noble gases **[SLO: C-09-C-18]** Define the Group-VIIIA noble gases as unreactive, monatomic gases. **[SLO: C-09-C-19]** Explain noble gases in terms of electronic configuration. **Properties of metals** **[SLO: C-09-C-20]** Compare the general physical properties of metals and non-metals. (Specifically in terms of: a. thermal conductivity b. electrical conductivity c. malleability and ductility d. melting points and boiling points.)			
Standard: (Group-IIA) **The students will be able to:** **Identify and classify Group-IIA elements based on their position in the Periodic Table** **Explain the reactivity trends of Group-IIA elements based on their electronic configuration and oxidation state**			

<table>
<tr><td colspan="4">Describe the industrial and everyday uses of Group-IIA elements, such as magnesium in alloys, calcium in construction, and barium in flame retardants.
Explain the methods for extraction and purification of Group-IIA elements, such as thermal reduction and electrolysis
Discuss the solubility and other properties of Group-IIA compounds, such as the high solubility hydroxides in water and the low reactivity of carbonates.</td></tr>
<tr><td colspan="2">N/A</td><td colspan="2">Benchmark 1: Describe the trend of atomic properties in Group-IIA and their chemical reactivity with the other elements. These include the trends of reactivity and solubility, and reactions to form oxides and carbonates.</td></tr>
<tr><td>N/A</td><td>N/A</td><td>N/A</td><td>[SLO: C-12-C-01]
Describe the properties and trends of Group-IIA elements, including their electronic configurations, reactivity, and common compounds such as oxides, hydroxides and carbonates.

[SLO: C-12-C-02]
Explain the chemical reactivity of Group-IIA elements (Be, Mg, Ca), including their reactions with oxygen, water, and acids.

[SLO: C-12-C-03]
Explain the reactivity of Group-IIA elements in terms of their electronic configuration and valence electrons.

[SLO: C-12-C-04]
Describe the industrial and everyday uses of Group-IIA elements.</td></tr>
</table>

			[SLO: C-12-C-05] Explain the term reactivity series and its application in predicting the outcome of chemical reactions. ***[SLO: C-12-C-06]*** *Explain the extraction and purification process of Group-IIA elements and their compounds.* **[SLO: C-12-C-07]** Understand the term thermal decomposition and its application in the analysis of Group-IIA compounds especially carbonates and nitrates. **[SLO: C-12-C-08]** Explain the trend in solubility of Group- IIA sulphates and hydroxides using terms enthalpy of hydration and enthalpy of solution. **[SLO: C-12-C-09]** Compare the properties and reactivity of Group-IIA elements with group IA in the Periodic Table. **[SLO: C-12-C-10]** Explain the term complex ion and its application in the formation of Group-IIA compounds.

			[SLO: C-12-C-11] Explain the term basic oxide and its application in the formation of Group-IIA compounds. **Solubility** **[SLO: C-12-C-12]** Describe qualitatively the trend in the thermal stability of the nitrates and carbonates including the effect of ionic radius on the polarisation of the large anion. **[SLO: C-12-C-13]** Describe qualitatively the variation in solubility and of enthalpy change of solution, ΔH_{sol}, of the hydroxides and sulphates in terms of relative magnitudes of the enthalpy change of hydration and the lattice energy.
Standard: (Group-VIIA) **The students will be able to:** **Describe the trends in the properties of Group-VIIA elements (fluorine, chlorine, bromine, iodine, and astatine) including volatility, reactivity, and thermal stability.** **Identify the halide ions (chloride, bromide, and iodide) and predict their reactivity as reducing agents.** **Demonstrate an understanding of the reactions of Group-VIIA elements and their compounds with other elements, including redox reactions and halide exchange reactions.**			
N/A		**Benchmark 1: Describe trends and reactivity of halogens and their tendency to form compounds with various elements in the Periodic Table.**	

N/A	N/A	**[SLO: C-11-C-19]** Describe the colours and trend in volatility of chlorine, bromine and iodine. **[SLO: C-11-C-20]** Describe the trend in bond strength of halogen molecules. **[SLO: C-11-C-21]** Interpret the volatility of the halogens in terms of instantaneous dipole-induced dipole forces. **[SLO: C-11-C-22]** Describe the relative reactivity of the halogen elements as oxidizing agents. **[SLO: C-11-C-23]** Describe the reactions of the halogens with hydrogen and explain their relative reactivity in these reactions. **[SLO: C-11-C-24]** Describe the relative thermal stabilities of the hydrogen halides and explain these in terms of bond strengths.	N/A

		[SLO: C-11-C-25] Describe the relative reactivity of halide ions as reducing agents. **[SLO: C-11-C-26]** Explain the reactions of halide ions with aqueous silver ions and concentrated sulphuric acid. **[SLO: C-11-C-27]** Describe the reaction of halide ions with aqueous silver ions followed by aqueous ammonia. **[SLO: C-11-C-28]** Interpret the reaction of chlorine with cold and hot aqueous sodium hydroxide as disproportionation reactions. **[SLO: C-11-C-29]** Explain the use of chlorine in water purification, including the production of the active species HOCl and ClO^-, which kill bacteria.	
Standard: (Nitrogen and Sulphur) **The students should be able to:** **Describe the reactivity of nitrogen and sulphur compounds.** **Describe the major chemical reactions and products involving nitrogen and sulphur.** **Explain the differences between nitrification and denitrification.** **Describe the industrial processes for the production of nitrates and sulphates.**			

N/A		Benchmark 1: Describe the reactivity of Nitrogen and Sulphur and the properties of their compounds in addition to their reactions and roles in our environment.	
N/A	N/A	**Nitrogen** **[SLO: C-11-C-30]** Explain the lack of reactivity of nitrogen (N_2) due to its triple bond strength and lack of polarity. **[SLO: C-11-C-31]** Describe the basicity of ammonia using the Bronsted–Lowry theory. **[SLO: C-11-C-32]** Identify the structure of the ammonium ion and explain how it is formed by an acid-base reaction. **[SLO: C-11-C-33]** Describe how ammonia can be displaced from ammonium salts through acid-base reactions. **[SLO: C-11-C-34]** Describe the natural and man-made occurrences of oxides of nitrogen and their catalytic removal from exhaust gases of internal combustion engines.	N/A

		[SLO: C-11-C-35] Differentiate between nitrification and denitrification. **Sulphur** **[SLO: C-11-C-36]** Explain the lack of reactivity of sulphur with reference to its bonding and stability of its compounds. **[SLO: C-11-C-37]** Describe the different oxidation states of sulphur and their relative stability. **[SLO: C-11-C-38]** Describe the properties and uses of sulphuric acid, including its production and industrial applications. **[SLO: C-11-C-39]** Describe the chemical reactions and processes involving sulphur, such as combustion and oxidation. ***[SLO: C-11-C-40]*** *Explain the uses of sulphur compounds in industry and everyday life, such as in fertilizers, gunpowder and rubber, and in the*	

		Synthetic organic chemistry, including the synthesis of dyes, drugs and fragrances.	
Standard: Transition Metals **Students should be able to:** **Describe the general physical properties of transition elements** **Describe the pattern in electronic configuration of transition elements and its implications for chemical bonding, reactions and for physical properties**			
N/A		**Benchmark 1: Identify the elements in the d-block of the Periodic Table and understand their general properties.**	
N/A	N/A		**[SLO: C-12-C-14]** Identify the general physical and chemical properties of the first row of transition elements. **[SLO: C-12-C-15]** Define a transition element as a d-block element which forms one or more stable ions with incomplete d orbitals. **[SLO: C-12-C-16]** Sketch the shape of a $3d_{xy}$ orbital and $3d_z^2$ orbital. **[SLO: C-12-C-17]** Identify the properties of transition elements. (Some examples include: a) they have variable oxidation states

			b) they behave as catalysts c) they form complex ions d) they form coloured compounds.) **[SLO: C-12-C-18]** Explain why transition elements have variable oxidation states in terms of the similarity in energy of the 3d and the 4s subshells. **[SLO: C-12-C-19]** Explain why transition elements behave as catalysts in terms of having more than one stable oxidation state, and vacant d orbitals that are energetically accessible and can form dative bonds with ligands. **[SLO: C-12-C-20]** Explain why transition elements form complex ions in terms of vacant d orbitals that are energetically accessible.
N/A	N/A		**[SLO: C-12-C-21]** Explain the reactions of transition elements with ligands to form complexes, including the complexes of copper (II) and cobalt (II) ions with

			water and ammonia molecules and hydroxide and chloride ions. **[SLO: C-12-C-22]** Define the term ligand as a species that contains a lone pair of electrons that forms a dative covalent bond to a central metal atom / ion. **[SLO: C-12-C-23]** Use the term mono-dentate ligand including as examples H_2O, NH_3, Cl^- and CN^-. **[SLO: C-12-C-24]** Use the term bidentate ligand including as examples 1, 2-diaminoethane, $H_2NCH_2CH_2NH_2$ and the ethanedioate ion, $C_2O_4^{2-}$polydentate ligand including as an example EDTA. **[SLO: C-12-C-25]** Define the term complex as a molecule or ion formed by a central metal atom / ion surrounded by one or more ligands. **[SLO: C-12-C-26]** Describe the geometry (shape and bond angles) of transition element complexes, which are linear, square planar, tetrahedral and octahedral.

			[SLO: C-12-C-27] State what is meant by coordination number. **[SLO: C-12-C-28]** Predict the formula and charge of a complex ion, given the metal ion, its charge or oxidation state, the ligand and its coordination number or geometry. **[SLO: C-12-C-29]** Explain qualitatively that ligand exchange can occur, including the complexes of copper (II) ions and cobalt (II) ions with water and ammonia molecules and hydroxide and chloride ions. **[SLO: C-12-C-30]** Predict, using E^0 values, the feasibility of redox reactions involving transition elements and their ions. **[SLO: C-12-C-31]** Analyse reactions involving MnO_4^- / $C_2O_4^{-2}$in acid solution given suitable data (including describing the reaction and doing calculations). **[SLO: C-12-C-32]** Analyse reactions involving MnO_4^- / Fe^{2+} in acid solution given suitable data

			(including describing the reaction and doing calculations). **[SLO: C-12-C-33]** Analyse reactions involving Cu^{2+} / I^{-} given suitable data (including describing the reaction and doing calculations.) **[SLO: C-12-C-34]** Perform calculations involving other redox systems given suitable data.
N/A	N/A		**Colour of complexes** **[SLO: C-12-C-35]** Explain the terms degenerate and non-degenerate d orbitals. **[SLO: C-12-C-36]** Describe the splitting of degenerate d orbitals into two non-degenerate sets of d orbitals of higher energy, and use of ΔE in: (a) octahedral complexes, two higher and three lower d orbitals (b) tetrahedral complexes, three higher and two lower d orbitals.

			[SLO: C-12-C-37] Explain why transition elements form-coloured compounds in terms of the frequency of light absorbed as an electron is promoted between two non-degenerate d orbitals. **[SLO: C-12-C-38]** Describe, in qualitative terms, the effects of different ligands on ΔE, frequency of light absorbed, and hence the complementary colour that is observed. **[SLO: C-12-C-39]** Use the complexes of copper (II) ions and cobalt (II) ions with water and ammonia molecules and hydroxide, chloride ions as examples of ligand exchange affecting the colour observed.
N/A	N/A		**Stereoisomerism in transition element complexes** **[SLO: C-12-C-40]** Describe the types of stereoisomerism shown by complexes, including those associated with bidentate ligands: (a) geometrical (cis-trans) isomerism, e.g. square planar such as $[Pt(NH_3)_2Cl_2]$ and octahedral such

			as $[Co(NH_3)_4(H_2O)_2]^{2+}$ and $[Ni(H_2NCH_2CH_2NH_2)_2(H_2O)_2]^{2+}$ (b) optical isomerism, e.g.$[Ni(H_2NCH_2CH_2NH_2)_3]^{2+}$ and $[Ni(H_2NCH_2CH_2NH_2)_2(H_2O)_2]^{2+}$ **[SLO: C-12-C-41]** Deduce the overall polarity of complexes. **Stability constants, K_{stab}** **[SLO: C-12-C-42]** Define the stability constant, K_{stab}, of a complex as the equilibrium constant for the formation of the complex ion in a solvent (from its constituent ions or molecules). **[SLO: C-12-C-43]** Write an expression for a K_{stab} of a complex ($[H_2O]$ should not be included). **[SLO: C-12-C-44]** Use K_{stab} expressions to perform calculations. **[SLO: C-12-C-45]** Explain ligand exchanges in terms of K_{stab} values and understand that a large

			K_{stab} is due to the formation of a stable complex ion.
Domain D: Environmental Chemistry			
Standard: (Atmosphere) **Students should be able to:** **Describe the composition and structure of the Earth's atmosphere, including the major gases and trace gases.** **Explain the role of the atmosphere in the Earth's climate, including the greenhouse effect.** **Discuss the sources and effects of atmospheric pollutants, including greenhouse gases and air pollutants.** **Apply the principles of chemical reactions to explain the formation and removal of atmospheric pollutants.** **Describe the role of ozone in the atmosphere and its depletion.** **Describe the role of atmospheric chemistry in environmental chemistry and its impact on air quality and climate.**			
Benchmark 1: Demonstrate an understanding of the composition and structure of the Earth's atmosphere, including the role of atmospheric gases, pollutants and greenhouse effect.		**Benchmark 1: Evaluate the impact of various pollutants on the environment and life and describe possible solutions to mitigate these impacts.**	
[SLO: C-09-D-01] State that composition of clean, dry air is approximately 78% nitrogen, N_2, 21% oxygen, O_2, and the remainder as a mixture of noble gasses and carbon dioxide, CO_2. **[SLO: C-09-D-02]** State the major sources of air pollutants, (Some examples include: a. carbon dioxide from the complete combustion of carbon-containing fuels	N/A	**[SLO: C-11-D-01]** Identify the properties and composition of the atmosphere. (Include the concepts of 4 layers of atmosphere and their composition.) **[SLO: C-11-D-02]** Describe the factors that affect air quality. **[SLO: C-11-D-03]** Describe the sources and understand the effects of air pollution,(This can include both natural and human-caused pollutants including Ozone (O_3), Lead (Pb), Mercury (Hg), Polycyclic aromatic hydrocarbons	N/A

b. carbon monoxide and particulates from the incomplete combustion of carbon-containing fuels c. methane from the decomposition of vegetation and waste gasses from digestion in animals d. oxides of nitrogen from car engines e. sulphur dioxide from the combustion of fossil fuels which contain sulphur compounds f. ground level ozone from reactions of oxides of nitrogen, from car engines, and volatile organic compounds, in presence of light.) **[SLO: C-09-D-03]** State the adverse effects of air pollutants, (Some examples include:		(PAHs), Persistent organic pollutants (POPs), Greenhouse gases (such as carbon dioxide, methane, and nitrous oxide), Chlorofluorocarbons (CFCs) and other ozone-depleting substances, Volatile organic compounds (VOCs), Heavy metals (such as lead, mercury, and cadmium). ***[SLO: C-11-D-04]*** *Familiarize with use of the methods and techniques to measure and monitor air quality.* **[SLO: C-11-D-05]** Describe the impact of human activities on the atmosphere, including the effects of burning fossil fuels, deforestation and ozone depletion. **[SLO: C-11-D-06]** Identify the chemical reactions and processes that occur in the atmosphere (some examples include the formation of smog and acid rain. ***[SLO: C-11-D-07]*** *Identify laws and regulations related to air quality and the*	

a. carbon dioxide: higher levels of carbon dioxide leading to increased global warming, which leads to climate change b. carbon monoxide: toxic gas c. particulates: increased risk of respiratory problems and cancer d. methane: higher levels of methane leading to increased global warming, which leads to climate change e. oxides of nitrogen: acid rain, photochemical smog and respiratory problems f. sulphur dioxide: acid rain and haze.) **[SLO: C-09-D-04]** Explain how the greenhouse gasses carbon dioxide and methane cause global warming, (Some examples include:		*measures used to control air pollution.* ***[SLO: C-11-D-08]*** *Analyse data and interpret air quality measurements and trends.* ***[SLO: C-11-D-09]*** *Explain the link between air quality and human health.* ***[SLO: C-11-D-10]*** *Evaluate the potential health risks associated with air pollution.* **[SLO: C-11-D-11]** Explain the technologies and strategies used to reduce air pollution and improve air quality, such as emissions control and renewable energy sources. ***[SLO: C-11-D-12]*** *Design experiments and collect data to test hypotheses about air quality.* **[SLO: C-11-D-13]** Identify with the global scale problems of air pollution, such as global warming and the greenhouse effect.	

a. the absorption, reflection and emission of thermal energy b. reducing thermal energy loss to space.) **[SLO: C-09-D-05]** Describe the role of sulphur in the formation of acid rain and its impact on the environment. **[SLO: C-09-D-06]** Identify the role of ozone in the atmosphere and the harmful effects of ozone depletion. **[SLO: C-09-D-07]** Describe the strategies to reduce the effects of major environmental issues. (Some examples include: a. climate change: planting trees, reduction in emission from livestock farming, decreasing use of fossil fuels, increasing use of hydrogen and renewable energy, e.g. wind, solar b. acid rain: use of catalytic converters in vehicles, reducing emissions of		***[SLO: C-11-D-14]*** *Analyse the economic, social and political issues related to air pollution and air quality management and demonstrate through answers.*	

sulphur dioxide by using low sulphur fuels and flue gas desulphurization with calcium oxide.) **[SLO: C-09-D-08]** Describe the role of NO and NO_2 in the formation of acid rain, both directly and through their catalytic role in the oxidation of atmospheric sulphur dioxide. **[SLO: C-09-D-09]** Explain how oxides of nitrogen form in car engines and describe their removal by catalytic converters, e.g. $2CO + 2NO \rightarrow 2CO_2 + N_2$ **[SLO: C-09-D-10]** Define photosynthesis as the reaction between carbon dioxide and water to produce glucose and oxygen in the presence of chlorophyll and using energy from light. ***[SLO: C-09-D-11]*** *Analyse how to use tools to reduce personal exposure to harmful pollutants*			

<table>
<tr><td>(some examples include the usage of masks, air quality indices and CO detectors.)

[SLO: C-09-D-12]
Identify high risk situations in life including those where long-term exposure to these pollutants can lead to respiratory issues and reduction in quality of life.</td><td></td><td></td><td></td></tr>
<tr><td colspan="4">Standard: (Water)
Students should be able to:
Describe the properties and composition of water, including its chemical and physical properties.
Discuss the effects of pollutants on water quality.
Apply the principles of chemical reactions to explain the formation and removal of water pollutants.</td></tr>
<tr><td colspan="2">Benchmark:
Explain how to measure the purity of water, water borne diseases, identify water scarcity as an important issue of Pakistan and evaluate the role of water in various natural and industrial processes.</td><td colspan="2">Benchmark:
Discuss the effects of pollutants on water quality and describe the impact of human activities on the quality and availability of freshwater resources.</td></tr>
</table>

[SLO: C-09-D-13] Investigate chemical tests for the presence of water using anhydrous copper (II) sulphate. **[SLO: C-09-D-14]** Explain how to test the purity of water using melting point and boiling point. **[SLO: C-09-D-15]** Distinguish between distilled water and tap water with their applications in practical chemistry. **[SLO: C-09-D-16]** State that water from natural sources may contain useful and harmful substances, (Some examples include: a. dissolved oxygen b. metal compounds c. plastics d. sewage e. harmful microbes	NA	**[SLO: C-11-D-15]** Describe different types of water pollution, (some examples include point source and nonpoint source pollution. **[SLO: C-11-D-16]** Identify common water pollutants (Some examples include oil, pesticides, and heavy metals. **[SLO: C-11-D-17]** Identify the sources and effects of water pollution on human health and the environment. **[SLO: C-11-D-18]** Explain water treatment methods and technologies, such as filtration and purification. ***[SLO: C-11-D-19]*** *Explain the laws and regulations related to water pollution and conservation.* **[SLO: C-11-D-20]** Evaluate the impact of human activities on water resources, such as agriculture and industrial processes. **[SLO: C-11-D-21]** Explain conservation and management	

f. nitrates from fertilizers g. phosphates from fertilizers and detergents) **[SLO: C-09-D-17]** Recognize that some naturally occurring substances in water are beneficial. (Some examples include: a. dissolved oxygen for aquatic life b. some metal compounds provide essential minerals for life.) **[SLO: C-09-D-18]** Recognize that some naturally occurring substances in water are potentially harmful. (Some examples include: a. some metal compounds that are toxic b. some plastics that harm aquatic life		strategies for protecting and preserving water resources. **[SLO: C-11-D-22]** Explain the chemical properties of water and how they relate to water quality and pollution.	

c. sewage that contains harmful microbes which cause disease d. nitrates and phosphates that lead to deoxygenation of water and damage to aquatic life; details of the eutrophication process is not required.) **[SLO: C-09-D-19]** Explain the treatment of the domestic water supply. (Some examples of this includes: (a) sedimentation and filtration to remove solids (b) use of carbon to remove tastes and odours (c) chlorination to kill microbes.) **[SLO: C-09-D-20]** Describe various water-borne diseases and the steps that can be taken to avoid them.			

[SLO: C-09-D-21] Identify the negative effects of water pollutants on life and the ways to avoid them. **[SLO: C-09-D-22]** Explain water scarcity as an important issue faced by Pakistan and the ways in which it can be resolved. **Fertilizers** **[SLO: C-09-D-23]** State that urea, ammonium salts and nitrates are used as fertilizers. ***[SLO: C-09-D-24]*** *Explain the use of NPK fertilizers to provide the elements nitrogen, phosphorus and potassium for improved plant growth.*			

Domain E: Organic Chemistry			
Standard: Basics of organic chemistry (catenation, isomerism, nomenclature, functional groups, homologous series) **Students should be able to:** **Describe the concept of catenation, including the ability of carbon atoms to bond with each other to form extended structures.** **Explain the concept of isomerism in organic compounds, including structural and stereoisomers.** **Discuss the systematic nomenclature of organic compounds, including IUPAC rules.** **Describe the functional groups in organic compounds, including alcohols, carboxylic acids, amines, and aldehydes.** **Explain the concept of homologous series, including the similarity in properties and reactivity among members of a series.** **Apply the knowledge of the properties of organic compounds to predict the outcome of common organic reactions, including substitution, elimination, addition, oxidation, and reduction.**			
Benchmark 1: Recognize and classify organic compounds based on their functional groups, nomenclature, isomerism, and homologous series.		**Benchmark 1: Analyse the chemical and physical properties of organic compounds based on their functional groups and be acquainted with the structures and terminology of different compounds and organic mechanisms.**	
[SLO: C-09-E-01] Define organic compounds with examples. **[SLO: C-09-E-02]** Describe organic molecules as either straight-chained, branched or cyclic. **[SLO: C-09-E-03]** Explain why a systematic method of naming chemical compounds is necessary.	**[SLO: C-10-E-01]** Name and draw the structural and displayed formulae of unbranched alkanes, alkenes, alcohols, and carboxylic acids by using IUPAC rules. (Include but-1-ene and but-2-ene, propan-1-ol, propan-2-ol, butan-1-ol and butan-2-ol.) **[SLO: C-10-E-02]** State the type of compound present given the chemical name ending in -ane, -ene, -yne, -ol, or -oic acid or from a molecular, structural or displayed formula.	**[SLO: C-11-E-01]** Recognize that hydrocarbons are compounds made up of C and H atoms only. **[SLO: C-11-E-02]** Recognize that alkanes are simple hydrocarbons with no functional group. **[SLO: C-11-E-03]** Recognize that compounds contain a functional group which dictates their physical and chemical properties.	**[SLO: C-12-E-01]** Explain stereoisomerism and its division into geometrical (cis/trans) and optical isomerism. **[SLO: C-12-E-02]** Describe geometrical (cis/trans) isomerism in alkenes, and explain its origin in terms of restricted rotation due to the presence of π bonds. **[SLO: C-12-E-03]** Describe the shape of benzene and other aromatic molecules, including

[SLO: C-09-E-04] State that a structural formula is an unambiguous description of the way the atoms in a molecule are arranged, including $CH_2=CH_2$, CH_3CH_2OH, CH_3COOCH_3. **[SLO: C-09-E-05]** Identify and draw structural formulae for molecules. **[SLO: C-09-E-06]** Interpret general formulae of compounds in the same homologous series including alkanes, alkenes, alkynes, alcohols and carboxylic acids. **[SLO: C-09-E-07]** Define structural isomers as compounds with the same molecular formula, but different structural formulae, including C_4H_{10} as $CH_3CH_2CH_2CH_3$ and $CH_3CH(CH_3)CH_3$ and C_4H_8 as $CH_3CH_2CH=CH_2$ and $CH_3CH=CHCH_3$. **[SLO: C-09-E-08]** Identify a functional group as an atom or group of atoms that	**[SLO: C-10-E-03]** Name and draw the displayed formulae of the esters which can be made from alcohols and carboxylic acids, each containing up to two carbon atoms.	**[SLO: C-11-E-04]** Interpret the general, structural, displayed and skeletal formulae of the classes of compounds. **[SLO: C-11-E-05]** Describe the use of systematic nomenclature of simple aliphatic organic molecules with functional groups. **[SLO: C-11-E-06]** Deduce the molecular and/or empirical formula of a compound, given its structural, displayed or skeletal formula. **[SLO: C-11-E-07]** Describe terminology associated with the types of organic compounds and reactions. (Some examples include: homologous series, saturated and unsaturated, homolytic and heterolytic fission, free radical, initiation, propagation, termination, nucleophile, electrophile, nucleophilic, electrophilic, addition, substitution, elimination, hydrolysis, condensation, oxidation and reduction.)	sp^2hybridisation, in terms of σ bonds and a delocalised π system. **[SLO: C-12-E-04]** Explain what is meant by a chiral centre and that such a centre gives rise to two optical isomers (enantiomers). **[SLO: C-12-E-05]** Describe that enantiomers have identical physical and chemical properties except for their ability to rotate plane-polarized light and potential biological activity. **[SLO: C-12-E-06]** Apply the terms optically active, racemic mixture and mesocompounds on given structure. **[SLO: C-12-E-07]** Describe the effect of two optical isomers of a single substance on a plane polarized light. **[SLO: C-12-E-08]** *Explain the significance of chirality in the synthetic preparation of drug molecules, including different biological activity of enantiomers, the need to separate racemic mixtures, and the use of chiral catalysts to produce a*

determine the chemical properties of a homologous series including that for alkyl halides alcohols, aldehydes, ketones, phenols, carboxylic acids, amine, esters, and amide. **[SLO: C-09-E-09]** Describe the general characteristics of a homologous series. (These can include: (c) having the same functional group (d) having the same general formula (e) differing from one member to the next by a –CH_2– unit (f) displaying a trend in physical properties (g) sharing similar chemical properties.) **[SLO: C-09-E-10]** State that a saturated compound has molecules in which all		**[SLO: C-11-E-08]** Define catenation and explain its importance in organic chemistry. **[SLO: C-11-E-09]** Describe terminology associated with types of organic mechanisms. (Some examples include: Free-radical substitution, electrophilic addition, nucleophilic substitution, nucleophilic addition.) **[SLO: C-11-E-10]** Draw the mechanism of a chemical reaction using curly arrows to represent the movement of a pair of electrons in at least three different types of reactions, including nucleophilic substitution, electrophilic addition, and elimination reactions. **[SLO: C-11-E-11]** Apply the term ‘planar’ when describing the arrangement of atoms in organic molecules. **[SLO: C-11-E-12]** Describe structural isomerism (in the context of organic molecules) and its division into chain, positional, functional group isomerism metamerism and tautomerism.	*single pure optical isomer using thalidomide as an example.*

carbon–carbon bonds are single bonds. **[SLO: C-09-E-11]** State that an unsaturated compound has molecules in which one or more carbon–carbon bonds are not single bonds.			
Standard: (Hydrocarbons) **Students should be able to:** **Describe the structures and properties of alkanes, alkenes, and alkynes, including their classification as saturated and unsaturated hydrocarbons.** **Explain the reaction mechanisms and products of alkane, alkene, and alkyne reactions, including combustion, addition, and substitution reactions.** **Discuss the applications of hydrocarbons, including their use as fuels and starting materials for the synthesis of other organic compounds.** **Apply the concepts of chemical bonding and reactivity to predict the products of hydrocarbon reactions (including aromatic compounds).** **Describe the importance of hydrocarbons in organic chemistry and their role in industry and daily life.**			
Benchmark 1: Classify and identify different types of hydrocarbons (alkanes, alkenes, alkynes) based on their molecular structure and reactivity.		**Benchmark 1: Understand the formation and reactions of hydrocarbons (including aromatic compounds), their nomenclature, shapes and properties.**	
[SLO: C-09-E-12] State that the bonding in alkanes is single covalent and that alkanes are saturated hydrocarbons. **[SLO: C-09-E-13]** Describe the properties of alkanes as being generally unreactive, except in terms of	**Alkanes and Alkenes** **[SLO: C-10-E-04]** State that the bonding in alkenes includes a double carbon–carbon covalent bond and that alkenes are unsaturated hydrocarbons.	**[SLO: C-11-E-13]** Classify hydrocarbons as aliphatic and aromatic compounds. **[SLO: C-11-E-14]** Describe nomenclature of alkanes and cycloalkanes.	**[SLO: C-12-E-09]** Explain the shape of the benzene molecule (molecular orbital aspect). **[SLO: C-12-E-10]** Define resonance, resonance energy and relative stability of benzene.

combustion and substitution by chlorine. **[SLO: C-09-E-14]** State that in a substitution reaction one atom or group of atoms is replaced by another atom or group of atoms. **[SLO: C-09-E-15]** Describe the substitution reaction of alkanes with chlorine as a photochemical reaction, and draw the structural or displayed formulae of the products, limited to mono-substitution. **[SLO: C-09-E-16]** Describe, using symbol equations, preparation of alkanes from cracking of larger hydrocarbons, hydrogenation of alkenes and alkynes, and reduction of alkyl halides.	**[SLO: C-10-E-05]** Describe the manufacture of alkenes by the cracking of largealkane molecules using a high temperature and a catalyst. **[SLO: C-10-E-06]** Describe the reasons for the cracking of large alkane molecules. **[SLO: C-10-E-07]** Describe the test to distinguish between saturated and unsaturated hydrocarbons by their reaction with aqueous bromine and $KMnO_4$. **[SLO: C-10-E-08]** Describe the properties of alkenes in terms of addition reactions with: a. bromine or aqueous bromine b. hydrogen in the presence of a nickel catalyst c. steam in the presence of an acid catalyst and	**[SLO: C-11-E-15]** Explain the shapes of alkanes and cycloalkanes exemplified by ethane and cyclopropane. **[SLO: C-11-E-16]** Explain unreactive nature of alkanes towards polar reagents. **[SLO: C-11-E-17]** Describe the mechanism of free radical substitution in alkanes exemplified by methane and ethane. **[SLO: C-11-E-18]** Identify organic redox reactions. **[SLO: C-11-E-19]** Explain the nomenclature of alkenes. **[SLO: C-11-E-20]** Explain shape of ethene molecule in terms of **σ** and π C-C bonds. **[SLO: C-11-E-21]** Describe the structure and reactivity of alkenes as exemplified by ethene. **[SLO: C-11-E-22]** Explain with suitable examples the terms isomerism, stereoisomerism and structural isomerism.	**[SLO: C-12-E-11]** Compare the reactivity of benzene with alkanes and alkenes. **[SLO: C-12-E-12]** Describe the mechanism of substitution reactions with chlorine and bromine, including the formation of ortho, para, and meta isomers, and predict the major product(s) of the reaction. **[SLO: C-12-E-13]** Explain the mechanism of nitration, including the formation of a nitronium ion, and predict the major product(s) of the reaction. **[SLO: C-12-E-14]** Explain the mechanism of Friedel-Crafts alkylation and acylation, respectively, including the role of the Lewis acid catalyst, and predict the major product(s) of the reaction. **[SLO: C-12-E-15]** Explain the mechanism of side chain oxidation, including the formation of a benzoic acid, and predict the major product(s) of the reaction.

	draw the structural or displayed formulae of the products. **[SLO: C-10-E-09]** Describe, using symbol equations, preparation of alkenes by elimination reaction in halogenoalkanes and alcohols. **Alkynes** **[SLO: C-10-E-10]** Identify alkynes as hydrocarbons containing triple carbon-carbon covalent bond and that alkynes are unsaturated hydrocarbons. **[SLO: C-10-E-11]** Describe the use of ethyne as fuel for welding, cutting and in artificially ripening fruits. **[SLO: C-10-E-12]** Describe separation of petroleum into useful fraction by fractional distillation. **[SLO: C-10-E-13]** Describe how the properties of fractions obtained from petroleum change from the bottom to the top	**[SLO: C-11-E-23]** Explain dehydration of alcohols and dehydrohalogenation of Alkyl halides for the preparation of ethene. **[SLO: C-11-E-24]** Describe the chemistry of alkenes by the following reactions of ethene: hydrogenation, hydrohalogenation, hydration, halogenation, halohydration, epoxidation, ozonolysis, and polymerization. **[SLO: C-11-E-25]** Explain the concept of conjugation in alkenes having alternate double bonds. **[SLO: C-11-E-26]** Describe the mechanism of electrophilic addition in alkenes, using bromine / ethene and hydrogen bromide /propene as examples. **[SLO: C-11-E-27]** Explain the inductive effects of alkyl groups on the stability of primary, secondary and tertiary cations formed during electrophilic addition (this should be used to explain Markovnikov addition).	**[SLO: C-12-E-16]** Explain the mechanism of hydrogenation, including the role of a metal catalyst, and predict the major product(s) of the reaction, which is cyclohexane. **[SLO: C-12-E-17]** Describe the mechanism of electrophilic aromatic substitution, including the role of the electrophile and the formation of a sigma complex, and predict the major product(s) of the reaction based on the directing effects of substituents on the aromatic ring.

	of the fractionating column, limited to: a. decreasing chain length b. higher volatility c. lower boiling points d. lower viscosity **[SLO: C-10-E-14]** Name the uses of the fractions as: a. refinery gas fraction for gas used in heating and cooking b. gasoline /petrol fraction for fuel used in cars c. naphtha fraction as a chemical feedstock d. kerosene /paraffin fraction for jet fuel e. diesel oil/ gas oil fraction for fuel used in diesel engines		

	f. fuel oil fraction for fuel used in ships and home heating systems g. lubricating oil fraction for lubricants, waxes and polishes h. bitumen fraction for making roads.		
Standard: (Halogenoalkanes) **The students should be able to:** **Explain the Synthesis of halogenoalkanes and their classification based on their molecular structure.** **Describe the common reactions of halogenoalkanes, including elimination reactions and substitutions, with a focus on S_N1 and S_N2 substitution mechanisms.** **Predict the reactivity of halogenoalkanes based on their molecular structure and the reaction conditions.** **Describe simple halogenoalkane syntheses and explain the organic functional groups involved in the reactions.** **Analyse the mechanisms and products of halogenoalkane reactions, using retro-synthesis to deduce the starting materials.**			
N/A		**Benchmark 1: Explain the reactions by which Halogenoalkanes and halogenoarenes are produced and the chemical reactions of these compounds.**	
N/A	N/A	**[SLO: C-11-E-28]** Classify halogenoalkanes based on the type of halogen atom and its position in the carbon chain, and explain how the molecular structure affects their reactivity. **[SLO: C-11-E-29]** Explain the organic functional groups involved in a simple halogenoalkane synthesis, and predict the major	**[SLO: C-12-E-18]** Describe production of halogenoarenes i.e. reaction of benzene with Cl_2 and Br_2 in the presence of catalyst. **[SLO: C-12-E-19]** Compare the reactivity of halogenoalkane and halogenoareneusing chloroethane and chlorobenzene as examples.

		product(s) based on the reaction conditions. (This includes: a) the free-radical substitution of alkanes by Cl_2 or Br_2 in the presence of ultraviolet light, as exemplified by the reactions of ethane b) electrophilic addition of an alkene with a halogen, X_2, or hydrogen halide, HX(g), at room temperature. c) substitution of an alcohol, e.g. by reaction with HX or KBr with H_2SO_4 or H_3PO_4; or with PCl_3 and heat; or with PCl_5; or with $SOCl_2$.) **[SLO: C-11-E-30]** Describe nucleophilic substitution reactions of halogenoalkanes, (Specifically: a. the reaction with $NaOH_{(aq)}$ and heat to produce an alcohol b. the reaction with KCN in ethanol and heat to produce a nitrile c. the reaction with NH_3 in ethanol heated under pressure to produce an amine d. the reaction with aqueous silver nitrate in ethanol as a method	**[SLO: C-12-E-20]** Predict the major product(s) based on the reaction conditions and the molecular structure of the halogenoalkane. **[SLO: C-12-E-21]** Analyse the mechanism and products of a reaction pathway involving a halogenoalkane, and use retro-synthesis to deduce the starting materials.

		of identifying the halogen present as exemplified by bromoethane.) **[SLO: C-11-E-31]** Describe the elimination reaction with NaOH in ethanol and heat to produce an alkene as exemplified by bromoethane.	
N/A		**Benchmark 2: Identify various substitution reactions and how different halogenoalkanes undergo substitution reactions and the compounds they produce.**	
N/A	N/A	N/A	**[SLO: C-12-E-22]** Describe the S_N1 and S_N2 mechanisms of nucleophilic substitution in halogenoalkanes including the inductive effects of alkyl groups. **[SLO: C-12-E-23]** Identify that primary halogenoalkanes tend to react via the S_N2 mechanism; tertiary halogenoalkanes via the S_N1 mechanism; and secondary halogenoalkanes by a mixture of the two, depending on structure. **[SLO: C-12-E-24]** Explain the different reactivities of halogenoalkanes (with particular reference to the relative strengths of the C–X bonds as exemplified by the

			reactions of halogenoalkanes with aqueous silver nitrates.)
Standard: (Hydroxy Compounds) **Students should be able to:** **Describe the structure and properties of alcohols, including primary, secondary, and tertiary alcohols.** **Explain the reaction mechanisms and products of alcohol reactions, including oxidation, esterification, and dehydration.** **Discuss the applications of alcohols, including their use as solvents, fuels, and starting materials for organic synthesis.** **Apply the concepts of chemical bonding and reactivity to predict the products of alcohol reactions.** **Describe the importance of alcohols in organic chemistry and their role in industry and daily life.**			
Benchmark 1: Identify the processes for manufacturing ethanol and its uses and effects.		**Benchmark 1: Analyse the different reactions through which different hydroxy compounds can be produced and their properties.**	
N/A	**[SLO: C-10-E-15]** Describe the manufacture of ethanol. (This can be done by discussing, – fermentation of aqueous glucose at 25–35°C in the presence of yeast and in the absence of oxygen – catalytic addition of steam to ethene at 300°C and 6000kPa /60 atm in the presence of an acid catalyst, including a comparison of the advantages and disadvantages of the two methods.)	**[SLO: C-11-E-32]** State the reactions (reagents and conditions) by which alcohols can be produced: a) Electrophilic addition of steam to an alkene, $H_2O_{(g)}$ and H_3PO_4 catalyst b) Reaction of alkenes with cold dilute acidified potassium manganate (VII) to form a diol c) substitution of a halogenoalkane using $NaOH_{(aq)}$ and heat d) reduction of an aldehyde or ketone using $NaBH_4$ or $LiAlH_4$	**[SLO: C-12-E-25]** Describe the reaction of alcohol with acyl chlorides to form esters (ethyl ethanoate). **[SLO: C-12-E-26]** State the reactions by which phenol can be produced: reaction of phenylamine with HNO_2 or $NaNO_2$ and dilute acid below 1°C to produce the diazonium salt; further warming of the diazonium salt with H_2O to give phenol. **[SLO: C-12-E-27]** Describe the chemistry of phenol, as exemplified by the following reactions: • with bases, for example $NaOH_{(aq)}$ to produce sodium phenoxide

	[SLO: C-10-E-16] Describe the combustion of ethanol. **[SLO: C-10-E-17]** Discuss the applications of ethanol as fuels, including their advantages and disadvantages over fossil fuels. **[SLO: C-10-E-18]** Explain the role of ethanol in various industries such as pharmaceuticals, cosmetics, and fuel production. **[SLO: C-10-E-19]** Discuss the impact of ethanol on daily life, including its use as solvent and disinfectant.	e) reduction of a carboxylic acid using $LiAlH_4$ f) hydrolysis of an ester using dilute acid or dilute alkali and heat. **[SLO: C-11-E-33]** Describe the reaction with oxygen (combustion) of organic hydroxy compounds. **[SLO: C-11-E-34]** Describe substitution of organic hydroxy compounds to halogenoalkanes, e.g. by reaction with HX or KBr with H_2SO_4 or H_3PO_4; or with PCl_3 and heat; or with PCl_5; or with $SOCl_2$. **[SLO: C-11-E-35]** Describe the reaction of hydroxy organic compounds with $Na_{(s)}$ **[SLO: C-11-E-36]** Describe the oxidation with acidified $K_2Cr_2O_7$ or acidified $KMnO_4$ to: carbonyl compounds by distillation, carboxylic acids by refluxing (primary alcohols give aldehydes, which can be further oxidized to carboxylic acids,	● with Na(s) to produce sodium phenoxide and $H_{2(g)}$. ● $NaOH_{(aq)}$ with diazonium salts, to give azo compounds ● nitration of the aromatic ring with dilute $HNO_{3(aq)}$ at room temperature to give a mixture of 2-nitrophenol and 4-nitrophenol ● bromination of the aromatic ring with $Br_{2(aq)}$ to form 2,4,6-tribromophenol. **[SLO: C-12-E-28]** Explain the acidity of phenol. **[SLO: C-12-E-29]** Describe the relative acidities of water, phenol and ethanol. **[SLO: C-12-E-30]** Explain why the reagents and conditions for the nitration and bromination of phenol are different from those for benzene. **[SLO: C-12-E-31]** Recall that the hydroxyl group of a phenol directs to the 2-, 4- and 6-positions.

		secondary alcohols give ketones, tertiary alcohols cannot be oxidized.) **[SLO: C-11-E-37]** Describe the dehydration of alcohols to alkenes by using a heated catalyst, e.g. Al_2O_3 or a concentrated acid. **[SLO: C-11-E-38]** Describe the formation of esters by reaction with carboxylic acids and concentrated H_2SO_4 or H_3PO_4 as catalyst as exemplified by ethanol. **[SLO: C-11-E-39]** Classify alcohols as primary, secondary and tertiary alcohols, and also include examples with more than one alcohol group. **[SLO: C-11-E-40]** State characteristic distinguishing reactions, e.g. mild oxidation with acidified $K_2Cr_2O_7$, colour change from orange to green. **[SLO: C-11-E-41]** Deduce the presence of a $CH_3CH(OH)–$ group in an alcohol, $CH_3CH(OH)–R$, from its reaction with alkaline $I_{2(aq)}$ to form a yellow	**[SLO: C-12-E-32]** Apply knowledge of the reactions of phenol to those of other phenolic compounds, e.g. naphthol.

		precipitate of tri-iodomethane and an ion, RCO_2^-. **[SLO: C-11-E-42]** Explain the acidity of alcohols compared with water.	
Standard: (Carbonyl Compounds) **Students should be able to:** **Describe the properties of carbonyl Compounds, including their characteristic functional groups.** **Explain the reaction mechanisms and products of carboxylic acid reactions, including decarboxylation, esterification, and acid-base reactions.** **Discuss the applications of carboxylic acids and esters, including their use as fragrances, flavours, and starting materials for organic synthesis.** **Apply the concepts of chemical bonding and reactivity to predict the products of carboxylic acid reactions.**			
Benchmark 1: Identify and explain the properties and reactions of carboxylic acids and esters, including their preparation, and use in industry and daily life.		**Benchmark 1: Explain the reactions by which aldehyde, ketones and carboxylic acids are produced and the nature, reactions and uses of these compounds.**	
N/A	**[SLO: C-10-E-20]** Describe the reactions of carboxylic acids with metals, bases and carbonates including names and formulae of the salts produced. **[SLO: C-10-E-21]** Describe the formation of ethanoic acid by the oxidation of ethanol: with acidified aqueous potassium manganate (VII) & by bacterial	**[SLO: C-11-E-43]** State the reactions (reagents and conditions) by which aldehydes and ketones can be produced: a. the oxidation of primary alcohols using acidified $K_2Cr_2O_7$ or acidified $KMnO_4$ and distillation to produce aldehydes b. the oxidation of secondary alcohols using acidified $K_2Cr_2O_7$ or acidified $KMnO_4$	**[SLO: C-12-E-33]** State the reaction by which benzoic acid can be produced: reaction of an alkylbenzene with hot alkaline $KMnO_4$ and then dilute acid, exemplified bymethylbenzene. **[SLO: C-12-E-34]** Describe the reaction of carboxylic acids with PCl_3 and heat, PCl_5, or $SOCl_2$ to form acyl chlorides.

	oxidation during vinegar production. **[SLO: C-10-E-22]** Describe the reaction of a carboxylic acid with an alcohol using an acid catalyst to form an ester. **SLO: C-10-E-23]** Describe the industrial applications of carboxylic acids and esters, including their use as solvents, flavours, fragrances, and in plastics. **SLO: C-10-E-24]** Explain the role of carboxylic acids and esters in daily life, including their use in food preservation, cosmetics, and pharmaceuticals.	and distillation to produce ketones. **[SLO: C-11-E-44]** Describe: a. the reduction of aldehydes and ketones, using $NaBH_4$ or $LiAlH_4$ to produce alcohols b. the reaction of aldehydes and ketones with HCN, KCN as catalyst, and heat to produce hydroxynitriles exemplified by ethanal and propanone. **[SLO: C-11-E-45]** Describe the mechanism of the nucleophilic addition reactions of hydrogen cyanide with aldehydes and ketones. **[SLO: C-11-E-46]** Describe the use of 2,4-dinitrophenylhydrazine (2,4-DNPH reagent) to detect the presence of carbonyl compounds. **[SLO: C-11-E-47]** Deduce the nature (aldehyde or ketone) of an unknown carbonyl compound from the results of simple	**[SLO: C-12-E-35]** Recognize that some carboxylic acids can be further oxidized: a. the oxidation of methanoic acid, HCOOH, with Fehling's reagent or Tollens' reagent or acidified $KMnO_4$or acidified $K_2Cr_2O_7$ to carbon dioxide and water b. the oxidation of ethanedioic acid, HOOCCOOH, with warm acidified $KMnO_4$ to carbon dioxide. **[SLO: C-12-E-36]** Explain the relative acidities of carboxylic acids, phenols and alcohols. **[SLO: C-12-E-37]** Explain the relative acidities of chlorine-substituted carboxylic acids. **[SLO: C-12-E-38]** Recall the reaction by which esters can be produced:reaction of alcohols with acyl chlorides using the formation of ethyl ethanoate and phenyl benzoate as examples.

		tests (Fehling's and Tollens' reagents; ease of oxidation). **[SLO: C-11-E-48]** Deduce the presence of a CH_3CO^- group in an aldehyde or ketone, $CH_3CO–R$, from its reaction with alkaline $I_{2(aq)}$ to form a yellow precipitate of tri-iodomethane and an ion, RCO_2^-. **[SLO: C-11-E-49]** Recall the reactions by which carboxylic acids can be produced: a) oxidation of primary alcohols and aldehydes with acidified $K_2Cr_2O_7$ or acidified $KMnO_4$ and refluxing b) hydrolysis of nitriles with dilute acid or dilute alkali followed by acidification c) hydrolysis of esters with dilute acid or dilute alkali and heat followed by acidification. **[SLO: C-11-E-50]** Describe: a. the redox reaction of carboxylic acids with reactive	**[SLO: C-12-E-39]** Recall the reactions (reagents and conditions) by which acyl chlorides can be produced: reaction of carboxylic acids with PCl_3 and heat, PCl_5, or $SOCl_2$. **[SLO: C-12-E-40]** Describe the following reactions of acyl chlorides: a. hydrolysis on addition of water at room temperature to give the carboxylic acid and HCl b. reaction with an alcohol at room temperature to produce an ester and HCl c. reaction with phenol at room temperature to produce an ester and HCl d. reaction with ammonia at room temperature to produce an amide and HCl e. reaction with a primary or secondary amine at room temperature to produce an amide and HCl.

		metals to produce a salt and $H_2(g)$ b. the neutralization reaction with alkalis to produce a salt and $H_2O_{(l)}$ c. the acid–base reaction with carbonates to produce a salt and $H_2O_{(l)}$ and $CO_{2(g)}$ d. esterification with alcohols with concentrated H_2SO_4 as catalyst e. reduction by $LiAlH_4$ to form a primary alcohol. **[SLO: C-11-E-51]** Recall the reaction (reagents and conditions) by which esters can be produced: the condensation reaction between an alcohol and a carboxylic acid with concentrated H_2SO_4 as catalyst. **[SLO: C-11-E-52]** Describe the hydrolysis of esters by dilute acid and by dilute alkali and heat.	**[SLO: C-12-E-41]** Describe the addition-elimination mechanism of acyl chlorides in reactions. **[SLO: C-12-E-42]** Explain the relative ease of hydrolysis of acyl chlorides, alkyl chlorides and halogenoarenes (aryl chlorides).
Standard: (Nitrogen Compounds) Students should be able to: **Describe the structure and properties of nitrogen compounds, including their characteristic functional groups.**			

Explain the reaction mechanisms and products of reactions with nitrogen containing compounds Discuss the formation of amide bonds to form amino acids			
N/A		**Benchmark 1: Explain the classification and reactions of aliphatic and aromatic amines including their conversion to amides, forming amino acids.**	
N/A		**[SLO: C-11-E-53]** Define primary and secondary amines, and explain their basic properties and reactivity. **[SLO: C-11-E-54]** Identify the differences between primary and secondary amines in terms of their structure and chemical properties. **[SLO: C-11-E-55]** Describe the preparation of primary and secondary amines, including nucleophilic substitution reactions and reduction of nitro compounds. **[SLO: C-11-E-56]** Explain the properties and reactivity of phenylamine and azo compounds, including their use as dyes and pigments.	**Primary and secondary amines** **[SLO: C-12-E-43]** Recall the reactions (reagents and conditions) by which primary and secondary amines are produced: (a) reaction of halogenoalkanes with NH_3 in ethanol heated under pressure (b) reaction of halogenoalkanes with primary amines in ethanol, heated in a sealed tube / under pressure (c) the reduction of amides with $LiAlH_4$ (d) the reduction of nitriles with $LiAlH_4$ or H_2/ Ni. **SLO: C-12-E-44]** Describe the reactions by which nitriles can be produced: reaction of a

			halogenoalkane with KCN in ethanol and heat. **[SLO: C-12-E-45]** Recall the reactions by which hydroxy nitriles can be produced: the reaction of aldehydes and ketones with HCN, KCN as catalyst, and heat. **[SLO: C-12-E-46]** Describe the hydrolysis of nitriles with dilute acid or dilute alkali followed by acidification. **[SLO: C-12-E-47]** Describe the basicity of aqueous solutions of amines. **Phenylamine and azo compounds** **[SLO: C-12-E-48]** Describe the reaction of phenylamine with $Br_{2(aq)}$ at room temperature. **[SLO: C-12-E-49]** Recall the reaction of phenylamine with HNO_2 or $NaNO_2$ and dilute acid below 1°C to produce the diazonium salt; further warming of the diazonium salt with H_2O to give phenol.

			[SLO: C-12-E-50] Explain the relative basicity of aqueous ammonia, ethylamine and phenylamine. **[SLO: C-12-E-51]** Identify the properties of azo compounds, (Some examples include: (a) describe the coupling of benzenediazonium chloride with phenol in $NaOH_{(aq)}$ to form an azo compound (b) identify the azo group (c) state that azo compounds are often used as dyes (d) Recognize that other azo dyes can be formed via a similar route). **Amides** **[SLO: C-12-E-52]** Identify the reactions (reagents and conditions) by which amides are produced. (Some examples include: (a) the reaction between ammonia and an acyl chloride at room temperature

			(b) the reaction between a primary amine and an acyl chloride at room temperature.) **[SLO: C-12-E-53]** Describe the reactions of amides. (Some examples include: (a) hydrolysis with aqueous alkali or aqueous acid (b) the reduction of the carbonyl group in amides with $LiAlH_4$ to form an amine.) **[SLO: C-12-E-54]** Explain why amides are much weaker bases than amines. **[SLO: C-12-E-55]** Describe the acid/ base properties of amino acids and the formation of Zwitter ion. **[SLO: C-12-E-56]** Describe the formation of amide (peptide) bonds between amino acids to give di- and tripeptides.

			[SLO: C-12-E-57] *Predict the results of electrophoresis on mixtures of amino acids and dipeptides at varying pHs.*
Standard: (Polymer) **Students should be able to:** **Describe the structure and properties of polymers, including homopolymers and copolymers.** **Explain the formation and synthesis of polymers, including addition polymerization and condensation polymerization.** **Discuss the applications of polymers, including their use in various industries such as plastics, textiles, and biomedicines.** **Apply the concepts of chemical bonding and reactivity to predict the properties and reactivity of polymers.** **Describe the importance of polymers in materials science and their impact on society and the environment.**			
Benchmark 1: Identify and describe the structure, properties, reactions and applications of various polymers.		**Benchmark 1: Describe the polymerization process and classification of polymers.**	
N/A	**[SLO: C-10-E-25]** Define polymers as large molecules built up from many smaller molecules called monomers. **[SLO: C-10-E-26]** Identify the repeating units and/or linkages in addition polymers and in condensation polymers. **[SLO: C-10-E-27]** Deduce the structure or repeating unit of an addition polymer from a given alkene and vice versa.	**N/A**	**[SLO: C-12-E-58]** Explain the chemical processes and properties of PVC and nylon, and the applications of these polymers in the industry. **[SLO: C-12-E-59]** Describe the condensation reaction of ammonia or an amine with an acyl chloride at room temperature to give an amide. **[SLO: C-12-E-60]** Discuss the importance of chemical industries in the economy of Pakistan, and describe the raw materials that are

	[SLO: C-10-E-28] Deduce the structure or repeating unit of a condensation polymer from given monomers and vice versa, limited to: a. Polyamides from a dicarboxylic acid and a diamine b. Polyesters from a dicarboxylic acid and a diol. **[SLO: C-10-E-29]** Describe the differences between addition and condensation polymerisation. **[SLO: C-10-E-30]** State that plastics are made from polymers. **[SLO: C-10-E-31]** Describe how the properties of plastics have implications for their disposal. **[SLO: C-10-E-32]** Describe the environmental challenges caused by plastics, limited to:		available in the country for various chemical industries. **[SLO: C-12-E-61]** Describe the chemical processes of addition and condensation polymerization and the differences between them. Examples include, a. addition polymers such as poly(ethene) and poly(chloroethene), PVC, b. polyesters (from reactions of diol and dicarboxylic or dioyl acid, and from hydroxycarboxylic acid), c. polyamides (from reactions of a diamine and a dicarboxylic acid or dioyl chloride, of an aminocarboxylic acid, or between amino acids.) **[SLO: C-12-E-62]** Identify the polymer formed, the monomer presents in a section of polymer, and classify them as one of the two polymers.

	a. disposal in landfill sites b. accumulation in oceans c. formation of toxic gases from burning. **[SLO: C-10-E-33]** Describe the structure of: a. nylon, a polyamide b. PET, a polyester. (The full name for PET, polyethylene terephthalate, is not required). **[SLO: C-10-E-34]** State that PET can be converted back into monomers and re-polymerised. **[SLO: C-10-E-35]** Outline the importance of polymers in the textile industry. (Examples for polymers being used may be given along with their specific properties.)		**[SLO: C-12-E-63]** Deduce the repeating unit of a polymer obtained from a given monomer or pair of monomers and identify the monomers present in a given section of a polymer molecule. **[SLO: C-12-E-64]** Predict the type of polymerization reaction for a given monomer or pair of monomers. **[SLO: C-12-E-65]** Explain the challenges associated with the disposal of non-biodegradable polymers. **[SLO: C-12-E-66]** Recognize that poly (alkenes) is chemically inert and can therefore be difficult to biodegrade. **[SLO: C-12-E-67]** Recognize that some polymers can be degraded by the action of light. **[SLO: C-12-E-68]** Recognize that polyesters and polyamides are biodegradable by acidic and alkaline hydrolysis.

			[SLO: C-12-E-69] *Outline the use of polymers to create artificial organs in biomedical science.*
Standard: (Organic Synthesis) **The students should be able to:** **Identify and name common organic functional groups and their physical and chemical properties.** **Understandthe basic mechanisms of common organic reactions of functional groups.** **Design a synthetic route for simple organic compounds using reagents and reaction conditions.** **Perform basic retro-synthetic analysis to deduce the starting materials for the synthesis of a target molecule.** **Evaluate the feasibility and efficiency of synthetic routes for the preparation of target molecules.**			
N/A		**Benchmark 1: Understand that functional groups have distinct and varied reactions and how to synthesize one organic compound of a functional group from another.**	
N/A	N/A	**[SLO: C-11-E-57]** Explain the concept of organic synthesis and functional group interconversions. **[SLO: C-11-E-58]** Identify organic functional groups using the reactions. **[SLO: C-11-E-59]** Predict properties and reactions of organic molecules based on functional group present. **[SLO: C-11-E-60]** Devise multi-step synthetic routes for preparing organic molecules.	**[SLO: C-12-E-70]** *Describe the use of Artificial Intelligence tools in designing organic molecules which may have the potential to be used as medicine. (Halicin can be used as an example).*

		[SLO: C-11-E-61] Analyse a given synthetic route in terms of type of reaction and reagents used for each step of it, and possible by-products. **[SLO: C-11-E-62]** Explain the concept of retro-synthesis and its application in organic synthesis.	
Standard: Biochemistry (carbohydrates, proteins, lipids, DNA, vitamins) **Students should be able to:** **Describe the structure and properties of carbohydrates, proteins, and lipids, including their classification.** **Explain the metabolic pathways and functions of carbohydrates, proteins, and lipids in living organisms, including energy storage and transfer, structural support, and regulatory roles.** **Describe the structure and function of DNA and RNA, including the role of DNA in genetics and the mechanism of transcription and translation.** **Discuss the importance of vitamins and minerals in human nutrition, including their role in metabolic processes and the consequences of deficiencies.** **Apply the concepts of biochemistry to understand the molecular basis of biological processes, diseases, and treatments.**			
Benchmark 1: Identify the importance of carbohydrates, proteins, lipids, DNA and vitamins in biological systems.		**Benchmark 1: Explain the structures of different biochemical compounds, their reactions and role inside living organisms.**	
[SLO: C-09-E-17] Explain the importance and basics of nutrition and healthy eating. **[SLO: C-09-E-18]** Recognize the main biomolecules; carbohydrates, proteins, lipids and nucleic	**[SLO: C-10-E-36]** Describe proteins as natural polyamides and that they are formed from amino acid monomers with the general structure.		**[SLO: C-12-E-71]** Explain the basis of classification and structure-function relationship of carbohydrates. **[SLO: C-12-E-72]** Explain the role of various carbohydrates in health and diseases.

acids. Their sources, along with the required daily intake for young adults. **[SLO: C-09-E-19]** Identify carbohydrates as a source of energy.	**[SLO: C-10-E-37]** Explain the sources, use and structure of proteins, lipids and carbohydrates. **[SLO: C-10-E-38]** Describe the importance of nucleic acids. **[SLO: C-10-E-39]** Explain vitamins, their sources and their importance to health. ***[SLO: C-10-E-40]*** *Identify applications of biochemistry in testing (blood test, pregnancy test, cancer screening, and parental genetic testing), genetic engineering, gene therapy and cloning.*		**[SLO: C-12-E-73]** Identify the nutritional importance of carbohydrates and their role as energy storage. **[SLO: C-12-E-74]** Explain the basis of classification and structure-function relationship of proteins. **[SLO: C-12-E-75]** Describe the role of various proteins in maintaining body functions and their nutritional importance. **[SLO: C-12-E-76]** Describe the role of enzyme as biocatalyst and relate this role to various functions such as digestion of food. **[SLO: C-12-E-77]** Identify factors that affect enzyme activity such as the effect of temperature and pH. **[SLO: C-12-E-78]** Explain the role of inhibitors of enzyme catalysed reactions. **[SLO: C-12-E-79]** Describe the basis of classification and structure-function relationship of lipids.

			[SLO: C-12-E-80] Identify the nutritional and biological importance of lipids. **[SLO: C-12-E-81]** Identify the structural components of DNA and RNA. **[SLO: C-12-E-82]** Differentiate between the structures of DNA polymer (double strand) and RNA (single strand). **[SLO: C-12-E-83]** Relate DNA sequences to its function as storage of genetic information. **[SLO: C-12-E-84]** Relate RNA sequence (transcript) to its role in transfer of information to protein synthesis (translation). **[SLO: C-12-E-85]** Identify the sources of minerals such as iron, calcium, phosphorus and zinc. **[SLO: C-12-E-86** Describe the role of iron, calcium, phosphorous and zinc in nutrition.

			[SLO: C-12-E-87] *Explain why animals and humans have large glycogen deposits for sustainable muscular activities. Hibernating animals (polar bear, reptiles and amphibians) accumulate fat to meet energy resources during hibernation.* ***[SLO: C-12-E-88]*** *Identify complex carbohydrates which provide lubrication to the elbow and knee.* ***[SLO: C-12-E-89]*** *Describe fibrous proteins from hair and silk.* ***[SLO: C-12-E-90]*** *Explain how cholesterol and amino acid serve as hormones.* ***[SLO: C-12-E-91]*** *Identify insulin as a protein hormone whose deficiency leads to diabetes mellitus.* ***[SLO: C-12-E-92]*** *Explain the role of minerals in structure and function.*

			[SLO: C-12-E-93] *Identify calcium as a requirement for coagulation.* ***[SLO: C-12-E-94]*** *Identify how milk proteins can be precipitated by lowering the pH using lemon juice.*

Domain F: Empirical Data Collection and Analysis			
Standard: Students should be able to: **Analyse and interpret data from experiments, using mathematical and statistical tools as needed.** **Evaluate the accuracy and precision of data, and identify sources of error in experimental results.** **Communicate experimental results clearly and effectively, using appropriate graphical and written formats.**			
Benchmark 1: Students can use standard scientific notation for physical quantities and can justify the appropriate use of common lab instruments to collect data on physical quantities related to chemistry		**Benchmark 2: Students can apply the scientific units and measurements used in chemistry, explain the kind of errors that can appear in such measurements, and use different graphical techniques to present the collected data.**	
Units **[SLO: C-09-F-01]** Explain that units are standardized for better communication and collaboration, (Some examples may include: – In the field of chemistry, the International System of Units (SI) is used to measure physical quantities such as mass, volume, and temperature. This standardized system ensures that chemists worldwide can use the same units to measure			**Uncertainties and errors in measurement and results** **[SLO: C-12-F-01]** Differentiate between Qualitative data and Quantitative Data – (Qualitative data includes all non-numerical information obtained from observations not from measurement. – Quantitative data are obtained from measurements, and are always associated with random errors/uncertainties, determined by the apparatus, and by human limitations such as reaction times.)

and communicate their results, facilitating communication and collaboration in the field. – Without standardized units, it would be difficult for chemists to compare their results with one another, and it would be challenging to develop consistent and accurate scientific models. For example, imagine if one chemist measured the mass of a substance in grams, while another used ounce. The two measurements would be difficult to compare and combine, potentially leading to inaccurate or inconsistent results.) **[SLO: C-09-F-02]** Identify SI units for abstract and physical quantities. (Some examples include mass, time and amount of matter.)			**[SLO: C-12-F-02]** Justify that the propagation of random errors in data processing shows the impact of the uncertainties on the final result. (Some examples may include: – When we process data that contains random errors, these errors can propagate or accumulate throughout the calculation, resulting in larger uncertainties in the final result. – For example, if we measure the length and width of a rectangle to calculate its area, any small errors in the measurement of length and width will propagate through to the area calculation, resulting in a larger uncertainty in the final area measurement. – This information is critical in scientific research as it helps us assess the reliability of our data and draw valid conclusions from our experiments.) **[SLO: C-12-F-03]** Analyse the concept that experimental design and procedure usually lead to systematic errors in measurement, which

[SLO: C-09-F-03] Apply the concept that units can be combined with terms for magnitude, especially kilo, deci, and milli. **[SLO: C-09-F-04]** Justify why chemists use 'cm^3, 'g' and'ts' as more practical units when working with small amounts in lab. **[SLO: C-09-F-05]** Explain with examples how different tools and techniques can be used to manage accuracy and precision for inherent errors that arise during measurement. **Scientific Notation/Standard Form** **[SLO: C-09-F-06]** Use the standard form $A \times 10^n$ where n is a positive or negative integer, and $1 \leqslant A < 10$. **[SLO: C-09-F-07]** Convert quantitative values into and out of the scientific notation form.			cause a deviation in a particular direction. **[SLO: C-12-F-04]** Justify that repeat trials and measurements will reduce random errors but not systematic errors Graphical techniques. **[SLO: C-12-F-05]** Explain that graphical techniques are an effective means of communicating the effect of an independent variable on a dependent variable, and can lead to determination of physical quantities. **[SLO: C-12-F-06]** Discuss that sketched graphs have labelled but unscaled axes, and are used to show qualitative trends, such as variables that are proportional or inversely proportional. **[SLO: C-12-F-07]** Discuss that drawn graphs have labelled and scaled axes, and are used in quantitative measurements.

[SLO: C-09-F-08] Calculate with values in standard form. **[SLO: C-09-F-09]** Identify appropriate apparatus for the measurement of time, temperature, mass and volume, including: a. stopwatches b. thermometers c. balances d. burettes e. volumetric pipettes f. measuring cylinders g. gas syringes **[SLO: C-09-F-10]** Suggest advantages and disadvantages of experimental methods and apparatus.			

<table>
<tr><td colspan="4">Standard: (Separation Techniques)
Students should be able to:
Understand the principles of different separation techniques and methods, including chromatography, distillation, and extraction.
Perform experimental procedures and techniques accurately and safely, using appropriate equipment and instruments.
Analyse and interpret data from experiments, using mathematical and statistical tools as needed.
Evaluate the efficiency and selectivity of different separation techniques for specific mixtures, and choose the appropriate technique for a given problem.</td></tr>
<tr><td colspan="2">Benchmark 1: Describe the principles and process of separation techniques in chemistry such as chromatography, distillation, and crystallization, and explain how each technique is used to separate mixtures based on their physical and chemical properties.</td><td colspan="2">N/A</td></tr>
<tr><td>Experimental design

[SLO: C-09-F-11]
Define important terms associated with creating chemical solutions. (Some examples include:

a) solvent as a substance that dissolves a solute

b) solute as a substance that is dissolved in a solvent

c) solution as a mixture of one or more solutes dissolved in a solvent</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
</table>

d) saturated solution as a solution containing the maximum concentration of a solute dissolved in the solvent at a specified temperature e) residue as a substance that remains after evaporation, distillation, filtration or any similar process f) filtrate as a liquid or solution that has passed through a filter.) **[SLO: C-09-F-12]** Explain methods of separation and purification. (Some examples include: a) using a suitable solvent (solvent extraction) b) filtration c) crystallization d) simple distillation e) fractional distillation			

<table>
<tr><td>f) chromatography.)

[SLO: C-09-F-13]
Suggest suitable separation and purification techniques, given information about the substances involved, and their usage in daily life.

[SLO: C-09-F-14]
Identify substances and assess their purity using melting point and boiling point information.</td><td></td><td></td><td></td></tr>
<tr><td colspan="4">Standard: (Qualitative Analysis)
Students should be able to:
Understand the principles of qualitative analysis, including the use of reagents and reaction tests to identify unknown substances.
Analyse and interpret data from experiments, using logical reasoning and inferential thinking to deduce the identity of unknown substances.</td></tr>
<tr><td colspan="2">Benchmark 1: Understand the principles and applications of various qualitative analysis techniques, including observation, precipitation, oxidation-reduction, and complexation reactions.</td><td colspan="2">Benchmark 1: Understand how mass spectrometers can help analyse different atoms including isotopes based on their m/e values and identify molecules based on their masses while looking at their mass spectra.</td></tr>
<tr><td>[SLO: C-09-F-15]
Describe tests to identify important gasses.
(Some examples include:
a. ammonia, NH_3, using damp red litmus paper

b. carbon dioxide, CO_2, using limewater</td><td>N/A</td><td>N/A</td><td>[SLO: C-12-F-08]
Analyse mass spectra in terms of m/e values and isotopic abundances (knowledge of the working of the mass spectrometer is not required).

[SLO: C-12-F-09]
Calculate the relative atomic mass of an element given the relative abundances of its isotopes, or its mass spectrum.</td></tr>
</table>

c. chlorine, Cl_2, using damp litmus paper d. hydrogen, H_2, using a lighted splint e. oxygen, O_2, using a glowing splint f. sulphur dioxide, SO_2, using acidified aqueous potassium manganate (VII).) **[SLO: C-09-F-16]** Explain the use of a flame test to identify important cations: (Some examples include: a) lithium, Li^+ b) sodium, Na^+ c) potassium, K^+ d) calcium, Ca^{2+} e) copper (II), Cu^{2+} f) barium, Ba^{2+}.)			**[SLO: C-12-F-10]** Deduce the molecular mass of an organic molecule from the molecular ion peak in a mass spectrum. **[SLO: C-12-F-11]** Suggest the identity of molecules formed by simple fragmentation in a given mass spectrum. **[SLO: C-12-F-12]** Deduce the number of carbon atoms, n, in a compound using the M^+ peak and the formula n = 100/1.1×abundance of M+1 ion/ abundance of M^+ ions. **[SLO: C-12-F-13]** Deduce the presence of bromine and chlorine atoms in a compound using the M+1 peak.

Standard: (Spectroscopy) **The students should be able to:** **Describe the principles of spectroscopy and relate them to the interaction of electromagnetic radiation with matter.** **Analyse spectra to determine the presence and concentration of chemical species.** **Explain the relationship between the absorption/emission spectrum of a substance and its electronic structure.** **Compare and contrast different types of spectroscopy (e.g. infrared, ultraviolet-visible, nuclear magnetic resonance).** **Use spectroscopic techniques to identify unknown compounds in a mixture.**

N/A		**Benchmark 1: Understand how spectroscopy works and can be used to identify different functional groups and structures of compounds and explain how emission and absorption spectra work.**	
N/A	N/A		**Spectroscopic identification of organic compounds** **[SLO: C-12-F-14]** Explain that the degree of unsaturation or index of hydrogen deficiency (IHD) can be used to determine from a molecular formula the number of rings or multiple bonds in a molecule. **[SLO: C-12-F-15]** Explore how Mass spectrometry (MS), proton nuclear magnetic resonance spectroscopy (^{1}H NMR) and infrared spectroscopy (IR) are techniques that can be used to help identify compounds and to determine their structure. **[SLO: C-12-F-16]** Interpret an infrared (IR) spectrum of a simple molecule to identify functional groups. **[SLO: C-12-F-17]** Deduce possible structures for organic compounds using IR spectrum and molecular formula (Examples: phenol, acetone, and ethanol).

			[SLO: C-12-F-18] Predict whether a given molecule will absorb in the UV/visible region. **[SLO: C-12-F-19]** Predict the colour of a transition metal complex from its UV/visible spectrum. **[SLO: C-12-F-20]** Explain atomic emission and atomic absorption spectrum.
Standard: (NMR) **The students will be able to:** **Describe the basic principles of NMR spectroscopy and explain how it is used to determine the structure of organic molecules** **Distinguish between the different types of NMR spectra and interpret the information they provide** **Use NMR spectra to determine the number and type of carbon atoms in an organic molecule** **Explain how Carbon-13 NMR spectra provide unique information about the structure of organic molecules.** **Analyse Carbon-13 NMR spectra to deduce the structure of simple organic compounds and recognize common spectral patterns in the spectra of different types of compounds.**			
N/A		**Benchmark 1: Explain how NMR can be used to identify the compounds present and help ascertain its structure in addition to deducing the relative number of different types of protons present inside a molecule.**	

N/A	N/A	N/A	**[SLO: C-12-F-21]** Analyse the different environments of carbon atoms present in a simple molecule using a C-13 NMR spectrum. **[SLO: C-12-F-22]** Use a C-13 NMR spectrum to deduce possible structures of a simple molecule. **[SLO: C-12-F-23]** Predict the number of peaks in a C-13 NMR spectrum for a given molecule. **[SLO: C-12-F-24]** Analyse the different environments of protons present in a simple molecule using a ^{1}H (proton) NMR spectrum. **[SLO: C-12-F-25]** Use a ^{1}HNMR spectrum to deduce relative numbers of each type of proton present, the number of equivalent protons on the carbon atom adjacent to the one to which the given proton is attached. **[SLO: C-12-F-26]** Deduce possible structures for the molecule.

			[SLO: C-12-F-27] Predict the chemical shifts and splitting patterns of the protons in a given molecule. **[SLO: C-12-F-28]** Explain the use of tetramethylsilane, TMS, as the standard for chemical shift measurement. **[SLO: C-12-F-29]** Recognize the need for deuterated solvents, e.g. $CDCl_3$, when obtaining a proton NMR spectrum **[SLO: C-12-F-30]** Describe the identification of O–H and N–H protons by proton exchange using D_2O.
Standard: (Chromatography) **The students should be able to:** **Define chromatography and explain the principles of its different types including paper chromatography and thin layer chromatography.** **Analyse the results of a chromatography experiment, including identifying spots or peaks and determining their relative sizes and positions.** **Design and execute chromatography experiments to separate mixtures of compounds based on their physical and chemical properties including the interpretation of R_f values.** **Identify any unknown materials in the mixture and determine its quantity.**			
Define chromatography and explain the principles of paper chromatography and discuss the underlying principles that govern the separation technique.		**Benchmark 1: Understand how chromatography works and how one can separate different components of a mixture.**	
	N/A	N/A	

Chromatography **[SLO: C-09-F-17]** Describe how paper chromatography is used to separate mixtures of soluble substances, using a suitable solvent. **[SLO: C-09-F-18]** Describe the use of locating agents when separating mixtures containing colourless substances. (For context, knowledge of specific locating agents is not required.) **[SLO: C-09-F-19]** Interpret simple chromatograms (For context, students should identify: a) unknown substances by comparison with known substances b) pure and impure substances.)			**[SLO: C-12-F-31]** Describe the terms stationary phase, mobile phase, R_f value, baseline and solvent front. **[SLO: C-12-F-32]** Explain the principles and applications of thin-layer chromatography in forensic chemistry and analysis of unknown materials. **[SLO: C-12-F-33]** Interpret R_f values and retention times in chromatograms to determine the composition of a mixture. **[SLO: C-12-F-34]** Explain the importance of selecting the appropriate stationary and mobile phases in chromatography and their impact on the separation of compounds. ***[SLO: C-12-F-35]*** *Describe the use of mass spectrometry in combination with chromatography for identifying and quantifying small amounts of unknown materials in forensic analysis.*

<table>
<tr><td>[SLO: C-09-F-20]
State and use the equation for R_f.</td><td></td><td></td><td></td></tr>
<tr><td colspan="4">Standard: (Materials)
The students should be able to:
Describe the properties of various materials, including metals, polymers, ceramics, and composites, and explain how these properties are related to the structure of the material.
Discuss the extraction of materials from natural sources.
Evaluate the sustainability of recycling processes for various materials, including the energy and material inputs required.
Assess the toxicity of materials and the effects of exposure on human health and the environment, and recommend measures to reduce these impacts.
Explain the principles and applications of X-ray crystallography, including the determination of crystal structures, the analysis of crystal defects, and the design of new materials with desired properties.</td></tr>
<tr><td colspan="2">N/A</td><td colspan="2">Benchmark 1: Explain the properties of different materials, their extraction techniques, uses and effects in the world around us</td></tr>
<tr><td>N/A</td><td>N/A</td><td>N/A</td><td>[SLO: C-12-F-36]
Explain the properties of different materials and how they can be applied to desired structures.

[SLO: C-12-F-37]
Explain the process of extracting metal (Cu) from ore and alloying them to achieve desired characteristics.

[SLO: C-12-F-38]
Explain the mechanism of catalysts and how they increase the rate of a reaction while remaining unchanged at the end.</td></tr>
</table>

			[SLO: C-12-F-39] *Explain the challenges associated with recycling and toxicity of some materials produced through materials science.* **[SLO: C-12-F-40]** *Explain the use of X-ray crystallography in analysing structures.*
Standard: (Energy) **The students should be able to:** **Compare and contrast the different energy sources based on their availability, efficiency, and environmental impact.** **Analyse the processing, and utilization of fossil fuels, including their effects on the environment and human health.** **Evaluate the advantages and disadvantages of nuclear energy, including the impact on the environment and safety concerns.** **Evaluate the potential of solar energy as a sustainable source of energy and analyse the feasibility of its implementation.** **Analyse energy consumption patterns and develop strategies to reduce energy waste and increase energy efficiency.**			
Benchmark 1: Describe the composition and properties of various fossil fuels, such as coal, oil, natural gas.		**Benchmark 1: Understand the use of different sources of energy, their properties and reusability and explain the effect of these sources on the atmosphere.**	
N/A	**[SLO: C-10-F-01]** Name fossil fuels; coal, natural gas and petroleum. **[SLO: C-10-F-02]** Name methane as main constituent of natural gas. **[SLO: C-10-F-03]** State that petroleum is a mixture of hydrocarbons, compounds containing hydrogen and carbon only.	**[SLO: C-11-F-01]** Differentiate between the petrochemical and chemicals derived from them. **[SLO: C-11-F-02]** Identify the various raw materials for the petrochemical industry. **[SLO: C-11-F-03]** Explain the process of fractional distillation and refining of	N/A

		petroleum, and identify the important fractions. ***[SLO: C-11-F-04]*** *Describe the basic building block processes in petrochemical technology, and explain the petrochemical process technology.* **[SLO: C-11-F-05]** List some major petrochemicals, and understand the importance of petrochemicals in the modern world. ***[SLO: C-11-F-06]*** *Distinguish between energy density and specific energy of different energy sources, and explain the efficiency of energy transfer.* **[SLO: C-11-F-07]** Explain the formation, properties, and uses of fossil fuels, and the importance of fossil fuels in the modern world. ***[SLO: C-11-F-08]*** *Explain the mechanism and importance of nuclear fusion and fission, and explain the importance of nuclear energy in the modern world.*	

		[SLO: C-11-F-09] *Explain the importance and mechanism of solar energy and its importance as a source of renewable energy in the modern world.* ***[SLO: C-11-F-10]*** *Explain the environmental impact of energy consumption, particularly in relation to global warming and its relation to the importance of reducing carbon footprint and moving towards sustainable energy sources.* ***[SLO: C-11-F-11]*** *Apply knowledge of energy sources and their properties to critically evaluate the advantages and disadvantages of different energy sources and make informed decisions about energy consumption.*	
Standard: (Medicine) **The students should be able to:** **Explain the concept of therapeutic index and therapeutic window, and how it affects drug efficacy and safety.** **Analyse the mechanisms of action of commonly used medications such as aspirin, penicillin, and opiates.** **Evaluate the pH regulation of the stomach and its impact on drug absorption.** **Evaluate the uses and limitations of antiviral medications.** **Analyse the trade-off between the benefits and potential side effects of different medications.**			
N/A		**Benchmark 1: Identify common drugs used in medicines and their reactivity inside the bodies of living organisms. Understand how these drugs bind to different receptors and affect their performance.**	

N/A	N/A	N/A	**[SLO: C-12-F-41]** *Recognize the concept of therapeutic index and therapeutic window in relation to drug administration.* **[SLO: C-12-F-42]** *Explain the mechanism of action and uses of aspirin and penicillin and explain their chemical structure.* **[SLO: C-12-F-43]** *Describe the mechanism of action of opiates and the concept of opioid receptors in the brain.* **[SLO: C-12-F-44]** *Describe the pH regulation of stomach and its relation to the concept of non-specific reactions and active metabolites.* **[SLO: C-12-F-45]** *Recognize the challenges in treating viral infections with drugs and the concept of antiviral medications.*

Standard: (Agriculture)
The students should be able to:
Describe the chemistry of fertilizers and its impact on plant growth and soil health.
Evaluate the benefits and risks of using pesticides in agriculture, including their effects on the environment and human health.
Analyse the impact of acid rain on soil and plant growth, and explain ways to mitigate its effects.
Describe the basic principles and applications of genetic engineering in agriculture, including the use of transgenic crops.
Assess the role of temperature in crop growth and development, and explain how changes in temperature can impact crop yields and quality.

N/A		**Benchmark 1: Identify the chemical nature of majorly used compounds in agriculture including those in fertilizers and pesticides, their positive and negative effects on crops and their reactivity based on external conditions like temperature and moisture.**	
N/A	N/A	N/A	**[SLO: C-12-F-46]** *Explain the chemical composition and function of different types of fertilizers, including their role in providing essential nutrients to crops and the impact of their application on soil health.* **[SLO: C-12-F-47]** *Identify the different types of pesticides used in agriculture and describe their mode of action, including the potential benefits and risks associated with their use.* **[SLO: C-12-F-48]** *Identify the chemical reactions that occur when acid rain falls on crops and soil and explain the effects it has on crop growth, including nutrient uptake and crop yield.* **[SLO: C-12-F-49]** *Explain the basics of genetic engineering and how it is used in agriculture, including the development of genetically modified crops and the*

<table>
<tr><td></td><td></td><td></td><td>potential benefits and risks associated with their use.

[SLO: C-12-F-50]
Explain how changes in temperature, precipitation, and extreme weather events can affect crop growth and yield, including the potential for crop failures and food shortages, as well as the potential to develop new crop varieties that are more resilient to changing climate conditions.</td></tr>
<tr><td colspan="4">Standard: (Industry)
The students should be able to:
Analyse the impact of industrial processes on the environment and human health
Evaluate the sustainability of different industrial processes based on the use of raw material and resources available in the context of Pakistan.
Describe the role of chemistry in key industrial sectors such as petrochemical, pharmaceutical and materials manufacturing.</td></tr>
<tr><td colspan="2">N/A</td><td colspan="2">Benchmark 1: Describe industrial use of chemical compounds for manufacturing, and elaborate on the reactions of various industrially used chemicals.</td></tr>
<tr><td>N/A</td><td>N/A</td><td>N/A</td><td>[SLO: C-12-F-51]
Justify the importance and significance of industrial chemistry in various industries such as manufacturing, energy, healthcare, and environmental protection.

[SLO: C-12-F-52]
Describe the chemical processes involved in industrial production,</td></tr>
</table>

			including addition and condensation polymerization, and the properties and uses of resulting materials. **[SLO: C-12-F-53]** *Identify the raw materials and resources used in industrial chemistry, including those readily available in the context of Pakistan.* **[SLO: C-12-F-54]** *Explain the applications of industrial chemistry in industries such as petrochemical, cosmetics, cement, food production and more.* **[SLO: C-12-F-55]** *Elaborate on the safety measures and precautions necessary in industrial chemical processes and facilities.*

Experimentation Skills Progression Grid

Guidance for the Reader

Guidance on Practical Work Expectations: For the sciences, there is no compulsory list of practical experiments that students have to conduct during their studies. Students *are* still expected to do extensive practical work (ideally two lessons in the lab per week), but the purpose of the lab work is to build their critical thinking, experiment designing, data collection and analysis skills. In their board exams, they will *not* be expected to reproduce a memorized practical that they have already studied in their classes. In Grade 10 board exams they are expected to conduct experiments (with apparatus and on broad topics that they have studied) as per the instructions they will be provided, and then Analyse the data collected and then critique the experimental methodology followed. A more advanced version of this practical exam is also expected to be conducted in Grade 11 board exams. In Grade 12 they are expected to be able to rigorously design experiments of their own to test provided hypotheses (on broad topics that they have studied).

Grade-Wise Progression of Skills: This progression grid is about building skills. Grades 9-10 have the same skills listed, because the idea is to reinforce them through the practical work, they will do associated with the topics they are studying. For example, in Grade 9 students may learn about exothermic reactions and conduct practical work to investigate the heat released during such a reaction. In this experiment they would learn experimental design, data collection and analysis skills. Similarly in Grade 10 they may learn about stoichiometry and then conduct titration experiments. Here again they would be building experimental design, data collection and analysis skills; just with a different topic. In contrast, Grade 11 and 12 have their skills learning outcomes separately listed. This is because in Grade 11, compared with Grade 10, the empirical research skills expected are more advanced. In Grade 12, there is a much stronger emphasis on learning how to design experiments to investigate given hypotheses, and these skills are hence listed in more detail at this level. Further guidance for educators on how to conduct lab classes keeping in mind this vision is provided in the Curriculum Guidelines.

Organization of the SLOs in the Progression Grid: Inside a grade, teachers are free to teach the content in any order of preference. Textbook publishers are also free to organize the contents of their books in any manner that they consider most effective, as long as all the SLOs in the Progression Grid and Cross-Cutting themes are covered. The SLOs inside a grade do not need to be taught in the order presented in a grade in this PG.

<table>
<tr><th>Grades 9-10</th><th>Grade 11</th><th>Grade 12</th></tr>
<tr><td colspan="3">Domain G: Lab and Practical Skills
This domain is about the skills necessary to understand how to plan and practically perform chemical experiments. These skills should be applied not only in the science laboratory, but also as critical analysis skills to understand empirical data.</td></tr>
<tr><td colspan="3">Standard: Students should be able to demonstrate knowledge of how to select and safely use techniques, apparatus and materials</td></tr>
<tr><td>Benchmark I:
Students should be able to follow provided safety instructions in general lab settings while using appropriate apparatus, equipment and methods.</td><td>Benchmark 1: Students should be able to identify and take safety measures required to conduct experiments.</td><td>Benchmark 1: Students should be able to identify hazards and design safe experiments.</td></tr>
<tr><td>[SLO: C-09-10-G-01]
Explain, with examples, the types of chemical hazards in the lab and suggest safety precautions. (Types of chemical hazards to be identified: flammable or explosive hazards, corrosive hazards, toxic hazards, reactive hazards, radiation hazards and asphyxiation hazards.)

[SLO: C-09-10-G-02]
Recognize the meaning of different chemical hazard signs in the lab and on chemicals.

[SLO: C-09-10-G-03]
Recognize the importance of personal protective equipment (PPE) by correctly identifying the types of PPE needed for different lab activities.</td><td>[SLO: C-11-G-01]
Identify the chemical hazards in the lab in context of the experiment being conducted.

[SLO: C-11-G-02]
Test that the equipment is working properly without any potential risk of injury before conducting an experiment.

[SLO: C-11-G-03]
Ensure that work space for conducting the experiment is not crowded with apparatus as to be hazardous.

[SLO: C-11-G-04]
Ensure that safe distance is kept at all times from other investigators who may be handling lab apparatus.</td><td>[SLO: C-12-G-01]
Analyse risks associated with experiments in the lab and suggest strategies to minimize hazards.

[SLO: C-12-G-02]
Develop guidelines for lab experiments that incorporate appropriate safety measures.

[SLO: C-12-G-03]
Communicate laboratory safety protocols to their peers and colleagues.

[SLO: C-12-G-04]
Analyse chemical hazards in terms of impact on the environment.</td></tr>
</table>

[SLO: C-09-10-G-04] Understand the use of fire extinguisher and emergency shower. **[SLO: C-09-10-G-05]** Show awareness of emergency procedures in the event of an emergency in the lab. **[SLO: C-09-10-G-06]** Identify apparatus from diagrams or descriptions. **[SLO: C-09-10-G-07]** Draw, complete or label diagrams of apparatus. **[SLO: C-09-10-G-08]** Explain the use of, common techniques, apparatus and materials. **[SLO: C-09-10-G-09]** Select the most appropriate apparatus or method for the task and justify the choice made. **[SLO: C-09-10-G-10]** Describe tests (qualitative, gas tests, other tests). **[SLO: C-09-10-G-11]** Describe and explain techniques used to ensure the accuracy of observations and data.	**[SLO: C-11-G-05]** Identify what potential bodily harm could occur from physical, chemical, biological and safety hazards in the context of the experiment being conducted. **[SLO: C-11-G-06]** Recognise that it is always better to ask for help from the lab instructor when unsure of how to use new apparatus. **[SLO: C-11-G-07]** Identify the proper waste disposal system for chemicals being used.	
Standard: Students should be able to plan and carry out experiments and investigations. Students should be able to make and record observations and measurements.		

Benchmark I: Students should be able to apply scientific knowledge to conduct simple experiments using appropriate apparatus.	**Benchmark I: Collect data under instructor supervision while ensuring quality of measurement and observation**	**Benchmark-1: Accurately carry out titration experiments ensuring quality of observation and tabulation of results.**
[SLO: C-09-10-G-12] Carry out the following tests under supervision: – identification of metal ions, non-metal ions and gases – chemical test for water – test-tube reactions of dilute acids, including ethanoic acid – tests for oxidising and reducing agents – melting points and boiling points – displacement reactions of metals and halogens – temperature changes during reactions. **[SLO: C-09-10-G-13]** Carry out separation and purification techniques (This may include: – filtration – crystallisation – simple distillation – chromatography – electrolysis.) **[SLO: C-09-10-G-14]** Suggest the most appropriate apparatus or technique and justify the choice made.	**[SLO: C-11-G-08]** Set up apparatus following instructions given in written or diagrammatic form. **[SLO: C-11-G-09]** Use apparatus to collect an appropriate quantity of data. **[SLO: C-11-G-10]** Make observations, including subtle differences in colour, solubility or quantity of materials. **[SLO: C-11-G-11]** Make measurements using pipettes, burettes, measuring cylinders, thermometers and other common laboratory apparatus. **[SLO: C-11-G-12]** Decide how many tests or observations to perform. **[SLO: C-11-G-13]** Identify where repeated readings or observations are appropriate.	**[SLO: C-12-G-05]** Explain the principle behind titration (Use the following types of titrations as examples: acid-alkali titration (this could be weak or strong acid and weak or strong alkali), potassium manganate (VII) titration with hydrogen peroxide, iron (II) ions, nitrite ions or ethanedioic acid or its salts and sodium thiosulphate and iodine titration) **[SLO: C-12-G-06]** Understand how to correctly set up a burette in order to carry out titrations. **[SLO: C-12-G-07]** Identify the importance of carrying out a rough titration before the experiment. **[SLO: C-12-G-08]** Carry out titrations until concordant results are obtained. **[SLO: C-12-G-09]** Identify and use appropriate indicators in the titration.

<table>
<tr>
<td rowspan="4">[SLO: C-09-10-G-15]
Describe experimental procedures.

[SLO: C-09-10-G-16]
Take readings from apparatus (analogue and digital) or from diagrams of apparatus with appropriate precision.

[SLO: C-09-10-G-17]
Take sufficient observations or measurements, including repeats where appropriate.

[SLO: C-09-10-G-18]
Record qualitative observations from chemical tests and other tests.

[SLO: C-09-10-G-19]
Record observations and measurements systematically (in a suitable table, to an appropriate degree of precision and using appropriate units).</td>
<td rowspan="4">[SLO: C-11-G-14]
Replicate readings or observations as necessary, including where an anomaly is suspected.

[SLO: C-11-G-15]
Identify where confirmatory tests are appropriate and the nature of such tests.

[SLO: C-11-G-16]
Select reagents to distinguish between given ions.

[SLO: C-11-G-17]
Carry out procedures using simple apparatus, in situations where the method may not be familiar to the students.</td>
<td>Benchmark-2: Accurately carry out rate experiments ensuring quality of observation and appropriate presentation of results.</td>
</tr>
<tr>
<td>[SLO: C-12-G-10]
Carry out rate investigation by mixing reagents and recording the time for an observation to occur.

[SLO: C-12-G-11]
Suggest experimental designs to measure the rate of a reaction.</td>
</tr>
<tr>
<td>Benchmark-3: Accurately carry out gravimetric experiments ensuring quality of observation and appropriate presentation of results.</td>
</tr>
<tr>
<td>[SLO: C-12-G-12]
Prepare a sample for gravimetric analysis.

[SLO: C-12-G-13]
Perform a gravimetric analysis using appropriate techniques (may include precipitation and filtration).

[SLO: C-12-G-14]
Ensure quality of observation by properly controlling variables, using appropriate equipment, and making accurate and precise measurements (for example heat a solid in a crucible on a pipe-clay triangle and record any mass change).</td>
</tr>
</table>

		Benchmark-4: Accurately carry out thermometric experiments ensuring quality of observation and appropriate results.
		[SLO: C-12-G-15] Prepare and set up a sample for a thermometric analysis, including appropriate mixing and stirring techniques. **[SLO: C-12-G-16]** Accurately use and take readings from thermometers to determine heat of reaction.
		Benchmark-5: Accurately carry out gas volume experiments ensuring quality of observation and tabulation of results.
		[SLO: C-12-G-17] Set up and prepare a gas volume experiment, including appropriate apparatus selection and assembly techniques. **[SLO: C-12-G-18]** Use a gas syringe, gas burette, or other appropriate equipment to measure gas volume.
		Benchmark-6: Accurately carry out qualitative analysis tests while taking necessary safety precautions and demonstrate knowledge and skill required for the respective experiment.

		[SLO: C-12-G-19] Understand the appropriate methods to be used when carrying out qualitative analysis tests: • to treat all unknown materials with caution • to use an appropriate quantity of the material under test • to add only the specified amount • to work safely, e.g. to use a test-tube holder when heating a solid in a hard-glass test-tube • to record all observations, even when there is 'no change' or 'remains a colourless solution' • to use excess alkali where a precipitate is produced on addition of $NaOH_{(aq)}$ or $NH_{3(aq)}$ to determine its solubility • to identify a gas whose formation is shown by effervescence. **[SLO: C-12-G-20]** Perform the following organic analysis tests and interpret the positive test result to identify the functional group present:

		• the production of an orange/red precipitate with Fehling's reagent to indicate the presence of the aldehyde functional group • the production of a silver mirror/black precipitate with Tollens' reagent to indicate the presence of the aldehyde functional group • the production of a yellow precipitate with alkaline aqueous iodine to indicate the presence of the CH_3CO^- or $CH_3CH(OH)^-$ group • the change in colour of acidified potassium manganate(VII) from purple to colourless to indicate the presence of a compound that can be oxidised.
	Benchmark II: Accurately carry out qualitative analysis tests while taking necessary safety precautions and demonstrate knowledge and skill required for the respective experiment.	
N/A	**Acid–base titrations** **[SLO: C-11-G-18]** Describe an acid–base titration to include the use of a: a. Burette	

	b. Pipette c. suitable indicator **[SLO: C-11-G-19]** Describe how to identify the end-point of a titration using an indicator **Identification of ions and gases** **[SLO: C-11-G-20]** Describe tests to identify the anions: a. carbonate by reaction with dilute acid and then testing for carbon dioxide gas b. chloride, bromide and iodide, by acidifying with dilute nitric acid then adding aqueous silver nitrate c. nitrate by reduction with aluminium foil and aqueous sodium hydroxide and then testing for ammonia gas d. sulphate by acidifying with dilute nitric acid then adding aqueous barium nitrate e. sulphite by reaction with acidified aqueous potassium manganate (VII).	

	[SLO: C-11-G-21] Describe tests using aqueous sodium hydroxide and aqueous ammonia to identify the aqueous cations: a. aluminium, Al^{3+} b. ammonium, NH_4^{+1} c. calcium, Ca^{2+} d. chromium(III), Cr^{3+} e. copper(II), Cu^{2+} f. iron(II), Fe^{2+} g. iron(III), Fe^{3+} h. zinc, Zn^{2+}	
Standard **Students should be able to:** **Present data present data in a tabulated or graphical form.** **Analyse and interpret data in a scientific way.**		
Benchmark I: Students should be able to present data in a tabulated or graphical form.	**Benchmark I: Students should be able to present data in a meaningful way and be able to interpret it.**	**Benchmark I: Students should be able to analyse the presented data.**
[SLO: C-09-10-G-20] Record the results of an experiment (Acid-base titration).	**[SLO: C-11-G-22]** Present numerical data, values or observations in a single table of results with headings and units that conform to accepted scientific conventions.	**[SLO: C-12-G-21]** Identify the best way to present collected and transformed data based on the experiment being performed.

[SLO: C-09-10-G-21] Process the results of an experiment to form a conclusion or to evaluate a prediction. **[SLO: C-09-10-G-22]** Predict the expected results of the experiment. **[SLO: C-09-10-G-23]** Interpret and evaluate experimental observations and data. **[SLO: C-09-10-G-24]** Process data, including for use in further calculations or for graph plotting. **[SLO: C-09-10-G-25]** Present data graphically, including the use of best-fit lines where appropriate. **[SLO: C-09-10-G-26]** Analyse and interpret observations and data, including data presented graphically. **[SLO: C-09-10-G-27]** Form conclusions justified by reference to observations and data and with appropriate explanation. **[SLO: C-09-10-G-28]** Evaluate the quality of observations and data, identifying any anomalous results.	**[SLO: C-11-G-23]** Record raw readings of a quantity to the same degree of precision and observations to the same level of detail. **[SLO: C-11-G-24]** Show working in calculations and key steps in reasoning. **[SLO: C-11-G-25]** Use the correct number of significant figures for calculated quantities. **[SLO: C-11-G-26]** Draw an appropriate table in advance of taking readings or making observations and record all data in the table. **[SLO: C-11-G-27]** Use the appropriate presentation method to produce a clear presentation of the data. **[SLO: C-11-G-28]** Plot appropriate variables on appropriate, clearly labelled x- and y-axes with carefully chosen scales. **[SLO: C-11-G-29]** Draw straight lines or smooth curves of best fit to show the trend of a graph.	**[SLO: C-12-G-22]** Interpret the collected data to draw conclusions based on the experiment being performed.

	[SLO: C-11-G-30] Describe the patterns and trends shown by data in tables and graphs. **[SLO: C-11-G-31]** Describe and summarize the key points of a set of observations. **[SLO: C-11-G-32]** Determine the gradient of a straight-line graph and extrapolate the line of a graph. **[SLO: C-11-G-33]** Draw conclusions from an experiment, giving an outline description of the main features of the data, considering whether experimental data support a given hypothesis, and making further predictions. **[SLO: C-11-G-34]** Draw conclusions from interpretations of observations, data and calculated values. **[SLO: C-11-G-35]** Make scientific explanations of data, observations and conclusions that they have described.	
Standard: Students should be able to evaluate methods and suggest possible improvements and identify errors.		
Benchmark I: Students should be able to suggest improvements in the experimental design	**Benchmark I: Students should be able to evaluate the method used and suggest**	**N/A**

	improvements based on validity, reliability and safety.	
[SLO: C-09-10-G-29] Identify potential sources of error in an experimental design. **[SLO: C-09-10-G-30]** Assess the limitations of an experimental design. **[SLO: C-09-10-G-31]** Evaluate experimental arrangements, methods and techniques, including the control of variables. **[SLO: C-09-10-G-32]** Suggest possible improvements to the apparatus, experimental arrangements, methods or techniques.	**[SLO: C-11-G-36]** Analyse intrinsic errors in measuring device. **[SLO: C-11-G-37]** Describe systematic errors. **[SLO: C-11-G-38]** Identify the most significant sources of error in an experiment. **[SLO: C-11-G-39]** State the uncertainty in a quantitative measurement and express such uncertainty in a measurement as an actual or percentage error. **[SLO: C-11-G-40]** Analyse the limitations of the experimental design and propose appropriate modifications that will improve the accuracy of the experiment. **[SLO: C-11-G-41]** Evaluate the validity of the methods used. **[SLO: C-11-G-42]** Explain improvements or extensions to the methods used.	

	[SLO: C-11-G-43] Apply scientific language effectively. **[SLO: C-11-G-44]** Document the work of others and sources of information used. **[SLO: C-11-G-45]** suggest ways in which to extend the investigation to answer a new question. **[SLO: C-11-G-46]** Suggest alternate chemicals in experimental design, which contribute to green chemistry.	

Pedagogical Principles

The purpose of this curriculum is to both train students in theoretical and experimental skills, while releasing their scientific imagination and instilling in them scientific critical consciousness. Every class has a different dynamic, and different cultures have different norms about the relationship between teachers and students. This curriculum celebrates this diversity, and makes an effort to make it a chief strength. Teachers know their contexts best, and this curriculum does not try to enforce a rigid teaching model. However, there are four principles that are great guides for success:

Dialogue: In order to inculcate scientific critical consciousness, earnest, respectful dialogue in a warm environment is important. Teachers should make every effort to ensure that students have a voice, and are able to express their views on critical issues. Such an environment is key to encouraging earnest self-reflection, and nurturing receptivity to different points of view. Teachers should present ideas in this curriculum as being open to debate and the understanding that our views about science and its impact in the world are never simply 'neutral', but are influenced by the narratives we are most familiar with.

Inclusive Classrooms: Classes should be conducive to the learning of all students, regardless of any disabilities, to the maximum extent possible. For all students, information should be presented in more than one form (i.e. through a combination of mediums such as multimedia, lecturing, lab demonstrations etc.), and they should be allowed to demonstrate their understanding in more than one way (i.e. not just through written tests, but also through presentations, project work, class conversation etc.).

Build on Existing Knowledge: Each student has their own prior experiences and existing knowledge base, which should be incorporated into teaching by building upon them. This will not only help with learning, but also help students from marginalised identities feel that science is something they can relate to and fully participate and excel in.

Hands-on Learning: Scientific concepts should, to the maximum possible given resource constraints, be taught through structured hands-on experience and experiments with the phenomena being studied. Modelling socio-scientific issues through activities such as role-play and presentations in front of community leaders are also very effective in helping inculcate scientific critical consciousness, and in motivating students to take social action.

Classroom Assessment Guidance

Teachers are encouraged to use a variety of methods to assess student learning. These should include both formative (ongoing; in every class) and summative (at the end of each topic or a group of topics) assessments. It is important to emphasize here that, as this curriculum values inclusive education, that students should be given opportunities to demonstrate their understanding through different mediums as well (e.g. through a combination of writing, speaking, artistic expression, project work etc.).

Formative Assessment: In each class, teachers should gauge how students are doing through their participation in class and their engagement and performance with class work. In order to assess their developing critical consciousness skills, in addition to a combination of other mediums, it might be good to have students keep a reflection journal, which they spend 5 minutes at the end of class writing in. The learning experience bank can all be used as means of formative assessment, since they allow for many quality opportunities to observe students as they gauge with the materials, and to even create work portfolio.

Summative Assessment: Teachers should also regularly formally assess students after covering an appropriate number of topics. Assessment does not have to be a written test, rather assessment should ideally be an educational experience in and of itself as well. Performance tasks are assessments that involve students carrying out tasks that mirror how they would be expected to use what they have learned in the real world. For example, the integrative project is a performance task, as it requires students to convey an argument about a socio-scientific issue to an actual external audience. An activity that they are likely to repeat in future in one job or another.

Formative Assessment Plan

The learning activities given in the Curriculum Guide can be used as formative assessments to gather evidence of student learning and give students the opportunity to measure their own growth and reflect and articulate key ideas. Here is a sample formative assessment plan that can be adapted by teachers, consisting of multiple assessment strategies. Teachers can pick a few from these for each unit that they cover.

Pre-assessment: Before starting a new topic, administer a pre-assessment to gauge students' current understanding and identify areas where they may need extra support. This can take the form of a diagnostic quiz, exit ticket, or quick poll.

Classroom Discussions: Encourage students to participate in regular class discussions, either in small groups or as a whole class. Ask questions, listen to students' responses, and provide feedback on their understanding. These discussions provide an opportunity to check for understanding, encourage critical thinking, and identify areas where students need further clarification.

Quizzes: Give quizzes or short assessments on the material covered in class. These can be conducted either once or twice within a unit to assess individual student's understanding of the mathematical ideas across lessons. These quizzes should consist of different types of questions that assess different levels of cognitive demand to push students to think, create, connect, and analyse. A rubric can be provided to students with the quizzes and can be used by the teacher to assess these quizzes. The scores will help inform what misconceptions the students have, or what area they lack a proper understanding of, so that the teacher can revise or revisit them during the unit.

Group project: Occasionally, at the end of a unit, students can be given group projects that require them to apply their knowledge and work together to solve problems. For example, one project might consist of presenting and comparing the three ways to solve systems of equations.

Provide the students a rubric before assigning each project and make sure they understand it. Halfway through the project, ensure that the students use the rubric to check their progress. Then use the rubric to score the projects after they have completed them, and provide them with the scores they earned based on the rubric. Offer them opportunities to earn more points by correcting any mistakes.

Performance Assessment: During the lesson, give students open-ended and authentic tasks to demonstrate their mathematical understanding. These tasks will be either individual assessments or group tasks that will be cognitively demanding but low floor and high ceiling problems that will allow students to apply the knowledge they learnt during the lesson and further their understanding. Do not collect this work but instead monitor what the students are doing. Students can be given a rubric to help them self-assess or peer-assess these tasks.

Classroom observations: While the students are solving tasks and having discussions within groups, roam around the class observing their written work and listening to their conversations. Use a monitoring sheet with student's names on them to record which student is using which strategy and keep a check of the different ideas that are being formulated. Help direct the students' thinking by asking them questions that will push them to critically think. The Notecan then be used to sequence ideas and pick particular students to present strategies to discuss in a whole-class discussion to help all students connect between different ideas.

Science Journals: Encourage students to reflect on their learning and set goals for improvement by writing them in their journals. Have students answer an open-ended question in a journal (like what did you learn today? Or what questions would you like me to answer tomorrow?) and select a few students to share. Reflection helps students see their progress, identify areas for improvement, and take ownership of their learning.

Gallery walk: Have students respond to questions about the classroom and respond to the ideas of others. Have students work on different tasks in groups and then create a visual display that summarizes their work and understanding of the topic. These displays can be placed around the classroom and have students walk around and interact with each display. They can ask questions, make observations, and give feedback to their peers using post-it Note. After the gallery walk, lead a discussion to debrief the experience. Students reflect on what they learned from their peers, what they found most helpful, and what areas they still need to work on. Instead of student, work displays, myths about a certain topic can also be placed around the classrooms and students asked to walk around and respond to the prompts as a group.

Jigsaw: Have students work in groups to solve a mathematics problem or concept. Each group is responsible for a specific part of the problem or concept, and then mix students up and have them share their findings and ideas to their new group. This process allows students to practice their problem-solving and critical thinking skills, as well as their ability to collaborate and communicate effectively with their peers. The teacher can observe and listen to the students during the activity, and use the information gathered to assess their understanding of the topic being covered and make any necessary adjustments to their instruction.

Exit Tickets: At the end of most lessons, have students individually complete and hand in an exit ticket. The exit ticket will consist of 1-3 questions ranging from closed questions to assess student's procedural fluency, open-ended questions to assess student's conceptual understanding, questions similar to the tasks done in class to allow students to apply the knowledge they learnt and questions to have them inform the teacher about any confusions/questions that they might still have. These exit tickets will be used to inform the teacher about individual student's current understandings and help him/her tailor the content of the next lesson to suit the students' needs.

Homework: Occasionally, give students homework to allow them to practice what they learnt during class. The homework questions will also be tasks that allow a deeper level of thinking instead of closed questions that have only one accurate answer. Students can choose a homework friend to ask for help with homework assignments and they will be encouraged to identify concepts they are struggling with. Homework might only be given a couple of times in a unit to not overburden students, but it will help students self-assess themselves and revisit the concepts discussed in class. At the beginning of the class following a class where a HW was assigned, have a brief discussion that draws connections across HW problems, talks about the challenges students faced, or asks students the justification behind their solving techniques.

Sample Activities

Note:

1. Different National and International Curricula were consulted while developing the NCP for this subject.
2. The mention of all websites and links, from which content for activities was adapted, will be referenced properly and cited after finalisation of the Curriculum Guidelines.
3. There are certain links given here for videos, websites and documents. All links were checked for authenticity on 7thApril, 2023, it has been established that they are valid. Since these are third party links, NCC will not be responsible if they are changed or do not work in the future. NCC is working on creating a repository of information which will be sustainable and accessible, all information from links will be downloaded and made available in due time to avoid this issue in the future.

For the reader of this document

Domain

<table>
<tr><td colspan="2">Standard:
Here the relevant parts of the appropriate standard from the Chemistry Progression Grid will be listed, including the relevant benchmarks under that standard</td></tr>
<tr><td colspan="2">Student Learning Outcomes:
Here only the relevant SLOs from the Progression Grid will be outlined</td></tr>
<tr><td>Knowledge:
Here the main important concepts that students should become familiar with are summarised</td><td>Skills:
Here the main important applications of concepts (whether experimental or in the form of solving analytical problems) that students should become skilled with are summarised</td></tr>
<tr><td colspan="2">Perspectives:
These are some (not exhaustive) suggested (not compulsory) topics/prompts for discussion in classes that help students think more critically and in an interdisciplinary fashion about the chemistry concepts they are learning. Perspectives will not be assessed in any exams; they are only intended to help enrich learning for students.</td></tr>
<tr><td colspan="2">Activities
Here the details of suggested activities for the chosen topic are elaborated on. These activities are not compulsory and they are not meant to be followed rigidly step by step. They are only intended to help inspire teachers to develop engaging lessons that help students unpack the concepts with hands-on learning.</td></tr>
</table>

Suggested Guidelines in line with Learning Outcomes

GRADE-IX

Domain A: Nature of Science in Chemistry

Standard:
Students will demonstrate an understanding, skill and attitude to deal in the areas of chemistry as an introduction.

Student Learning Outcomes:

- Explain with examples that chemistry has many sub-fields and interdisciplinary fields.
- Formulate examples of essential questions that are important for the branches of Chemistry.

Knowledge:	**Skills:**
Students can identify, ▪ different branches of chemistry. ▪ the divisions allow students to choose particular branch of chemistry.	Students learn the uses of, ▪ branches of chemistry. ▪ the career scopes of the respective branches.

Perspectives:

- **Industrial Applications:** Explore how different branches of chemistry, such as organic chemistry, inorganic chemistry, and physical chemistry, are applied in various industries, such as pharmaceuticals, materials science, and energy. For example, in Pakistan, the pharmaceutical industry heavily relies on organic chemistry to synthesize new drugs and the energy sector relies on inorganic chemistry to improve fuel efficiency.

- **Historical Development:** Trace the historical development of each branch of chemistry. How it evolved over time. For instance, physical chemistry originated in the late 19th century and was heavily influenced by the development of thermodynamics, whereas biochemistry only became a separate branch of chemistry in the early 20^{th} century with the discovery of DNA.

- **Interdisciplinary Nature:** Emphasise the interdisciplinary nature of chemistry. How the branches of chemistry overlap and interact with each other and with other sciences such as biology, physics, and engineering. For example, physical chemistry provides the foundation for understanding the behaviour of biological molecules, and biochemistry builds upon the principles of organic chemistry.

- **The Importance of Units in Scientific Measurements**: Understanding the importance of having a standardised system of units for chemical measurements is crucial for accurate communication in the scientific community. In the context of Pakistan, it is important for students to understand the use of units in industrial processes, such as the production of fertiliser, textiles, and pharmaceuticals, and the role that accurate measurements play in the quality control of these products.

- **The Historical Development of Units:** Throughout history, different civilizations have used different systems of units for measurements, such as the Egyptian cubit or the Roman foot. Understanding the evolution of these systems and the need for a standardised system highlights the role of science in shaping our understanding of the world and the importance of accurate measurements in scientific advancement.

- **The Role of Scientific Notation in Chemical Calculations:** Scientific notation is a useful tool for expressing very large or very small numbers in a concise and readable manner. In the context of chemistry, this can be used to represent the amount of a chemical substance, the concentration of a solution, or the energy of a chemical reaction. Understanding the importance of scientific notation helps students to accurately perform calculations and interpret data in chemistry experiments.

Activity#1

Materials

- o Writing board
- o Instruction sheet
- o Chart papers and coloured markers.
- o Pictures related to branches of chemistry.

Methodology

Introduction: Teacher will introduce the classification and branches of chemistry to the students with the help of activity:

Teachers will bring different objects of different colours like orange, red, black and green. Firstly, teacher will ask students to separate all the things according to their colour and then students will be told that the green colour things are related to the biochemistry, red colour indicates inorganic chemistry.

Instructions: Teacher will give instructions about the activity to the students.

- Students will be divided into groups of 4 or 6, each group will have pictures of related branch of chemistry for example in Industrial chemistry the pictures that clarify the formation of products.
- Teacher will mount a chart paper on the board, which will have the same-coloured boxes on it, and the students will be asked to paste pictures in their relevant colour boxes (Each branch will have a specific colour). It related with Biology like Green plants, Greenhouse effect.

- Then students will name the branches and by using their knowledge, they will name the branches with the help of the teacher.
- Students will define branches with the help of pictures.

Assessment of objectives: (specify tools of assessment)

- **Assessment based on following Rubrics:**

Rubrics:
1. Defining the branches.
2. Clarity of concept (accurate positioning of the objects in the boxes).
3. Visibility of chart paper content (Presentation)

Domain B: Physical Chemistry

Standard:
Describe the structure of atoms, including the nucleus and electron shells.

Student Learning Outcomes:
- State the relative charges and relative masses of a subatomic particles (an electron, proton and neutron)

Knowledge:	**Skills:**
Students will learn and understand, ▪ structure of atom and get information about characteristic properties i.e. charge, atomic mass, relative atomic mass of subatomic particles.	Students capable to, ▪ tell properties of subatomic particles.

Perspectives:
- Concept of mole
- Avogadro numbers
- Mole ratio
- Mass - mole conversion
- Mole - number (particle) conversion

Activity # 2

Materials
- Writing board,
- Instruction sheet,
- Chickpeas, white beans and peas/ modelling kit can be used,

- Balance.

Methodology
Introduction: Teacher will introduce the term relative mass to the students.

Instructions: Teacher will give instructions about the activity to the students.
Students will be divided into pairs; each pair will have related materials for the activity.

Activity:
1. Each pair will count 12 grains of chickpeas and record their mass. They will repeat the same process with 12 white beans and 12 peas by using a balance and record the masses.
2. Repeat step 1 twice again with a different 12 of each of the three.
3. Average the masses for each of the three from steps one and two. In this way, you will be getting an average mass of 6 of each of the three.
4. Determine the relative mass in g of peas, white beans and chickpeas using peas as the standard. To do this, divide each of the average masses by the lightest (the peas) which of course gives the lightest a relative mass value of one.
5. Mass out one relative mass in g of each substance (use whole pieces) and count the number of particles in each sample. Record these numbers. Put the sample on the balance and add enough whole beans (or grains) to achieve the desired weight.
6. Determine the actual mass in g of one grain of rice, one red bean, and one black bean from the data gathered in the previous steps.

Discussion: They will share their understanding with the class by discussion. For example What are the strengths and limitations of modelling chemical elements as grains of rice? How does this experiment act as an analogy for helping us appreciate the concept of relative mass?

Conclusion: Teacher will relate relative masses with the atoms of elements.

Teacher's Note: Teacher can ask following questions in the next class.
1. If you knew the relative masses of the chickpeas, white beans and peas but the actual mass of only one of them, could you determine the actual masses of the other two? Show how.
2. What concept (or numbers) in chemistry do these "relative masses" represent (step 4 above)? We used peas for the standard in this activity; what is the chosen standard in chemistry?

Skills: Thinking skills, inquirers, Time management skill, Analytical skills.

Assessment of objectives: (specify tools of assessment)
- **Assessment based on following Rubric**

- **Rubrics:**
  1. Calculating the relative masses of different elements
  2. Clarity of concept
  3. Discussion based on relative mass

Domain: Domain B: Physical Chemistry

Standard: Apply the principles of thermochemistry to calculate heat transfer and changes in enthalpy.

Student Learning Outcomes:
- Explain that enthalpy change is sum of energies absorbed and released in bond breaking and bond forming
- Calculate enthalpy change of a reaction given bond energy values

Knowledge:	**Skills:**
Students will get idea of, ▪ energetics of a reaction ▪ tell about the experimental parameter use to describe the term.	Students, ▪ can define parameter enthalpy ▪ will be able to calculate it.

Perspectives:
- Introduction to thermodynamics
- Terms in thermodynamic i.e. internal energy, Enthalpy
- Explain that enthalpy change is sum of energies absorbed and released in bond breaking and bond forming
- Calculate enthalpy change of a reaction given bond energy values

Activity # 3
Materials
- Writing board
- Instruction sheet
- Play dough balls and toothpicks
- Bond enthalpy sheet
- Chart papers and coloured markers.

Methodology:
Introduction: Teacher will introduce the bond enthalpies to the students.

Instructions:
- Teacher will give instructions about the activity to the students.
- Students will be divided into groups of 4-6; each group will have related materials for the activity.

- They will make model of their respective equations (each group will be given different chemical equations) by using play dough beads and toothpicks for reactants and products, they break and make the bonds for products.
- They will record the relative bond enthalpies of the reactants and products from the provided data sheet.

Activity: Students will find out number of bonds in reactants and products and write the bond enthalpies in the provided worksheet

Conclusion: After that, they will calculate the energies in reactants and products and finally find out the overall change after calculations.
They will write the given equation and enthalpy calculations on their chart papers for presentation.

Group presentation: They will display their chart papers in the class for presentation.

Assessment of objectives: (specify tools of assessment)

- **Assessment based on following Rubric**

- **Rubrics:**
  1. Data tables (accurate calculation of data and tabulation)
  2. Clarity of concept (Finding of accurate bond enthalpy)
  3. Visibility of chart paper content (Presentation)
  4. Conclusion (based on calculations)

Domain B: Physical Chemistry

Standard: (Chemical Bonding) Students should be able to:
Explain the concept of chemical bonding and describe the different types of bonds, including ionic, covalent, and metallic bonds.
Discuss the factors that affect bond strength, including bond length and bond energy.

Student Learning Outcomes:

- Explain the properties of compounds in terms of bonding and structure
- Interpret the strength of forces of attraction and their impact on melting and boiling points of ionic and covalent compounds.

Knowledge:	**Skills:**
Students will get knowledge about,	Students can identify, ▪ the types of bonding,

▪ the properties of different compounds based on the types of compounds (ionic compounds, covalent compounds and giant covalent compounds ▪ types of bonding, properties of ionic and covalent compound ▪ compare the properties of different compounds ▪ identify the compounds.	▪ why boiling point and melting points of compounds are high or low?

Perspectives:

- Why atoms form bond?
- Inert gas configuration, complete shell configuration
- Concept of ionic bond
- Concept of covalent bond

Activity#4

Materials

- Writing board
- Instruction sheet
- Table salt, sugar, giant covalent compounds like sand.
- China dish, spirit lamp, spatula.

Methodology

Introduction:

Teacher will introduce the properties of different compounds based on the types of compounds (ionic compounds, covalent compounds and giant covalent compounds should be introduced before this topic) to the students.

Instructions: Teacher will give instructions about the activity to the students.
Students will be divided into 3 groups; each group will have different compounds in terms of their bonding for the activity.

Activity:

- Each group will be provided with all three compounds and then the teacher will ask them to heat them on a spirit lamp in a china dish until it melts.
- Students will observe the time taken by the compounds to melt.
- They will record the time and then they will discuss their properties (melting point) in terms of bonding and structure.

- In the end, they will be given homework to find some more compounds and their properties based on bonding.

Discussion: They will share their understanding with the class by discussion.

Conclusion: Teachers will relate bonding with the properties and explain to the students.

Teacher's Note: Teacher will have to plan another activity by using some other compounds to explain the boiling points, solubility etc. to the students.

Assessment of objectives: (specify tools of assessment)
Assessment based on following Rubric

Rubrics:

1. Why atoms form bond?
2. How ions are formed?
3. What is cation and anion?
4. Differentiate between ionic bond and covalent bond.

Teaching learning Evaluation:

Domain B: Physical Chemistry

Standard: Constructing chemical equations and understanding the balancing of these chemical equations

Student Learning Outcomes:

- Deduce the formula of a molecular substance from the given structure of molecule.
- Deduce the formula and name of binary ionic compounds from ions given relevant information

Knowledge:	**Skills:**
Students can, ▪ get idea of valency ▪ write chemical formula and chemical equation.	Students can write, ▪ chemical formula and chemical equation ▪ name of compounds.

Perspectives:

- valency of an atom
- group number and valency of an atom
- concept of chemical formula

– molecular & ionic formula

Activity # 5

Materials

- Writing board
- Instruction sheet
- Modelling kits,
- Worksheets with different structural formulas like, MgO, CH_4, C_2H_6, C_3H_6, C_6H_6 etc.

Methodology

Introduction: Teacher will display the chart paper with different molecular formulas on the wall and ask the students to make possible structures out of these formulas.

Activity:

Firstly, students will use the modelling kit or beads and toothpicks to make different arrangements of the molecules and then they share it with the teacher and find out all possible structural arrangements of the molecular formulas.

Secondly, students (randomly asked by the teacher) will draw the structures of different molecules on the board.

Finally, the teacher will explain some more complex structures and molecular arrangements of some other compounds and homework will be given to find some other molecules and their possible structures.

Teacher's Note: Teachers will have to plan another activity by using some other compounds to explain the structural formulas of different compounds to the students.

Skills: Communication skills, Time management skills.

Assessment of objectives: (specify tools of assessment)

- **Assessment based on following Rubric**

- **Rubrics:**

1. How the valency of an atom is characteristic property?
2. How the group number and valency of an atom are related?
3. Write chemical formula of compounds of group- IA and group- VIIA elements.
4. Differentiate between Molecular & ionic formula

Teaching learning Evaluation:

Domain: Domain B: Physical Chemistry

Standard: (Electrochemistry) Students should be able to:
Describe the principles of electrochemistry, including the movement of electrons in terms of oxidation and reduction in a chemical reaction.
Explain the concept of oxidation and reduction, including the role of electrons in these processes.

Student Learning Outcomes:

- Identify the reducing and oxidizing agents in a redox reaction in terms of electrons.
- Explain that the sum of the oxidation numbers in a neutral compound is zero.
- Define redox reactions as simultaneous oxidation and reduction in terms of oxygen, hydrogen, electrons and changes in oxidation state.

Knowledge:	Skills:
Students will get knowledge about, ▪ the fact that the sum of the oxidation numbers in a neutral compound is zero ▪ redox reactions as simultaneous oxidation and reduction in terms of oxygen, hydrogen, electrons and changes in oxidation state	Students will be able to, ▪ explain that the sum of the oxidation numbers in a neutral compound is zero ▪ define redox reactions as simultaneous oxidation and reduction in terms of oxygen, hydrogen, electrons and changes in oxidation state.

Perspectives:

- Definition of electrochemistry
- Insulator & conductors
- Electrochemical reaction
- Oxidation number
- Describe the principles of electrochemistry, including the movement of electrons in terms of oxidation and reduction in a chemical reaction.
- Explain the concept of oxidation and reduction, including the role of electrons in these processes.

Activity # 6

Materials

- Writing board
- Instruction sheet
- Ping-pong balls and table tennis rackets

Methodology

Introduction:
Teacher will introduce the term oxidation and reduction in terms of loss and gain of electrons and oxygen to the students.

Instructions: Teacher will give instructions about the activity to the students.
Students will be divided into pairs; each pair will be provided with the ping-pong ball and rackets.

Activity:

- Teacher will explain that the balls represent the electrons and rackets work like atoms
- Each pair will play with the ball and rackets. The teacher will explain that the transfer of electron from one racket to the other is actually like an electron transferring from one atom to the other the racket, which will lose the ball, is acting like a reducing agent and the racket getting the ball is reduced and acting as an oxidising agent. In other words, Reduction is gain of electron and when ball is move against racket, it is loss and the ball act as reducing agent with respect to 2^{nd} racket.
- Teacher will write a few redox reactions on the board and the students will identify the oxidizing and reducing agents.

Discussion: Students will share their understanding with the class by answering the questions written on the board.

Conclusion: Teacher will explain the oxidizing and reducing agents in terms of the OIL-RIG term. (OIL oxidation is loss and RIG reduction is gain of electrons)

Teacher's Note: Teacher will have to plan another activity for the next lesson in which the concept of oxidation and reduction given in terms of addition and loss of oxygen, addition and loss of hydrogen to explain the redox reactions.

Skills: Thinking skills, communication skills.

Assessment of objectives: (specify tools of assessment)

- **Assessment based on following Rubric**

- **Rubrics:**

1. Define oxidation and reduction.
2. Define oxidizing and reducing agent.
3. Give thename of elements acting as oxidizing and reducing agent.

Teaching learning Evaluation:

Domain B: Physical Chemistry

Standard:(Energetics) Students should be able to:
Describe the nature of energy, including energy profile diagrams.
Explain the relationship between energy and chemical reactions, including exothermic and endothermic reactions.
Apply the principles of thermochemistry to calculate heat transfer and changes in enthalpy.

Student Learning Outcomes:

- Draw, label and interpret reaction pathways for exothermic and endothermic reactions.
- Draw, label and interpret reaction pathway diagram for exothermic and endothermic reaction which includes enthalpy change, activation energy (un-catalysed and catalysed), reactants and products
- Explain that activation energy depends on reaction pathway which can be changed using catalysts or enzyme (detailed pathways not required)
- Recognize that bond breaking is endothermic and bond making is exothermic processes.
- Explain that enthalpy change is sum of energies absorbed and released in bond breaking and bond forming

Knowledge:	**Skills:**
Students get knowledge of, ▪ heat of reaction ▪ exothermic & endothermic reaction ▪ activation energy	Students can identify, ▪ endothermic & exothermic reaction ▪ define activation energy ▪ heat of reaction

Standard:
Concept of energy

- Describe the nature of energy
- Exothermic and endothermic reactions.
- Energy profile diagrams, exothermic and endothermic reactions.
- Calculate heat transfer and changes in enthalpy.

Activity # 7

Materials

- Writing board
- Instruction sheet
- Chart papers and coloured markers.

Methodology

Introduction: Teacher will introduce the term '**exo**' and '**endo**' to the students.
Exothermic and endothermic changes to the students.

Activity:

- Teacher will display a chart paper with two pictures, one of melting ice and the other one of fire.
- Teacher will ask questions about the pictures like
- From which process you will feel heat and which will give a cooling effect.
- Students will give correct answers that fire will give out heat and ice will be felt colder.
- Teacher will draw energy profile diagrams of both the processes and explain it to the students.For example,in melting ice, it take energy from surrounding and absorbs energy.
- Students will be provided with a worksheet in which they will have to fill at least one exothermic and one endothermic change from their daily life into two columns. (like photosynthesis is endothermic, condensation is exothermic). Then they will draw energy profile diagrams for both the processes on their worksheets.

Wrap up by the students.

Skills: Thinking and Communication skills

Assessment of objectives: (specify tools of assessment)

- **Assessment based on following Rubric**

- **Rubrics:**

1. Define exothermic & endothermic reaction.
2. Give example of exothermic & endothermic reaction.
3. Define activation energy.

Domain C: Inorganic Chemistry

Standard:(Periodic Table and Periodicity) Students should be able to:
Describe the organization of the periodic table, including the arrangement of elements by atomic number, electronic configuration, and chemical properties.
Explain the concept of periodicity, including the repeating patterns of physical and chemical properties of elements.
Discuss the trends in the periodic table, including ionization energy, electron affinity, and electronegativity.

Apply the principles of periodicity to predict the properties and reactivity of elements. Describe the role of the periodic table in the study of chemistry and its importance in the prediction of chemical behaviour.

Student Learning Outcomes:

- Understand the relationships between group number and ion.
- Explain the relationship between group number and the charge of ions formed from elements in the group in terms of their outermost shells.
- Explain similarities in the chemical properties of elements in the same group in terms of their electronic configuration.
- Predict the characteristic properties of an element in a given group by using knowledge of chemical periodicity.
- Deduce the nature, possible position in the Periodic Table and the identity of unknown elements from given information about their physical and chemical properties.

Knowledge:	Skills:
Students get information about, • valency • relate group number and valency • elements in group have samechemical properties • predict the position of elements in periodic table.	Students can identify, • valency • relate group number and valency • elements in group have samechemical properties • tell the position of elements in periodic table.

Perspectives:

- Classification and arrangement of elements by atomic number, electronic configuration, and chemical properties.
- Concept of periodicity, including the repeating patterns of physical and chemical properties of elements.
- The trends in the periodic table, including ionization energy, electron affinity, and electronegativity.
- Apply the principles of periodicity to predict the properties and reactivity of elements.
- Describe the role of the periodic table in the study of chemistry and its importance in the prediction of chemical behaviour.

Activity # 8

Materials

- Writing board
- Instruction sheet
- Periodic table.
- Cards with the symbols of elements and their ions at least one from each group.

Methodology
Introduction: Teacher will display periodic table in the class and explain the arrangement of elements in the periodic table. Arrangement of elements in the groups will be explained.

Activity:

- Teacher will distribute cards, which have symbols of the first 20 elements to the students.
- Teacher will make 8 columns on the board for the activity
- Students will tell the ion formation of the element/s assigned to them on their cards according to the position of the respective element in the periodic table.
- They will write the ion of their respective element on their cards.
- They will show the movement of electron in the elements.
- They will display their cards on the black/white board according to the group to show their ion formation in the periodic table.
- They will tell that why ions will have + ive or – ive signs on the ions.

Wrap up by the students.

Skills: Critical thinking and communication skills

Assessment of objectives: (specify tools of assessment)

- **Assessment based on following Rubric**

- **Rubrics:**

1. Give valency of elements of Group –IA, IIA, IIIA, VIIA of periodic table.
2. What is Relationship between group number and valency?
3. Why chemical properties of elements in-group are same?
4. Predict the position of elements in periodic table with 8 electrons in outermost shell.

Teaching learning Evaluation:

Domain C: Inorganic Chemistry

Standard:
Describe the properties of elements in different groups, including the alkali metals, alkaline earth metals, halogens, and noble gases.

Student Learning Outcomes:

- Analyse the relative thermal stabilities of the hydrogen halides and explain these in terms of bond strengths

Knowledge: Student will get, ▪ insight of bond strength.	**Skills:** Students will be capable of, ▪ telling which bond is strong or weak.

Perspectives:

- Introduction to concept of group
- Number of groups in periodic table
- Describe the properties of different groups
- Properties of the alkali metals, alkaline earth metals, halogens, and noble gases

Activity#9

Materials

- Writing board
- Instruction sheet
- Beads and toothpicks / modelling kits

Methodology

Introduction: Teacher will introduce the term relative thermal stabilities to the students.

Instructions:

- Teacher will give instructions about the activity to the students.
- Students will be divided into 4 groups; each group will have related materials for the activity.

Activity:

- Each group will be provided with the coloured beads (black for carbon, white for hydrogen and other different colours for halogens F, Br, Cl and I).
- According to the bond stability, bond lengths and bond strengths were told to students in previous lectures students will make models of methyl halogens.
- Teacher will explain the importance and stabilities of bond enthalpies to the students to explain how chemicals use the energy during chemical reaction.
- Students will arrange the alkyl halides according to the thermal stabilities of the compounds.
- In the end, they will make a presentation on chart paper about bond enthalpies and will display it on the soft board in the class.

Discussion: They will share their understanding with the class by discussion by solving bond enthalpy

Conclusion: Teacher will relate relative thermal stabilities of bonds with the halogen positioning and bond enthalpies.

Teacher's Note: Teacher will have to plan the activity based on prior knowledge and will distribute the instruction sheets to the students before starting the activity.
Assessment of objectives: (specify tools of assessment) ▪ **Assessment based on following Rubric** ▪ **Rubrics:** 1. Defining the relative thermal stabilities 2. Clarity of concept 3. Discussion based on relative thermal stabilities.

Domain C: Inorganic Chemistry	
Standard: Discuss the chemical behaviour of elements in different oxidation states and their role in chemical reactions.	
Student Learning Outcomes: • Identify the properties of transition elements; high density, high melting point, variable oxidation states, coloured compounds formation. • Describe the transition elements as metals that: have high densities, high melting points, variable oxidation numbers, form coloured compounds and act as catalysts for industrial purposes. (some examples include catalysts being used are the Haber process, catalytic converters, Contact process and manufacturing of margarine)	
Knowledge: Students can get information about, ▪ the properties of transition elements (i.e. high density, high melting point, variable oxidation states, coloured compounds formation).	**Skills:** Students can, ▪ identify the transition elements ▪ tell the Properties of transition elements ▪ discuss coloured compounds
Standard: Oxidation state of hydrogen, oxygen, halogens, alkali metal , alkaline earth metal The chemical behaviour of elements in different oxidation states and their role in chemical reactions.	
Activity # 10 **Materials**	

- Writing board
- Instruction sheet
- Beakers containing some transition elements like Iron and its salts Iron (II), Iron (III), copper and copper (II) Sulphate, salt of manganese, Potassium permanganate ($KMnO_4$), water, empty beakers, glass rod and spirit lamp.

Methodology

Introduction: Teacher will introduce the transition elements and their properties by showing the samples in the beakers.

Activity:

- Students will come in pairs to observe the samples and the teacher will explain their properties to them as their properties will make a difference.
- Teacher will show iron and its salts to the students, ask if there is a difference in them, and then explain that this is due to variable oxidation states (different colours).
- Students will also observe high density of metals.
- One student will take one of the metals and try to burn it on a spirit lamp in front of the class to show the high melting point of metals.
- Another student from the class will come and make a solution of copper (II) sulphate, which will have blue colour to show coloured compounds.
- In the end, students will fill the worksheet with their observations provided to them.

Wrap up by the teacher:
Teacher Note:
Teacher will make a worksheet in which students will write their observations related to the materials provided to them.

Skills: Analytical skills, communication skills.

Assessment of objectives: (specify tools of assessment)

- **Assessment based on following Rubric**

- **Rubrics:**

1. By checking the correct placement of elements in the worksheet.
2. Transition elements have variable oxidation states give at least two examples.
3. What is the colour of Iron (II) & Iron (III) salts?

Teaching learning Evaluation:

GRADE X

Domain A: Nature of Science in Chemistry

Standard: Students will demonstrate an understanding, skill and attitude to deal in the areas of chemistry as an introduction.

Student Learning Outcomes:
- Justify, with examples, that to do science is to be involved in a community of inquiry.

Knowledge:	**Skills:**
Students get knowledge, ▪ about Science i.e. social & natural science.	Students will be able to, ▪ differentiate between natural science and social science.

Perspectives:
- Natural & social science
- Application of natural science
- Understanding, skill and attitude to deal in the areas of chemistry as an introduction.

Activity#11

Materials
- Writing board
- Instruction sheet
- Chart papers and coloured markers.
- Computer and internet

Methodology

Introduction: Teacher will introduce the community and the inquiry upon it with the help of examples.

Instructions: Teacher will give instructions about the activity to the students.
- Students will be divided into groups of 4 or 6, each group will be provided with the reading articles on the above topic (Discoveries)
- Students will read the articles and make points out of it about
    - How they discover?
    - What are the drawbacks?
    - What are the struggles?
- They will use computers to research about the topic and pick/discuss important points.
- They will make a power point/presentation.
- They will present it in the class.
- They have to explain about their perception of understanding.

Wrap up by the teacher.

Skills: Research skills, communication skills, time management skills

Assessment of objectives: (specify tools of assessment)

Assessment based on following Rubric

Rubrics:

1. Defining the topic.
2. Content used for information
3. Visibility of slides (Presentation)
4. Way of presentation.

Teaching learning Evaluation:

Domain: Domain A: Nature of Science in Chemistry

Standard: Students will demonstrate an understanding, skill and attitude to deal in the areas of chemistry as an introduction.

Student Learning Outcomes:

- Explain, with examples, that a 'scientific paradigm' is a theoretical model of how nature works.

Knowledge:	**Skills:**
Students will be able to, ▪ understand the nature, ▪ scientific model of how nature works ▪ theoretical model of how nature works.	Students will understand, ▪ scientific and theoretical model of how nature works.

Perspectives:

- Natural & social science
- Application of natural science
- Understanding, skill and attitude to deal in the areas of chemistry as an introduction to chemistry.

Activity# 12

Materials

- Writing board
- Instruction sheet

- Chart papers and markers, computer with active internet

Methodology

Introduction: Teacher will introduce the topic scientific model is a theoretical model of how nature works to the students.

Instructions: Teacher will give instructions about the activity to the students.

- Students will be divided into groups; each group will have related materials for the activity.
- Teacher will ask few questions
- Use of scientific models
- Can you name some of the models?
- Then teacher will display some information about the model on the board Like:
    - Objects that are too small to see is a model of atom or cell
    - Objects like galaxy that are too big are model of planets/ galaxy
    - Events those are too fast to see models of earthquakes etc.

Activity:

i. Each group will do research and design a model
ii. They will find types of these models and record them
iii. They will find and record their models advantages and limitations
iv. Students will display their models in the class

Discussion: They will share their understanding with the class and discuss advantages and limitations.

Wrap up by the teacher.

Skills: Thinking skills, inquirers, research skills

Assessment of objectives: (specify tools of assessment)

- **Assessment based on following Rubric**

- **Rubrics:**

1. Observing the discussion and presentations
2. Visibility of slides (Presentation)
3. Content used for information

Teaching learning Evaluation:

Domain B: Physical Chemistry

Standard:(Matter) Students should be able to:
Discuss the behaviour of matter at the macroscopic and microscopic levels, including the kinetic molecular theory and phase changes.

Student Learning Outcomes:

- Distinguish between evaporation and boiling.
- *Explain qualitatively the effect of external pressure on rate of boiling and evaporation.*

Knowledge:	**Skills:**
Students get information, ▪ about matter ▪ macroscopic and microscopic properties ▪ kinetic molecular theory to describe behaviour of matter ▪ about states of matter and phase changes.	Students can define, ▪ matter ▪ can tell properties of matter ▪ can describe phase changes (gases, liquid, solid).

Perspectives:

- Kinetic molecular theory of gases
- phase changes
- Distinguish between evaporation and boiling.
- *Explain qualitatively the effect of external pressure on rate of boiling and evaporation*
- Macroscopic and microscopic properties
- Kinetic molecular theory to describe behaviour of matter
- about states of matter and phase changes.

Activity#13

Materials

- Writing board
- Instruction sheet
- Syringes with a plunger, rubber cork

Methodology

Introduction: Teacher will introduce the topic that how increasing and decreasing the pressure will affect the boiling and evaporation.

Higher atmospheric pressure = More energy required to boil = Higher boiling point.
It can be explained by an activity.

Instructions: Teacher will give instructions about the activity to the students about pressure

- Students will be divided into groups; each group will have related materials for the activity.
- Teacher will provide syringes water and a rubber cork to all the groups.
- They will half fill the syringe with water, which will have an air bubble.
- They will block the front of the syringe with rubber cork and then pull out the plunger to reduce pressure.
- They will observe that the air bubble increases in size and putting back the plunger to its original position will increase the pressure.
- If they pull the plunger for a longer period of time, they will see that the water will start boiling at lower temperature.

Conclusion: After that, they will conclude that at lower pressure, the boiling point will decrease and at higher pressure, the water will boil at high temperature.

Worksheet: Students will answer the following questions.

1. What is boiling point?
2. What is effect of vapour pressure on boiling point?
3. How atmospheric pressure affect the boiling point?
4. Define melting point.
5. At sea level, the atmospheric pressure is 101.3 kPa and at mars, it will be 0.6kPa. Where water will boil at lower temperature?

Skills: Thinking skills, inquirers, Analytical skills

Assessment of objectives: (specify tools of assessment)

- **Assessment based on following Rubric**

- **Rubrics:**
  1. Answer given on the worksheet
  2. Clarity of concept
  3. Conclusion (based activity)

Teaching learning Evaluation:

Domain B: Physical Chemistry

Standard: (Reaction Kinetics) Students should be able to:
Describe the nature of chemical reactions including the activation energy and rate of reaction.

Student Learning Outcomes:

- Describe the physical parameters that may affect the rate of reaction including change in concentration, temperature, pressure and surface area.

Knowledge:
Students get information about,

- kinetics
- rate of reaction
- factors (temperature, concentration, catalyst) effect rate of reaction
- activation energy.

Skills:
Students can define,

- kinetics
- differentiate between kinetics & thermodynamics
- rate of reaction
- interpreting the graph to find the rate of reaction.
- effect of temperature, concentration, catalyst on rate of reaction
- activation energy.

Perspectives:

- Rate of reaction
- Factors (temperature, concentration, catalyst) effect rate of reaction
- Activation energy
- Differentiate between kinetics & thermodynamics
- Graph of concentration and time, interpreting the graph to find the rate of reaction.
- Effect of temperature, concentration, catalyst on rate of reaction
- Activation energy
- Activation energy and temperature

Activity#14

Materials

- Writing board
- Instruction sheet
- Digital balance, cotton plug, calcium carbonate powder and lumps, vinegar/ HCl, conical flask, stop watch.

Methodology

Introduction: Teacher will introduce the rate of reaction to the students.

Instructions: Teacher will give instructions about the activity to the students.
Students will be divided into groups; each group will have related materials for the activity.

Activity:

1. Each group will be provided with apparatus.
2. Teacher will set up sample apparatus for students.
3. One group will add lumps of calcium carbonate in the conical flask. The other group will add powdered calcium carbonate and they will record the mass on the digital balance and add 50 ml of HCl into the conical flask. Plug the mouth of the conical flask with cotton and record the mass loss by switching on the stopwatch after every 30 seconds.
4. They will record the mass loss until it becomes constant.
5. After constant weight, they will stop the reaction and plot a graph with the help of the teacher.
6. They will compare the rate of reaction of both the reactions by using this graph.
7. They will interpret the rate of reaction in both experiments and compare both the reaction rates.

Discussion: They will share their understanding with the class by discussion.

Teacher's Note: Teacher will have to plan the activity based on the materials and time taken. It can be extended for the next class in which they can plot the graph.

Skills: Thinking skills, Analytical skills.

Assessment of objectives: (specify tools of assessment)

- **Assessment based on following Rubric**

- **Rubrics:**
  1. Kinetics of reaction
  2. Rate of reaction
  3. Interpreting the graph to find the rate of reaction.

Teaching learning Evaluation:

Domain B: Physical Chemistry

Standard: students should be able to:
Discuss the relationship between electricity and chemical reactions, including the use of electrodes and electrolytes.
Apply the principles of electrochemistry to explain the behaviour of batteries, fuel cells, and other electrochemical devices.

Student Learning Outcomes:

- State that hydrogen-oxygen fuel cell uses hydrogen and oxygen to produce electricity with water as the only chemical product.
- Describe the advantages and disadvantages of using hydrogen–oxygen fuel cells in comparison with gasoline /petrol engines in vehicles.

Knowledge:	**Skills:**
Students get knowledge of, ▪ electricity and chemical reactions, electrodes and electrolytes ▪ understand the principles of electrochemistry ▪ behaviour of batteries, electrochemical devices such as fuel cells, dry cell ▪ describe the advantages and disadvantages of using hydrogen–oxygen fuel cells in comparison with gasoline /petrol engines in vehicles.	Students understand the electrochemical cells, ▪ the advantages and disadvantages of hydrogen–oxygen fuel cells in comparison with gasoline /petrol engines in vehicles.

Perspectives:

- Electrochemical chemical reactions, electrodes i.e. anode, cathode and electrolytes
- principles of electrochemistry
- electrochemical cells and batteries such as fuel cells, dry cell
- hydrogen–oxygen fuel as Example of fuel cell
- describe the advantages and disadvantages of using hydrogen–oxygen fuel cells in comparison with gasoline /petrol

Activity#15

Materials

- Writing board
- Instruction sheet
- Reading material
- Chart papers and coloured markers.

Methodology

Introduction: Teacher will introduce the hydrogen–oxygen fuel cell and its application in the class.

Instructions: Teacher will give instructions about the activity to the students.

- Students will be divided into 3 groups.

- Each group will have different information about the hydrogen–oxygen fuel cell for the activity (principle of hydrogen fuel cell construction of the cell and the application of the hydrogen–oxygen fuel cell).

Activity:

1. Each group will be provided with the reading material, chart papers and markers.
2. Students will read the articles and then pick main points from the reading material to make relevant presentations.
3. They will write the basic information on their chart papers and make a presentation.
4. They will present in front of the class.
5. First group will talk about the principles of hydrogen–oxygen fuel cell.
6. Second group give information about the construction of the cell.
7. Third group will share the application of hydrogen–oxygen fuel cells.

Teacher's Note: Teacher will have to bring relevant reading material for the students. In the end, the teacher will give the following questions in the homework.

1. How will fuel cell vehicles differ from the vehicles we use today?
2. Name the three main parts of a fuel cell.
3. What is necessary for a fuel cell to produce electricity?
4. What does a catalyst do?
5. How do fuel cells work?
6. List two advantages of using fuel cell vehicles instead of our current fossil fuel vehicles.

Skills: Research skills, Time management skills, comprehensive skills

Assessment of objectives: (specify tools of assessment)

- **Assessment based on following Rubrics**

- **Rubrics**

1. Main points in the presentation
2. Understanding and delivery of the information
3. Presentation of the work.

Teaching learning Evaluation:

Domain: Domain B: Physical Chemistry

Standard: (Reaction Kinetics) Students should be able to
Explain the factors that affect the rate of reaction, including temperature, concentration, surface area, and catalyst.

Student Learning Outcomes:
Describe collision theory in terms of number of particles per unit volume, frequency of collisions of particles, kinetic energy of particles and activation energy

Knowledge:	**Skills:**
Students get knowledge of, ▪ collision between the molecules ▪ theory in terms of number of particles per unit volume, ▪ frequency of collisions of particles.	Student will be capable to, ▪ explain reactions in term of collisions ▪ explain the term related to collision of molecule.

Perspectives:
- collision theory
- frequency of collisions of particles
- kinetic energy of particles
- activation energy

Activity# 16

Materials
- Writing board
- Instruction sheet
- Different colour plasticine/play dough

Methodology
Introduction: Teacher will explain the collision theory in the class with the examples of car collisions.
Activity:
1. Students will be divided into three groups.
2. Firstly, Students will use the plasticine/ play dough to make different atoms or balls of reactants.
3. Secondly, one by one student's groups will be called in front of the class.
4. Finally, First group will collide the balls with low force and will observe the result.
5. Second group will collide the balls with medium force and will see the result.
6. Third group will collide the balls with higher force and they will see that the balls, which were collided with higher and medium force, they merged with each other and

converted into new shapes same like an effective collision taking place in a chemical reaction.

Wrap up by the teacher:
Teacher will relate this activity with collision theory to wrap up the lesson.

Skills: Thinking skills, analytical skills

Assessment of objectives: (specify tools of assessment)

- **Assessment based on following Rubric**

- **Rubrics:**
  1. By getting feedback on the collision of the balls
  2. Getting information about frequency of collisions of particles
  3. Rate of reaction is proportional to collision Frequency

Teaching learning Evaluation:

Domain B: Physical Chemistry

Standard: (Reaction Kinetics) Students should be able to:
Describe the nature of chemical reactions, including the activation energy and rate of reaction.

Student Learning Outcomes:

- Describe the physical parameters that may affect the rate of reaction including change in concentration, temperature, pressure and surface area.
- Interpret data, including graphs, for investigating rate of reaction

Knowledge:	**Skills:**
Students get knowledge of, ▪ factors affecting rate of reaction ▪ activation energy ▪ effect of temperature on activation energy ▪ data interpretation	Students can describe, ▪ the physical parameters that may be affected by the rate of reaction including change in concentration, temperature, and pressure of gas ▪ interpret data, interpret the graphs, for investigating rate of reaction

Perspectives:

- Rate of reaction
- Factors (temperature, concentration, catalyst) affect rate of reaction
- Activation energy
- Differentiate between kinetics & thermodynamics
- Graph of concentration and time, interpreting the graph to find the rate of reaction.

- Effect of temperature, concentration, catalyst on rate of reaction
- Activation energy
- Activation energy and temperature

Activity# 17

Materials

- Writing board
- Instruction sheet
- Salt, sugar, water, powdered sugar, vinegar, baking soda
- Beakers, glass rod, tripod stand, spirit lamp/Bunsen burner, spatula, stopwatch
- Chart papers and markers

Methodology

Introduction: Teacher will introduce the factors, which can affect the rate of reaction like concentration, temperature, surface area, catalyst.

Instructions: Teacher will give instructions about the activity to the students.
Students will be divided into 4 groups; each group will be provided with the different materials. 1 group will explore the effect of concentration; the other will explore the effect of temperature, surface area and catalyst respectively.

Activity:
Group 1: Will explore the **effect of concentration**

i. They will take one spatula of baking soda in a beaker and will add 20 ml of concentrated vinegar (acetic acid) in it and will see the bubbles coming out of it and record the time for completion of the reaction'
ii. In the second step, they will add 5 ml of vinegar and 15 ml of water to dilute it and repeat the above step and will record the time for their presentation and make a conclusion based on results.

Group 2: Will explore the **effect of temperature**

i. They will take two full spatulas of salt in a beaker and add 20 ml of water in it to dissolve the salt in it at room temperature and record the time.
ii. In the second step, they will take two full spatulas of salt, add them in boiling water (20 ml), and record the time taken by the salt to dissolve then they make a conclusion based on results.

Group 3: Will explore the **effect of a surface area**

i. This group will take granulated and powdered sugar and dissolve them separately in two different beakers half filled with water and record the time of sugar dissolution in water for both the beakers.
ii. Make a conclusion and record it on the chart paper for presentation.

Group 4: Will explore the **effect of a catalyst**

i. This group will add water in sugar and then add one or two drops of dilute sulphuric acid in it and record the changes going on in the reaction mixture.
ii. Sugar will quickly oxidize and change its colour.
iii. Dilute acid works as a catalyst in this reaction.
iv. Students will find out some more catalysts in different reactions.

Presentation: Students will share their understanding with the class by presenting their presentations.

Wrap up by the teacher:
Teacher will explain the factors affect the rate of reaction

Teacher's Note: Teacher will have to plan this activity.
Skills: Thinking skills, communication skills

Assessment of objectives: (specify tools of assessment)

- **Assessment based on following Rubric**

- **Rubric**
  1. Rate of reaction is directly proportional to temperature
  2. Pressure effect on rate
  3. Definition of catalyst
  4. Effect of catalyst on rate of reaction

Teaching learning Evaluation:

Domain E: Organic Chemistry

Standard: Basics of organic chemistry (catenation, isomerism, nomenclature, functional groups, homologous series) Students should be able to:
Describe the concept of catenation, including the ability of carbon atoms to bond with each other to form extended structures.
Explain the concept of isomerism in organic compounds, including structural and stereoisomers.
Discuss the systematic nomenclature of organic compounds, including IUPAC rules.

<table>
<tr><td colspan="2">Student Learning Outcomes:
Name and draw the displayed formulae of the esters which can be made from alcohols and carboxylic acids, each containing up to two carbon atoms</td></tr>
<tr><td>Knowledge:
Students get knowledge of,
catenation,
structural isomerism and stereoisomerism
homologous series & IUPAC rules of nomenclature of organic compounds functional groups.</td><td>Skills:
Students can describe and define,
characteristic properties of organic compounds i.e.
catenation, structural isomerism and stereoisomerism
homologous series & IUPAC rules of nomenclature of organic compounds functional groups.</td></tr>
<tr><td colspan="2">Perspectives:
Basics of organic chemistry (catenation, isomerism, nomenclature, functional groups, homologous series)
Isomerism in organic compounds, including structural isomerism and stereoisomerism
Systematic nomenclature of organic compounds, including IUPAC rules</td></tr>
<tr><td colspan="2">Activity# 18

Materials
Writing board
Instruction sheet
Modelling kits or play dough and toothpicks
Methodology

Introduction: Teacher will introduce the esters and their formulae in previous class and will continue the concept in this lesson.

Activity:<ol type="i">
Teacher will display a chart paper with two different 4 carbon membered esters.
Students will be provided with a worksheet having the same formulas and then they will make molecules by using the playdough and toothpicks or modelling kits.
They will mark carbon atoms and write their names in the provided worksheets.
Wrap up by the students:
Students will share their understanding with the class by presenting their presentations.

Skills: Thinking skills, communication skills</td></tr>
</table>

Assessment of objectives: (specify tools of assessment)
By checking the correct names of esters on the worksheet.

- **Assessment based on following Rubric**

- **Rubric**

1. Make esters from alcohols and carboxylic acids
2. Displayed the formulae of esters
3. Write the names of the displayed esters

Teaching learning Evaluation:

Grade 9

Domain E: Organic Chemistry

Standard: (Hydrocarbons) Students should be able to:
Explain the reaction mechanisms and products of alkane, alkene, and alkyne reactions, including combustion, addition, and substitution reactions.

Student Learning Outcomes:

- Describe the substitution reaction of alkanes with chlorine as a photochemical reaction, and draw the structural or displayed formulae of the products, limited to Mono substitution

Knowledge:	**Skills:**
Students will get information about, ▪ the substitution reaction of alkanes with chlorine as a photochemical reaction, ▪ draw the structural or displayed formulae of the products, limited to mono-substitution reaction.	Students should be able to, ▪ explain the reaction mechanisms and products of alkane, alkene, and alkyne reactions, ▪ including combustion, addition, and substitution reactions.

Perspectives:

- the substitution reaction of alkanes with chlorine as a photochemical reaction
- draw the structural or displayed formulae of the products, limited to mono-substitution reaction

Activity#19

Materials

- Writing board
- Instruction sheet

- Modelling kits, 5 chairs and 6 students to play musical chairs.

Methodology

Introduction: Teacher will explain the substitution reactions with the help of the modelling kit and reactions.

Activity:

- Teacher will give instructions to the students.
- Students will play musical chairs
- They will see that out of 5 chairs in students will substitute the other and then they will relate it with the reactions that how one atom will substitute the other
- They will use modelling kit to explore types of substitution reactions

Wrap up by the students.
Students will share their understanding with the class by presenting their presentations.

Skills: Critical thinking, communication skills.

Assessment of objectives: (specify tools of assessment)

- By using the modelling kit to show substitution reactions.

- **Assessment based on following Rubric**

- **Rubric**

1. explain the substitution reactions
2. Displayed the reaction with the help of the modelling kit and reactions.
3. Draw the substitution reaction of alkanes with chlorine as a photochemical reaction
4. draw the structural or displayed formulae of the products, limited to mono-substitution reaction

Teaching learning Evaluation:

Domain E: Organic Chemistry

Standard:(Hydroxy Compounds) Students should be able to:
Discuss the applications of alcohols, including their use as solvents, fuels, and starting materials for organic synthesis.
Describe the importance of alcohols in organic chemistry and their role in industry and daily life.

Student Learning Outcomes:

- Discuss the applications of ethanol as fuels, including their advantages and disadvantages over fossil fuels.
- Explain the role of ethanol in various industries such as pharmaceuticals, cosmetics, and fuel production.

Knowledge:	**Skills:**
Students will get knowledge of, ▪ hydroxy compounds i.e. alcohol, ▪ identify functional group – OH, ▪ the applications of alcohols, ▪ use of alcohols in organic chemistry and their role in industry and daily life.	Students will able to, ▪ identify alcohol functional group – OH, ▪ importance of alcohol.

Perspectives:

- Alkane, alkene, alkyne
- Homologous series
- Concept of Saturation and unsaturation
- Difference between Saturation and unsaturation
- Reaction mechanisms and identification of combustion, addition, and substitution reactions.

Activity# 20

Materials

- Writing board
- Instruction sheet.
- Hand sanitizers, perfumes, medicines, spirit, alcoholic swabs, ethanol as fuel in spirit lamp, as solvents.
- Worksheet.

Methodology

Introduction: Teacher will introduce the types and application of alcohols

Activity:

i. Teacher will display all above samples on the table and will call students in groups.
ii. Students will come in groups of 4 to observe the samples and the teacher will ask questions about the displayed samples.
    - What does a hand sanitizer contain?
    - What is the solvent for perfumes and medicines?
    - Why are spirit and alcohol swabs used?

- What is used as fuel in spirit lamps?

iii. Teacher will give a worksheet containing the same questions and some advanced questions related to alcohol, which have already been taught in the class.

iv. Students will answer the questions given in the worksheet.

Wrap up by the students:
Students will share their understanding with the class by answer the questions given in the worksheet.

Teacher Note:
Teacher will make a worksheet in which students will write their answers related to the materials provided to them.

Skills: Analytical and Communication skills

Assessment of objectives: (specify tools of assessment)

1. By checking the answers in the worksheet.

Teaching learning Evaluation:

Grade 9 & 10

Domain: Organic Chemistry
Topic: Basics of organic chemistry

Standard: Students should be able to:
Discuss the systematic nomenclature of organic compounds, including IUPAC rules.
Describe the functional groups in organic compounds, including alcohols, carboxylic acids, amines, and aldehydes.
Explain the concept of homologous series, including the similarity in properties and reactivity among members of a series.

Benchmark 1: Recognize and classify organic compounds based on their functional groups, nomenclature, isomerism, and homologous series.

Naming organic compounds

1. Name and draw the structural and displayed formulae of unbranched:

   (a) alkanes

   (b) alkenes, including but-1-ene and but-2-ene

(c) alcohols, including propan-1-ol, propan-2-ol, butan-1-ol and butan-2-ol

(d) carboxylic acids

(e) the products of the reactions stated in next sections containing up to four carbon atoms per molecule

2. State the type of compound present given the chemical name ending in -ane, -ene, -ol, or -oic acid or from a molecular, structural or displayed formula
3. Name and draw the displayed formulae of the unbranched esters which can be made from unbranched alcohols and carboxylic acids, each containing up to four carbon atoms

Knowledge:	Skills:
Students will know, ▪ the formulae and functional groups of different organic compounds. ▪ nomenclature of commonly used organic compounds like alkanes, alkenes, alcohols, and carboxylic acids. ▪ the common characteristics of a homologous series. ▪ the distinction between saturated and unsaturated compounds and the process of interconversion. Students will understand, ▪ terms like homologous and saturated compounds, catenation, isomerism, and functional groups.	Students will be able to, ▪ identify the organic compounds commonly used in cooking, agriculture, labs, and industries. ▪ distinguish between various groups of organic compounds and explain their general characteristics. ▪ explain the catenation of organic compounds and the change in properties with the addition of my CH_2 units.

Perspectives

- The impact of early discoveries and experiments in organic chemistry on modern medicine and drug development, including the isolation and synthesis of important natural products like aspirin, quinine, and penicillin.

- The role of organic chemistry in the development of industrial processes and products, including the synthesis of synthetic materials, such as plastics and fibres, and the production of fuels, such as gasoline and diesel.

- The environmental impact of organic chemistry and the role of organic chemists in developing sustainable and environmentally friendly alternatives to traditional processes and products.

- Impact of colonialism on organic chemistry nomenclature: Colonialism played a significant role in shaping the way organic compounds were classified and named, as European colonizers brought back new knowledge and samples from their colonies and introduced new naming systems and taxonomies to the Western world. This had a lasting impact on the field of organic chemistry, and in some cases, has perpetuated Eurocentric biases and hierarchies in the classification of organic compounds.

Learning Activities

1. **Introduction to Organic Nomenclature**

Objective: To introduce students to the basic principles and conventions of organic nomenclature.

Materials:

- Structural formulas of different organic compounds
- Molecular models or ball-and-stick models of different organic compounds
- Nomenclature worksheets
- Pencils
- Erasers

Introduction:
In organic chemistry, it is important to be able to name compounds in a standardised way. This allows for clear communication among chemists and helps to avoid confusion. In this activity, students will learn the basic rules and conventions used in naming organic compounds.

Procedure:

- Divide students into small groups of 2-3 students each.
- Provide each group with a set of structural formulas of different organic compounds.
- Instruct students to use their knowledge of organic structure and functional groups to name each compound according to IUPAC (International Union of Pure and Applied Chemistry) nomenclature rules.
- Once students have completed the worksheet, have them check their answers with their group members.
- As a class, review any incorrect answers and discuss the reasoning behind the correct nomenclature.
- Use molecular models or ball-and-stick models to demonstrate the relationships between the structural formula and the nomenclature of each organic compound.

– Assign additional practice problems for students to complete on their own or in groups.

Assessment:

- Students will be assessed on their ability to correctly name organic compounds using IUPAC nomenclature.
- This can be done through the completion of a written test or through a practical demonstration, such as modelling the structure of a given compound and providing its correct name.

References:

Clayden, J., Greeves, N., Warren, S., & Wothers, P. (2012). Organic chemistry (2nd ed.). Oxford, UK: Oxford University Press.
Carey, F. A., & Sundberg, R. J. (2007). Advanced organic chemistry: Part A: Structure and mechanisms (5th ed.). New York, NY: Springer.
McMurry, J. (2008). Organic chemistry (7th ed.). Boston, MA: Brooks/Cole.

2. Organic Molecules: What's in Your Food?"

Objective: Students will learn about the different types of organic molecules (carbohydrates, lipids, proteins, and nucleic acids) and identify them in common food items.

Materials:

- A variety of food items (e.g. fruits, vegetables, snacks, etc.)
- Small cups or containers
- Filter paper or coffee filters
- Glucose test strips
- Benedict's solution
- Biuret reagent
- Sudan III/IV solution
- Toothpicks or droppers

Procedure:

i. Divide students into small groups.
ii. Give each group a different food item to test.
iii. Have students use the filter paper or coffee filters to extract the organic molecules from their food item.
   - To test for carbohydrates, use the glucose test strips or Benedict's solution.
   - To test for lipids, use Sudan III/IV solution.
   - To test for proteins, use Biuret reagent.
iv. Have students observe and record the results of their tests.
v. Have students discuss their results and identify which type of organic molecule is present in their food item.

vi. Finally, have students present their results to the class and discuss the importance of each type of organic molecule in our diet.

References:
Brown, T.L., LeMay, H.E., Bursten, B.E., and Burdge, J.J. (2017). Chemistry: The Central Science, 14th Edition. Pearson Education Inc.
"Organic Molecules Lab" by Science With Mrs. Lau, https://sciencewithmrslau.com/organic-molecules-lab/

Domain: Biochemistry

Standard: Students should be able to:
Describe the structure and properties of carbohydrates, proteins, and lipids, including their classification.
Explain the metabolic pathways and functions of carbohydrates, proteins, and lipids in living organisms, including energy storage and transfer, structural support, and regulatory roles.
Describe the structure and function of DNA and RNA, including the role of DNA in genetics and the mechanism of transcription and translation.
Discuss the importance of vitamins and minerals in human nutrition, including their role in metabolic processes and the consequences of deficiencies.
Apply the concepts of biochemistry to understand the molecular basis of biological processes, diseases, and treatments.

Benchmark I: Identify the importance of carbohydrates, proteins, lipids, DNA and vitamins in biological systems.

Student Learning Outcomes

- Describe proteins as natural polyamides and that they are formed from amino acid monomers with the general structure
- Explain the sources, use and structure of proteins, lipids and carbohydrates
- Describe the importance of nucleic acids
- Explain vitamins, their sources and their importance to health
- *Identify applications of biochemistry in testing (blood test, pregnancy test, cancer screening, parental genetic testing), genetic engineering, gene therapy and cloning*

Knowledge:	***Skills:***
Students will know, ▪ the differences between the four major biomolecules. ▪ the sources and use of different biomolecules in the body. ▪ the applications of biology in healthcare and industries. Students will understand, ● terms like Nucleic Acids, Lipids, Vitamins, Carbohydrates, and Proteins.	Students will be able to, ▪ describe the structures of different biomolecules and their composition. ▪ identify the different sources of food that these biomolecules are obtained from. ▪ explain how different biomolecules are stored inside our bodies and how energy is extracted from them.

Perspectives

- Biochemistry is the study of the chemical processes that occur within living organisms, and it is a fundamental part of understanding how living things work.
- The structure and properties of carbohydrates, proteins, and lipids play a critical role in the functions and metabolic processes of living organisms.
- Understanding the role of DNA and RNA in genetics and cellular processes is crucial for comprehending how living organisms function and evolve.
- Vitamins and minerals play a vital role in maintaining health and wellbeing, and their deficiencies can have significant impacts on human biology.
- The application of biochemistry has significant implications for medicine and biotechnology, providing insights into disease processes and enabling the development of new treatments.

Learning Activities

1. **Exploring the Properties of Proteins**

Objective*:* To understand the properties of proteins and how they can be affected by changes in temperature, pH, and other conditions.

Materials*:*

- 4 test tubes
- 4 mL of egg white (or another protein solution)
- 4 mL of distilled water
- 1 mL of 1 M HCl
- 1 mL of 1 M NaOH
- Bunsen burner or hot plate
- Test tube holder
- Graduated cylinder

Procedure:

i. Label four test tubes as T1, T2, T3, and T4.
ii. Fill T1 with 4 mL of egg white.
iii. Fill T2 with 4 mL of distilled water.
iv. Fill T3 with 4 mL of egg white and 1 mL of 1 M HCl.
v. Fill T4 with 4 mL of egg white and 1 mL of 1 M NaOH.
vi. Use a Bunsen burner or hot plate to gently heat T1 until it reaches 70-80°C.
vii. Keep T2, T3, and T4 at room temperature.
viii. Observe and record any changes in the appearance of the solutions in each test tube.
ix. Compare the results of each test tube to the original solution in T1.

Sample Results:

- T1 (original egg white solution): A clear, viscous solution with a slightly opaque appearance.
- T2 (distilled water): A clear, colourless solution with no change in appearance.
- T3 (egg white + HCl): The solution may become cloudy or form a precipitate, indicating that the protein has denatured due to the change in pH caused by the addition of HCl.
- T4 (egg white + NaOH): The solution may become clearer or less viscous, indicating that the protein has denatured due to the change in pH caused by the addition of NaOH.

Discussion:

This activity helps students understand the properties of proteins and how they can be affected by changes in temperature, pH, and other conditions. By observing and recording the changes in the appearance of the solutions, students are able to understand the concept of denaturation and the role of pH in protein structure and function.

2. **Lipid Extraction and Analysis**

Objectives:

To extract lipids from a food source and identify their chemical structure
To understand the role of lipids in biological systems

Materials:

- Vegetable oil
- Ethanol
- Sodium hydroxide
- Beaker
- Test tubes
- Hot plate or Bunsen burner
- Dropper
- TLC (Thin Layer Chromatography) plate

- Solvent (such as hexane and ether)
- Ruler
- Pencil
- Spot plate

Procedure:

i. Place about 10 mL of vegetable oil in a test tube and add 1 mL of sodium hydroxide solution. Shake the test tube to mix the two liquids.
ii. Slowly add ethanol to the test tube while swirling the mixture. You will notice a solid material precipitating out of the solution. You will extract the lipid.
iii. Filter the mixture using a filter paper or funnel. Collect the solid material in a spot plate.
iv. Using a TLC plate, spot a small amount of the extracted lipid and a known lipid (such as olive oil) onto the plate.
v. Develop the TLC plate by placing it in a solvent system (such as hexane and ether). As the solvent moves up the plate, the lipids will separate and migrate up the plate.
vi. Observe the position of the spots on the TLC plate and measure the distance each spot has travelled. This will give you an idea of the chemical structure of the lipids.
vii. Compare the distance travelled by the unknown lipid with the known lipid. Based on the distance travelled, you can make an educated guess as to the type of lipid extracted from the vegetable oil.
viii. Repeat the procedure using different food sources and compare the results.
ix. Discuss the role of lipids in biological systems, such as the role of fats in energy storage and membrane structure.

References:

"Lipid Analysis - Thin Layer Chromatography." ScienceDirect Topics, Elsevier, www.sciencedirect.com/topics/chemistry/lipid-analysis-thin-layer-chromatography
"Thin Layer Chromatography of Lipids." Bitesize Bio, www.bitesizebio.com/11673/thin-layer-chromatography-of-lipids/

Discussion:

This activity provides hands-on experience in lipid extraction and analysis, and helps students understand the role of lipids in biological systems. In schools where TLC plates may not be available, teachers can use an activity to make nylon instead.
(Note: If Nylon is not available, use cellulose filters instead of nylon, as an alternative.)

3. **Demonstrating the Insulating Properties of Lipids Using Metal Rods**

Objective: To demonstrate how lipids function as thermal insulators by measuring the temperature change of metal rods covered in lipid substances.

Materials:

- o 2 metal rods with the same diameter
- o Cooking oil
- o Shortening or margarine
- o Water
- o Thermometer
- o Beaker
- o Heat source (e.g. hot plate or stove)

Procedure:

i. Measure the initial temperature of both metal rods using the thermometer. Record the temperature and plot the graph in your lab notebook.

ii. Place one metal rod into a beaker filled with water and heat the beaker using a heat source until the temperature of the water reaches 50°C.

iii. Quickly remove the metal rod from the hot water and measure its temperature again using the thermometer. Record the temperature in your lab notebook.

iv. Repeat steps 2 and 3 with the second metal rod, but this time, cover the rod with a thin layer of cooking oil or shortening/margarine before heating it in the beaker of hot water.

v. Measure the temperature of the second metal rod after heating and record the temperature in your lab notebook.

Data Analysis:

- Calculate the temperature change for both metal rods by subtracting the initial temperature from the final temperature.
- Compare the temperature change of the two metal rods.

Expected Results:

- o The metal rod covered in lipid substances (cooking oil or shortening/margarine) should experience a smaller temperature change compared to the metal rod without any lipid covering.
- o This demonstrates that lipids are effective thermal insulators, as they slow down the transfer of heat from the metal rod to the surrounding water.

Conclusion:

The experiment shows how lipids function as thermal insulators, which is important for maintaining the temperature stability of living organisms. Lipids play a crucial role in protecting the body from extreme temperature changes and maintaining the internal temperature of cells and tissues.

Grade-XI

Domain B: Physical Chemistry

Standard:
Describe the arrangement of electrons in the electron shells and explain how this arrangement affects the chemical properties of an atom.

Student Learning Outcomes:

- Describe the electronic configuration to include the number of electrons in each shell, subshell and orbital.
- *Illustrate the importance of electronic configuration in development of new materials for electronic devices. (For example, semiconductors such as silicon have a specific electronic configuration that makes them ideal for use in electronic devices.)*

Knowledge: Students will understand	**Skills:**
▪ the electronic configuration of elements ▪ describe the arrangement of electrons in the electron shells ▪ explain how electronic configuration helps to determine the chemical properties of an atom.	Students will be able, ▪ to do electronic configuration ▪ to relate the electronic configuration and chemical properties

Perspectives:

- Atomic number and arrangement of electrons
- understand the electronic configuration of elements
- Describe the arrangement of electrons in the electron shells
- explain how electronic configuration helps to determine the chemical properties of an atom

Activity # 1

Materials needed:

- Whiteboard or blackboard
- Markers or chalk
- Chart paper
- Coloured pencils or markers
- Handouts with examples of materials and their electronic configurations (optional)

Procedure:	
Introduction	The teacher begins the lesson by introducing the topic of electronic configuration and its importance in the development of new materials. The teacher explains that the electronic configuration of atoms determines their chemical properties and how they interact to form different materials.
Discussion and Examples	▪ The teacher initiates a class discussion on the concept of electronic configuration and its relationship to the properties of materials. ▪ The teacher provides examples of materials and their electronic configurations, such as conductors, insulators, and semiconductors. ▪ Students are encouraged to participate actively in the discussion, ask questions, and share their observations.
Group Activity: Building Molecular Models	i. Divide the students into small groups of 3-4 members. ii. Provide each group with a set of molecular model kits or other materials for building models (e.g., coloured beads, pipe cleaners). iii. Assign each group a specific material to create a model for (e.g., diamond, graphene, silicon). iv. Instruct the groups to build the molecular models of their assigned materials, considering the electronic configuration of the atoms involved. v. Encourage students to discuss and analyse how the electronic configuration affects the properties of the material they are modelling. The teacher moves around the classroom, providing guidance, answering questions, and facilitating discussions among the groups.
Group Presentation and Discussion	▪ Each group presents their model to the class, explaining the electronic configuration and discussing the properties of the material they created. ▪ The teacher facilitates a class discussion by asking questions related to the electronic configuration, properties, and potential applications of the materials presented. ▪ Students are encouraged to ask questions and provide feedback to their peers.

Conclusion and Wrap-up	➢ The teacher summarizes the key points discussed during the activity, emphasizing the importance of electronic configuration in the development of new materials. ➢ The teacher provides additional resources or references for further exploration of the topic.

Note for teachers:

- ➢ Prior to the lesson, familiarize yourself with different materials and their electronic configurations to facilitate the discussion and answer students' questions effectively.
- ➢ Ensure that the molecular model kits or alternative materials for building models are readily available and in good condition.
- ➢ Encourage active participation and collaboration among students during the group activity.
- ➢ Time management is crucial, so ensure that each section of the activity stays within the allocated time frame.

Note for students:

- ➢ Actively engage in the class discussion and ask questions to enhance your understanding.
- ➢ Collaborate effectively with your group members during the molecular model building activity.
- ➢ Pay attention to the properties of the materials discussed and connect them to the electronic configuration.
- ➢ Participate in the group presentations and class discussions by sharing your insights and asking relevant questions.

Domain: Domain B: Physical Chemistry

Standard:
Describe the arrangement of electrons in the electron shells and explain how this arrangement affects the chemical properties of an atom.

Student Learning Outcomes:

- Relate Quantum Numbers to Electronic distribution of elements
- Describe the number of orbitals making up s, p, d and f sub-shells, and the number of electrons that can fill s, p d and f sub-shells

Knowledge:	**Skills:**
Student will get knowledge,	Students will be able to,

▪ of quantum numbers ▪ of assignment of quantum numbers	▪ identify quantum numbers ▪ relate quantum numbers and properties of electrons ▪ describe the number of orbitals making up s, p d and f sub-shells.

Perspectives:

- Concept of quantum number
- Identify quantum numbers
- Relate quantum numbers and properties of electrons
- Describe the number of orbitals making up s, p d and f sub-shells

Activity # 2

Materials Needed:

- Whiteboard or blackboard
- Markers or chalk
- Chart paper or poster board
- Coloured pens or markers
- Handouts with practice problems (optional)

Stage	**Activity**
Introduction	• Begin the lesson by discussing the concept of quantum numbers and their significance in understanding the electronic distribution of atoms. • Emphasize the importance of quantum numbers in describing the location, energy levels, and orientation of electrons in an atom.
Discussion and Examples	• Present a detailed explanation of the four quantum numbers: principal quantum number (n), azimuthal quantum number (l), magnetic quantum number (m), and spin quantum number (s). • Use the whiteboard or blackboard to illustrate each quantum number and its role in determining the electronic distribution. • Provide examples of electronic configurations for different elements, explaining how quantum numbers are applied to determine the distribution of electrons in different energy levels and orbitals.
Group Activity: Quantum Number Charts	• Divide the students into small groups of 3-4 members.

	• Distribute chart paper or poster boards and coloured pens or markers to each group. • Instruct the students to create a large chart representing the quantum numbers and their possible values. • Each group should draw columns for the four quantum numbers (n, l, m, s) and rows representing the corresponding values. • Guide the students in filling out the chart by discussing the valid ranges of each quantum number and their significance in electronic distribution. • Encourage the groups to collaborate and discuss the patterns and relationships between the quantum numbers.
Group Presentation and Discussion	• Have each group present their quantum number chart to the class. • Facilitate a class discussion on how the quantum numbers relate to the electron distribution and the principles of Pauli exclusion and Aufbau principle. • Students are encouraged to ask questions and provide feedback to their peers.
Conclusion and Wrap-up	• Provide handouts with practice problems related to electronic configurations and quantum numbers. • Instruct students to work individually or in pairs to solve the problems, applying their understanding of quantum numbers.

Note for teachers:

- Ensure a clear explanation of each quantum number, highlighting its definition and significance.
- Use visual aids, such as diagrams or models, to enhance students' understanding.
- Encourage active participation and collaboration among students during the interactive activity and group discussions.
- Monitor the groups during the activity to provide guidance and address any misconceptions.
- Provide additional resources, such as online simulations or interactive tutorials, for students to further explore quantum numbers and electronic distribution.

Note for students:

- Actively participate in class discussions and ask questions to clarify any doubts.
- Collaborate effectively with your peers during the group activity and take turns in presenting the quantum number charts.
- Engage in problem-solving during the practice session to reinforce your understanding of quantum numbers and electron distribution.

Domain B: Physical Chemistry

Standard: (Chemical Bonding) Students should be able to:
Explain the concept of chemical bonding and describe the different types of bonds, including ionic, covalent, and metallic bonds.
Discuss the factors that affect bond strength, including bond length and bond energy.

Student Learning Outcomes:
Use the differences in Pauling electronegativity values to predict the formation of ionic and covalent bonds

Explain the trends in electronegativity across a period and down a group of the Periodic Table

Explain the factors influencing the electronegativities of elements in terms of nuclear charge, atomic radius, shielding by inner shells electrons.

Knowledge:	**Skills:**
Students will get information about ▪ chemical bonding	Students will able to tell ▪ why atoms form bond

▪ types of bonds (ionic, covalent, and metallic bonds). ▪ periodicity in electronegativity ▪ its values to predict the formation of ionic and covalent bonds ▪ the factors (nuclear charge, atomic radius, shielding effect) influencing the electronegativities of elements.	▪ types of bonds (ionic, covalent, and metallic bonds). ▪ about electronegativity and type of bonding ▪ the factors influencing the electronegativities.

Perspectives:

Stage	**Activity**
Introduction	Begin the lesson by introducing the concept of electronegativity and its significance in bond formation. Explain that electronegativity is a measure of an atom's ability to attract electrons in a chemical bond. Emphasise that differences in electronegativity values between atoms determine the type of bond that forms (ionic, covalent, or polar covalent).
Discussion on Electronegativity	Present a detailed explanation of electronegativity values and explain how they are determined. Use the periodic table to demonstrate trends in electronegativity across periods and down groups. Discuss how electronegativity varies among elements and how it affects their chemical behaviour.
Electronegativity and Bond Types	Provide examples of different elements and their electronegativity values. Explain how the difference in electronegativity values between two atoms can predict the type of bond that will form between them. - Large electronegativity difference (ΔEN) indicates an ionic bond. - Small electronegativity difference (ΔEN) indicates a covalent bond. - Moderate electronegativity difference (ΔEN) indicates a polar covalent bond.
Practice Problems	Provide handouts with practice problems related to predicting bond types based on electronegativity values. Instruct students to work individually or in pairs to solve the problems. Encourage students to use the periodic table and their understanding of electronegativity to determine bond types in each case.
Group Discussion	Facilitate a class discussion on the practice problems, allowing students to share their answers and explanations. Clarify any misconceptions and reinforce the concept of electronegativity and bond prediction. Encourage students to ask questions and engage in critical thinking.

Conclusion and Wrap-up	Summarize the key points about electronegativity and its role in predicting bond formation. Highlight the importance of electronegativity in understanding the nature of chemical bonds. Encourage students to continue exploring electronegativity and its applications in future topics.

Activity # 3
Materials Needed:

- Whiteboard or blackboard
- Markers or chalk
- Periodic table (physical or digital)
- Chart paper or poster board
- Coloured pens or markers
- Handouts with practice problems (optional)

Procedure

Note for teachers:

- Ensure a clear explanation of electronegativity and its relation to bond formation.
- Use visual aids, such as the periodic table, to enhance students' understanding.
- Monitor students' progress during practice problems and provide guidance as needed.
- Encourage active participation and discussion to foster a deeper understanding of the concept.

Note for students:

- Actively participate in class discussions and ask questions to clarify any doubts.
- Work collaboratively during practice problems to reinforce your understanding of electronegativity and bond prediction.
- Review the periodic table regularly to familiarize yourself with electronegativity trends.

Domain B: Physical Chemistry

Standard:
Explain the relationship between energy and chemical reaction, including exothermic and endothermic.
Apply the principles of thermochemistry to calculate heat transfer and change in enthalpy.

Student Learning Outcomes:

- Explain Gibbs free energy
- Apply the concept of Gibbs free energy to solve problems

• Explain the relationship between Gibbs free energy change, ΔG, and the feasibility of a reaction

Knowledge:	Skills:
Student will Understand ▪ the thermodynamic terms Gibbs Free Energy ▪ role of Gibbs free energy in predicting spontaneity, equilibrium in chemical reactions and the feasibility of a reaction	Student will able to ▪ define Gibbs Free Energy ▪ predict spontaneity, equilibrium in chemical reactions

Perspectives:

– the thermodynamic terms Gibbs Free Energy
– role of Gibbs free energy in predicting spontaneity, equilibrium in chemical reactions and the feasibility of a reaction

Activity # 4

Materials Needed:

- Whiteboard or blackboard
- Markers or chalk
- Periodic table (physical or digital)
- Chart paper or poster board
- Coloured pens or markers
- Handouts with practice problems
- Calculators (optional but recommended for some calculations)

Stage 1: Introduction

- Begin the lesson by introducing the concept of Gibbs Free Energy (G) and its significance in chemical reactions.
- Explain that Gibbs Free Energy is a thermodynamic function that indicates whether a chemical reaction is spontaneous or non-spontaneous under specific conditions.
- Emphasize that Gibbs Free Energy is related to enthalpy (ΔH) and entropy (ΔS) through the equation: $\Delta G = \Delta H - T\Delta S$, where T is the temperature in Kelvin.
- Discuss the concept of spontaneity and how it is related to Gibbs Free Energy. A negative ΔG indicates a spontaneous reaction, while a positive ΔG indicates a non-spontaneous reaction.

Stage 2: Gibbs Free Energy and Spontaneity

- Present a detailed explanation of how to determine the spontaneity of a reaction using Gibbs Free Energy.
- Use the equation $\Delta G = \Delta H - T\Delta S$ to calculate ΔG values for various chemical reactions at different temperatures.

- Demonstrate how to interpret the sign of ΔG to predict whether a reaction is spontaneous or not.

Stage 3: Gibbs Free Energy and Equilibrium

- Explain the relationship between Gibbs Free Energy and chemical equilibrium.
- Discuss the conditions for equilibrium, where $\Delta G = 0$.
- Illustrate how changes in temperature and reaction conditions affect the position of the equilibrium using the Gibbs-Helmholtz equation: $\Delta G = \Delta H - T\Delta S = -RT \ln(K)$, where R is the gas constant and K is the equilibrium constant.

Stage 4: Practice Problems

- Provide handouts with practice problems related to calculating Gibbs Free Energy, determining spontaneity, and predicting equilibrium positions.
- Instruct students to work individually or in pairs to solve the problems.
- Encourage students to use the provided equations and periodic table as needed to perform the calculations.

Stage 5: Group Discussion

- Facilitate a class discussion on the practice problems, allowing students to share their answers and explanations.
- Clarify any misconceptions and reinforce the concept of Gibbs Free Energy and its applications in predicting spontaneity and equilibrium.
- Encourage students to ask questions and engage in critical thinking.

Stage 6: Conclusion and Wrap-up

- Summarize the key points about Gibbs Free Energy and its role in predicting spontaneity and equilibrium in chemical reactions.
- Highlight the importance of understanding Gibbs Free Energy for making predictions about the feasibility of reactions.
- Encourage students to continue exploring thermodynamics and its applications in future topics.

Note for Teachers:

- Ensure a clear explanation of Gibbs Free Energy and its relation to spontaneity and equilibrium.
- Use visual aids and examples to enhance students' understanding of the concept.
- Monitor students' progress during practice problems and provide guidance as needed.
- Encourage active participation and discussion to foster a deeper understanding of Gibbs Free Energy.

Note for Students:

- Actively participate in class discussions and ask questions to clarify any doubts.
- Work collaboratively during practice problems to reinforce your understanding of Gibbs Free Energy and its applications.

- Review the provided equations and concepts regularly to solidify your grasp on the topic.

Domain B: Physical Chemistry

Standard: (Reaction Kinetics) Students should be able to:
Describe the nature of chemical reactions, including the activation energy and rate of reaction.

Student Learning Outcomes:

- Use the Boltzmann distribution curve to explain the effect of temperature on the rate of a reaction

Knowledge:	**Skills:**
Students will Understand ▪ the concept of Boltzmann ▪ distribution constant and its significance in statistical mechanics. ▪ use the Boltzmann distribution curve to explain the effect of temperature on the rate of a reaction	Students will be able to ▪ describe the Boltzmann Distribution and its constant ▪ use the Boltzmann distribution curve to explain the effect of temperature on the rate of a reaction

Perspectives:

– the concept of Boltzmann Distribution Constant and its significance in statistical mechanics.
– use the Boltzmann distribution curve to explain the effect of temperature on the rate of a reaction

Activity # 5
Materials Needed:

- Whiteboard or blackboard
- Markers or chalk
- Handouts with practice problems
- Calculators (optional but recommended for some calculations)

Stage 1: Introduction

- Begin the class activity by introducing the concept of the Boltzmann Distribution Constant (k) and its role in statistical mechanics.
- Explain that k is a fundamental constant that relates temperature and energy in statistical distributions of particles.
- Emphasize that the Boltzmann Distribution describes how particles are distributed among different energy levels in a system at a given temperature.

Stage 2: Basic Concept and Equation

- Present a detailed explanation of the Boltzmann Distribution equation: P(E) = (1/Z) * e^(-E/kT), where P(E) is the probability of a particle being in an energy state E, T is the absolute temperature, k is the Boltzmann constant, and Z is the partition function.
- Discuss the significance of the partition function in calculating probabilities of different energy states.

Stage 3: Interactive Simulation

- Conduct an interactive simulation using the students as "particles" to demonstrate the Boltzmann Distribution.
- Divide the students into different energy states, with each group representing an energy level.
- Have a "temperature moderator" (teacher or student) randomly move the students between energy levels to simulate the distribution of particles at a given temperature.
- Discuss how the distribution changes with temperature and how the Boltzmann Distribution Constant influences the probability of particles being in different states.

Stage 4: Practice Problems

- Provide handouts with practice problems related to the Boltzmann Distribution and the calculation of probabilities for different energy states.
- Instruct students to work individually or in pairs to solve the problems.
- Encourage students to use the Boltzmann Distribution equation and apply their understanding of the concept.

Stage 5: Group Discussion and Conclusion

- Facilitate a class discussion on the simulation and practice problems, allowing students to share their answers and explanations.
- Clarify any misconceptions and reinforce the concept of the Boltzmann Distribution Constant and its significance in statistical mechanics.
- Summarize the key points about the Boltzmann Distribution and its role in describing the distribution of particles in different energy states at a given temperature.

Note for Teachers:

- Ensure active participation of students during the interactive simulation.
- Use visual aids and examples to enhance students' understanding of the concept.
- Encourage student interactions and discussions to foster a deeper understanding of the Boltzmann Distribution Constant.

Note for Students:

- Actively participate in the interactive simulation and group discussions.
- Work collaboratively during practice problems to reinforce your understanding of the Boltzmann Distribution Constant.
- Review the concepts regularly to solidify your grasp on the topic of statistical mechanics.

Domain B: Physical Chemistry

Standard:
Discuss the principles of isotopes, including atomic mass and isotopic abundance.

Student Learning Outcomes:

- Explain how a mass spectrometer can be used to determine the relative atomic mass of an element from its isotopic composition

Knowledge:	**Skills:**
Students will understand, ▪ the experimental determination of molecular mass of a compound from a given mass spectrum ▪ how a mass spectrometer can be used to determine the relative atomic mass of an element from its isotopic composition	Students will be able to, ▪ describe mass spectrum ▪ determine molecular mass of a compound ▪ determine the relative atomic mass of an element from its isotopic composition with the help of a mass spectrometer

Perspectives

- isotopes, including atomic mass and isotopic abundance.
- describe mass spectrum
- determine molecular mass of a compound
- determine the relative atomic mass of an element from its isotopic composition with the help of a mass spectrometer
- the experimental determination of molecular mass of a compound from a given mass spectrum
- how a mass spectrometer can be used to determine the relative atomic mass of an element from its isotopic composition

Activity# 6
Materials Needed:

- Whiteboard or blackboard
- Projector or screen (optional, for displaying mass spectrum)
- Mass spectrometry data of a compound (provided in handouts or projected on the screen)

Stage 1: Introduction

- Begin the activity by briefly introducing the concept of mass spectrometry and its application in determining the molecular mass of compounds.
- Explain that a mass spectrum is a plot of the intensity of ions against their mass-to-charge ratio (m/z).
- Emphasize that students will work together to deduce the molecular mass of a compound based on the given mass spectrum.

Stage 2: Analysing the Mass Spectrum

- Divide the students into small groups (3-4 students per group).
- Provide each group with a mass spectrum of a compound (either in handouts or displayed on the screen).
- Instruct the groups to analyze the mass spectrum collaboratively.
- Guide students to identify the molecular ion peak, fragment peaks, and other relevant peaks in the spectrum.
- Encourage students to discuss and interpret the peak patterns and intensities.

Stage 3: Deduction and Calculation

- Ask each group to deduce the molecular mass of the compound based on the mass spectrum analysis.
- Remind students to consider the mass of the molecular ion and any fragment ions present in the spectrum.
- Assist the groups as needed and encourage them to use critical thinking and problem-solving skills.
- Once each group has calculated the molecular mass, have them share their findings with the class.

Stage 4: Group Presentations and Discussion

- Ask each group to present their deduction process and the calculated molecular mass to the class.
- Encourage other students to ask questions and engage in discussions about the analysis and results.
- Facilitate a class discussion to compare the results from different groups and ensure a clear understanding of the concept.

Note for Teachers:

- Provide support and guidance to students as they analyze the mass spectrum and deduce the molecular mass.

- Encourage active student participation and discussions to foster a student-centred learning environment.
- Use the opportunity to clarify any misconceptions and reinforce the concepts related to mass spectrometry and molecular mass determination.

Note for Students:

- Collaborate and actively participate in the group analysis of the mass spectrum.
- Use critical thinking skills to deduce the molecular mass of the compound based on the given data.
- Be prepared to present your findings to the class and engage in discussions with other students.

Domain B: Physical Chemistry

Standard:
Apply the principles of chemical bonding to explain the physical properties of materials.

Student Learning Outcomes: *Explain the importance of VSEPR theory in the field of drug design by discussing how the shape and bond angles of the molecules helps chemists predict their interactions in the body.*

Knowledge:	**Skills:**
Students will understand, ▪ VSEPR theory ▪ Shape of molecules ▪ the importance of VSEPR theory in the field of drug design.	Students will be able to, ▪ describe VSEPR theory ▪ explain the Shape of molecules with the help of VSEPR theory ▪ explain how the shape and bond angles of the molecules helps chemists predict their interactions in the body. ▪ the importance of VSEPR theory in the field of drug design.

Perspectives:

- chemical bonding and physical properties of materials.
- bonding theory VSEPR theory
- explain the Shape of molecules with the help of VSEPR theory
- explain how the shape and bond angles of the molecules helps chemists predict their interactions in the body.
- the importance of VSEPR theory in the field of drug design

Activity # 7
Materials Needed:

- Whiteboard or blackboard
- Markers or chalk
- Projector or screen (optional, for displaying 3D molecular structures)
- Handouts with practice problems or case studies related to drug design

Stage 1: Introduction

- Begin the activity by introducing the concept of the VSEPR theory and its role in understanding molecular geometries.
- Explain that the VSEPR theory predicts the three-dimensional shapes of molecules based on the repulsion between electron pairs in the valence shell of atoms.
- Emphasize that the knowledge of molecular geometries is essential in drug design to understand how drugs interact with biological targets.

Stage 2: Collaborative Exploration

- Divide the students into small groups (3-4 students per group).
- Provide each group with molecular models or 3D structures of different drug molecules or biological targets (if available).
- Instruct the groups to use the VSEPR theory to determine the molecular geometries of the provided molecules.
- Encourage students to discuss and analyze how the molecular geometry affects the drug's interactions with its target.

Stage 3: Group Discussions and Presentations

- Ask each group to present their findings to the class, focusing on the importance of VSEPR theory in drug design.
- Prompt students to explain how the molecular geometry influences the drug's binding interactions, specificity, and activity.
- Encourage other students to ask questions and engage in discussions about the presented drug molecules and their geometries.

Stage 4: Case Studies or Practice Problems

- Provide handouts with additional case studies or practice problems related to drug design and molecular geometries.
- Instruct the students to work on these problems individually or in groups.
- Foster critical thinking and problem-solving skills as they apply the VSEPR theory to drug design scenarios.

Note for Teachers: ➢ Facilitate student interactions and discussions during the collaborative exploration and group presentations. ➢ Use real-life drug design examples or case studies to illustrate the practical application of the VSEPR theory. ➢ Encourage students to think critically about the relationship between molecular geometries and drug activity. **Note for Students:** ➢ Work collaboratively with your group to explore the molecular geometries of drug molecules. ➢ Prepare to present your findings and insights to the class during the group discussions. ➢ Engage actively in case studies or practice problems to reinforce your understanding of the importance of VSEPR theory in drug design.

<table>
<tr><td colspan="2">Domain B: Physical Chemistry</td></tr>
<tr><td colspan="2">Standard:
Apply the principles of thermochemistry to calculate heat transfer and changes in enthalpy.</td></tr>
<tr><td colspan="2">Student Learning Outcomes:
• Apply Hess's Law to calculate enthalpy changes in a reaction carried out in multiple steps.</td></tr>
<tr><td>Knowledge:
Students will get information about,
▪ the principles of thermochemistry to calculate heat transfer and changes in enthalpy.
▪ the laws of thermodynamics and their application in chemical systems.</td><td>Skills:
Enable students,
▪ to understand Hess's Law to calculate enthalpy changes for chemical reactions
▪ Apply Hess's Law to calculate enthalpy changes in a reaction carried out in single and multiple steps reaction.</td></tr>
<tr><td colspan="2">Perspectives:
– the principles of thermochemistry to calculate heat transfer and changes in enthalpy.
– the laws of thermodynamics and their application in chemical systems.
– to understand Hess's Law to calculate enthalpy changes for chemical reactions</td></tr>
</table>

- apply Hess's Law to calculate enthalpy changes in a reaction carried out in single and multiple steps reaction.

Activity# 8

Materials Needed:

- Whiteboard or blackboard
- Markers or chalk
- Chemicals for conducting three different chemical reactions (e.g., magnesium ribbon, hydrochloric acid, copper oxide, etc.)
- Calorimeter or Styrofoam cups for measuring heat changes (optional but recommended)
- Thermometer
- Safety goggles and lab coats

Stage 1: Introduction to Hess's Law

- Begin the activity by introducing the concept of Hess's Law and its significance in calculating enthalpy changes.
- Explain that Hess's Law states that the total enthalpy change for a reaction is independent of the reaction pathway and depends only on the initial and final states.
- Emphasize that it allows us to calculate enthalpy changes indirectly by using known enthalpy changes of other reactions.

Stage 2: Experimental Setup

- Divide the students into small groups (3-4 students per group).
- Provide each group with the necessary chemicals and equipment to conduct three different chemical reactions, each with a known enthalpy change.
- Instruct the groups to conduct the reactions and measure the heat changes using a calorimeter or Styrofoam cups.

Stage 3: Calculating Enthalpy Changes

- After the reactions are completed, guide the groups to calculate the enthalpy changes for each reaction based on the measured heat changes.
- Instruct the students to record their results and make sure they understand the calculations.

Stage 4: Applying Hess's Law

- Once the groups have calculated the enthalpy changes for each reaction, explain how to apply Hess's Law to find the enthalpy change for a target reaction.
- Provide a target reaction and guide the students to use the known enthalpy changes of the three reactions they conducted to calculate the enthalpy change for the target reaction.

Stage 5: Group Discussions and Presentations

- Ask each group to present their findings and results to the class, explaining how they applied Hess's Law to calculate the enthalpy change for the target reaction.
- Encourage other students to ask questions and engage in discussions about the application of Hess's Law.

Note for Teachers:

- ➢ Facilitate student interactions and discussions during the experimental setup and group presentations.
- ➢ Provide guidance and support as needed, especially during the application of Hess's Law to calculate enthalpy changes.

Note for Students:

- ➢ Work collaboratively with your group during the experimental setup and calculations.
- ➢ Prepare to present your findings and insights to the class during the group presentations.
- ➢ Engage actively in discussions to understand the application of Hess's Law in calculating enthalpy changes.

Domain B: Physical Chemistry

Standard:

Explain the relationship between concentration of reactants or products and the position of equilibrium.

Student Learning Outcomes:

- Determine the relationship between different equilibrium constants for the same reaction at the same temperature
- Write the equilibrium expression for a given chemical reaction in terms of concentration, Kc, partial pressure Kp, number of moles Kn and mole fraction, Kx.

Knowledge:	**Skills:**
Students will get concept of, ▪ chemical equilibrium ▪ the equilibrium expression for a given chemical reaction in terms of concentration ▪ equilibrium constant and the position of equilibrium. ▪ the relationships between different	Students will be able to, ▪ write the equilibrium expression for a given chemical reaction in terms of concentration ▪ predict the position of equilibrium. ▪ write the relationships between different equilibrium constants (Kp, Kc, and Kx) for chemical reactions.

equilibrium constants (Kp, Kc, and Kx) for chemical reactions.	

Perspectives:

- chemical equilibrium with example
- the equilibrium expression for a given chemical reaction in terms of concentration
- equilibrium constant and the position of equilibrium.
- the relationships between different equilibrium constants (Kp, Kc, and Kx) for chemical reactions

Activity # 9

Materials Needed:

- Whiteboard or blackboard
- Markers or chalk
- Chemicals for conducting two reversible chemical reactions (e.g., the reaction between iron chloride and silver nitrate to form iron nitrate and silver chloride)
- Apparatus for measuring pressures and concentrations (e.g., pressure gauges, volumetric flasks)
- Safety goggles and lab coats

Stage 1: Introduction

- Begin the activity by introducing the concept of equilibrium constants (Kp, Kc, and Kx) and their significance in understanding the state of equilibrium for chemical reactions.
- Explain that Kp is the equilibrium constant expressed in terms of partial pressures of gases, Kc is the equilibrium constant expressed in terms of molar concentrations, and Kx is the equilibrium constant expressed in terms of other properties, such as activities or solubilities.

Stage 2: Experimental Setup

- Divide the students into small groups (3-4 students per group).
- Provide each group with the necessary chemicals and equipment to conduct two reversible chemical reactions.
- Instruct the groups to set up the reactions and measure the equilibrium concentrations for both reactions.

Stage 3: Calculating Equilibrium Constants

- After the reactions have reached equilibrium, guide the groups to calculate the equilibrium constants (Kp and Kc) for each reaction based on the measured concentrations and pressures.

- Instruct the students to record their results and make sure they understand the calculations.

Stage 4: Applying the Relationship between Equilibrium Constants

- Once the groups have calculated the equilibrium constants for both reactions, explain the relationship between Kp and Kc for reactions involving gases and how to convert between them using the ideal gas law.
- Provide a sample reaction involving gases and guide the students to convert the equilibrium constant (Kc) to Kp using the appropriate equation.

Stage 5: Group Discussions and Presentations

- Ask each group to present their findings and results to the class, including the calculated equilibrium constants and their relationship for the reactions they conducted.
- Encourage other students to ask questions and engage in discussions about the relationships between different equilibrium constants.

Note for Teachers:

- ➢ Facilitate student interactions and discussions during the experimental setup and group presentations.
- ➢ Provide guidance and support as needed, especially during the calculation of equilibrium constants and their relationships.

Note for Students:

- ➢ Work collaboratively with your group during the experimental setup and calculations.
- ➢ Prepare to present your findings and insights to the class during the group presentations.
- ➢ Engage actively in discussions to understand the relationships between different equilibrium constants.

Domain B: Physical Chemistry
Standard: Discuss the use of buffers to control pH, including the relationship between buffer capacity and the concentration of buffer components.
Student Learning Outcomes: • Calculate the pH of buffer solutions from given appropriate data.

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Knowledge:
Enable students to understand,

- the concept of buffer solutions
- calculate their pH of solutions

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Skills:
Students will be able,

- To define the buffer solutions
- calculate their pH of solutions

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Perspectives:

- acid, base concept
- pH, concentration of H ion concentration
- the concept of buffer solutions
- buffer solution is a mixture of a weak acid and its conjugate base or a weak base and its conjugate acid.
- calculate their pH of solutions

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Activity # 10

Materials Needed:

- Whiteboard or blackboard
- Markers or chalk
- pH meter or pH indicator paper
- Chemicals to prepare buffer solutions (e.g., acetic acid and sodium acetate)
- Beakers or containers for preparing buffer solutions
- Calculators

Stage 1: Introduction

- Begin the activity by introducing the concept of buffer solutions and their significance in maintaining a stable pH.
- Explain that a buffer solution is a mixture of a weak acid and its conjugate base or a weak base and its conjugate acid.
- Emphasize that buffer solutions resist large changes in pH when small amounts of acid or base are added.

Stage 2: Experimental Setup

- Divide the students into small groups (3-4 students per group).
- Provide each group with the necessary chemicals and equipment to prepare buffer solutions of different concentrations.
- Instruct the groups to prepare buffer solutions using a weak acid (e.g., acetic acid) and its conjugate base (e.g., sodium acetate).

Stage 3: pH Measurement

- After preparing the buffer solutions, guide the groups to measure the pH of each solution using a pH meter or pH indicator paper.

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- Instruct the students to record their pH measurements and make sure they understand how to use the pH meter or indicator paper.

Stage 4: Calculating pH of Buffer Solutions

- Explain to the students how to calculate the pH of a buffer solution using the Henderson-Hasselbalch equation: $pH = pKa + \log([A-]/[HA])$.
- Provide the pKa value for the weak acid used in the buffer solutions and the concentrations of the conjugate base and weak acid.
- Instruct the groups to calculate the pH of their buffer solutions using the Henderson-Hasselbalch equation.

Stage 5: Group Discussions and Presentations

- Ask each group to present their findings and results to the class, including the calculated pH values for their buffer solutions.
- Encourage other students to ask questions and engage in discussions about buffer solutions and pH calculations.

Note for Teachers:

- Facilitate student interactions and discussions during the experimental setup and pH measurements.
- Provide guidance and support as needed, especially during the calculation of pH for buffer solutions.

Note for Students:

- Work collaboratively with your group during the experimental setup and pH calculations.
- Prepare to present your findings and insights to the class during the group presentations.
- Engage actively in discussions to understand the concept of buffer solutions and pH calculations.

Domain E: Organic Chemistry	
Standard: Perform basic retro-synthetic analysis to deduce the starting materials for the synthesis of a target molecule.	
Student Learning Outcomes: • Explain the concept of retro-synthesis and its application in organic synthesis.	
Knowledge:	**Skills:**

Enable students to understand, – the retrosynthetic analysis. – the application of retro-synthesis in organic synthesis.	Students will be capable to, – explain the retrosynthetic analysis. – apply retro-synthesis in organic synthesis.

Perspectives:

- the retrosynthetic analysis.
- the application of retro-synthesis in organic synthesis.

Activity # 11

Materials Needed:

- Whiteboard or blackboard
- Markers or chalk
- Handouts with complex molecules and their retrosynthetic analysis
- Organic chemistry model kits (optional but recommended)
- Safety goggles and lab coats

Stage 1: Introduction to Retrosynthesis

- Begin the activity by introducing the concept of retrosynthesis and its significance in organic chemistry.
- Explain that retrosynthesis is a strategic process to break down complex molecules into simpler starting materials or building blocks.
- Emphasize that retrosynthetic analysis is a crucial skill for designing efficient and practical synthesis routes in organic chemistry.

Stage 2: Retrosynthetic Analysis Practice

- Divide the students into small groups (3-4 students per group).
- Provide each group with handouts containing complex molecules and their retrosynthetic analysis.
- Instruct the groups to analyze the given molecules and perform retrosynthetic analysis to identify potential starting materials or intermediates.

Stage 3: Organic Chemistry Model Kit Activity

- If available, provide organic chemistry model kits to the groups for a hands-on activity.
- Instruct the groups to use the model kits to visualize the retrosynthetic analysis and build the identified starting materials or intermediates.
- Encourage students to discuss and explain their strategies for retrosynthesis and synthesis using the model kits.

Stage 4: Group Discussions and Presentations

- Ask each group to present their retrosynthetic analysis and their chosen synthesis routes to the class.
- Encourage other students to ask questions and engage in discussions about the retrosynthetic analysis strategies.

Stage 5: Conclusion and Wrap-up

- Summarize the key points about retrosynthesis and its importance in organic chemistry synthesis.
- Emphasize the practical applications of retrosynthetic analysis in drug design and other areas of organic chemistry.

Note for Teachers:

- ➢ Facilitate student interactions and discussions during the retrosynthetic analysis and model kit activity.
- ➢ Provide guidance and support as needed, especially during the analysis of complex molecules.

Note for Students:

- ➢ Work collaboratively with your group during the retrosynthetic analysis and model kit activity.
- ➢ Prepare to present your findings and insights to the class during the group discussions.
- ➢ Engage actively in discussions to understand the concept of retrosynthesis and its applications in organic chemistry.

GRADE XII

Domain F: Empirical Data Collection and Analysis

Standard:
Compare and contrast different types of spectroscopy (e.g. infrared, ultraviolet-visible, nuclear magnetic resonance).
Use spectroscopic techniques to identify unknown compounds in a mixture.

Student Learning Outcomes:
- Predict the colour of a transition metal complex from its UV/visible spectrum.

Knowledge:	**Skills:**
Student will study the, ▪ different types of spectroscopies (e.g. infrared, ultraviolet-visible, nuclear magnetic resonance). ▪ use of spectroscopic techniques to identify unknown compounds in a mixture.	Student will be able to, ▪ use of spectroscopic (e.g. infrared, ultraviolet-visible, nuclear magnetic resonance) techniques to identify unknown compounds in a mixture.

Perspectives:
Spectroscopy
- types of spectroscopy infrared, ultraviolet-visible, nuclear magnetic resonance
- introducing the concept of transition metal complexes and their characteristic colours.
- UV-Vis spectra of different transition metal complexes
- UV-Vis spectra and corresponding colours of transition metal complexes
- use of spectroscopic techniques to identify unknown compounds in a mixture.

Activity # 12
Materials Needed:

- Whiteboard or blackboard
- Markers or chalk
- UV-Vis spectrophotometer or access to UV-Vis spectra of different transition metal complexes
- Handouts with UV-Vis spectra and corresponding colours of transition metal complexes
- Safety goggles and lab coats

Stage 1: Introduction
- Begin the activity by introducing the concept of transition metal complexes and their characteristic colours.

- Explain that the colour of transition metal complexes arises due to the absorption of certain wavelengths of light in the UV-Vis region.
- Emphasize that the UV-Vis spectrum provides valuable information about the electronic transitions within the complexes, leading to their distinct colours.

Stage 2: UV-Vis Spectrum Analysis

- Divide the students into small groups (3-4 students per group).
- Provide each group with handouts containing UV-Vis spectra of different transition metal complexes and their corresponding colours.
- Instruct the groups to analyze the provided spectra and identify the wavelength of maximum absorption (λ_{max}) for each complex.

Stage 3: Colour Prediction and Justification

- After analyzing the UV-Vis spectra, guide the groups to predict the colour of each transition metal complex based on their knowledge of the relationship between absorption and colour.
- Instruct the students to justify their predictions by relating them to the wavelengths of maximum absorption (λ_{max}) and electronic transitions.

Stage 4: Group Discussions and Presentations

- Ask each group to present their predictions and justifications for the colours of the transition metal complexes to the class.
- Encourage other students to ask questions and engage in discussions about the relationship between UV-Vis spectra and the colours of transition metal complexes.

Stage 5: Conclusion and Wrap-up

- Summarize the key points about the relationship between the colour of transition metal complexes and their UV-Vis spectra.
- Emphasize the importance of UV-Vis spectroscopy in characterizing transition metal complexes and understanding their electronic transitions.

Note for Teachers:

- ➢ Facilitate student interactions and discussions during the UV-Vis spectrum analysis and colour prediction.
- ➢ Provide guidance and support as needed, especially in relating UV-Vis spectra to the colours of transition metal complexes.

Note for Students:

- ➢ Work collaboratively with your group during the UV-Vis spectrum analysis and colour prediction.
- ➢ Prepare to present your predictions and justifications to the class during the group discussions.

- Engage actively in discussions to understand the relationship between UV-Vis spectra and the colours of transition metal complexes.

Domain B: Physical Chemistry

Standard:(Electrochemistry) Students should be able to:
Describe the principles of electrochemistry, including the movement of electrons in terms of oxidation and reduction in a chemical reaction.
Explain the concept of oxidation and reduction, including the role of electrons in these processes. .

Student Learning Outcomes:

- Apply the concept of changes in oxidation numbers to balance chemical equations.
- Apply the concept of oxidation numbers in identifying oxidation and reduction reactions.
- Define the terms redox, oxidation, reduction, and disproportionation (in terms of electron transfer and changes in oxidation number).

Knowledge:	Skills:
Students will get knowledge of, ▪ Electrochemistry ▪ the oxidation and reduction reaction. ▪ Balancing the chemical equations using changes in oxidation numbers.	Students will be able to, ▪ Define the Electrochemistry ▪ Define and identify the oxidation and reduction reaction. ▪ Balance the chemical equations by oxidation numbers method.

Perspectives:

- Definition of electrochemistry
- Insulator & conductors
- Electrochemical reaction
- Oxidation number
- Describe the principles of electrochemistry, including the movement of electrons in terms of oxidation and reduction in a chemical reaction.
- Explain the concept of oxidation and reduction, including the role of electrons in these processes.

Activity #1

Materials Needed:

- Whiteboard or blackboard
- Markers or chalk

- Handouts with chemical equations to balance
- Calculators (optional but recommended)
- Safety goggles and lab coats

Stage 1: Introduction

- Begin the activity by introducing the concept of oxidation numbers and their role in balancing chemical equations.
- Explain that oxidation numbers indicate the charge of an atom in a compound and can help identify which elements are oxidized or reduced during a reaction.
- Emphasize that changes in oxidation numbers can be used to balance redox reactions.

Stage 2: Handout with Unbalanced Equations

- Divide the students into small groups (3-4 students per group).
- Provide each group with handouts containing chemical equations that are not balanced.
- Instruct the groups to identify the elements undergoing oxidation and reduction and calculate the change in oxidation numbers for each element.

Stage 3: Balancing Chemical Equations

- Guide the groups to use the changes in oxidation numbers to balance the chemical equations.
- Instruct the students to write half-reactions for oxidation and reduction, and then balance the atoms and charges on each side.
- Encourage the groups to collaborate and discuss their approaches to balancing the equations.

Stage 4: Group Discussions and Presentations

- Ask each group to present their balanced chemical equations to the class, explaining their reasoning and steps in the balancing process.
- Encourage other students to ask questions and engage in discussions about the balancing of redox reactions.

Stage 5: Conclusion and Wrap-up

- Summarize the key points about balancing chemical equations using changes in oxidation numbers.
- Emphasize the importance of understanding oxidation numbers in identifying redox reactions and balancing them effectively.

Note for Teachers:

- Facilitate student interactions and discussions during the equation balancing process.
- Provide guidance and support as needed, especially in understanding changes in oxidation numbers.

Note for Students:

- Work collaboratively with your group during the equation balancing process.
- Prepare to present your balanced chemical equations and explanations to the class during the group discussions.
- Engage actively in discussions to understand the concept of changes in oxidation numbers in balancing chemical equations.

Domain F: Empirical Data Collection and Analysis

Standard: (Spectroscopy)
Use spectroscopic techniques to identify unknown compounds in a mixture.

Student Learning Outcomes:

- Explain that the degree of unsaturation or index of hydrogen deficiency (IHD) can be used to determine from a molecular formula the number of rings or multiple bonds in a molecule.

Knowledge:	**Skills:**
Students will get knowledge of, ▪ spectroscopic techniques to identify unknown compounds in a mixture. ▪ spectroscopic techniques to measure the degree of unsaturation (index of hydrogen deficiency) and how it can be used to determine the number of rings or multiple bonds in a molecule.	Students will be able to, ▪ identify unknown compounds in a mixture by spectroscopic methods. ▪ determine the number of rings or multiple bonds in a molecule by measure of the degree of unsaturation in organic compounds.

Perspectives:

- spectroscopic techniques to identify unknown compounds in a mixture.
- spectroscopic techniques to measure the degree of unsaturation (index of hydrogen deficiency) and how it can be used to determine the number of rings or multiple bonds in a molecule.useful for identifying aromatic compounds and compounds with double or triple bonds.
- identify unknown compounds in a mixture by spectroscopic methods.
- determine the number of rings or multiple bonds in a molecule by measure of the degree of unsaturation in organic compounds

Activity # 2

Materials Needed:

- Whiteboard or blackboard
- Markers or chalk
- Handouts with molecular structures of various organic compounds
- Calculators (optional but recommended)
- Safety goggles and lab coats

Stage 1 - Introduction

- Begin the activity by introducing the concept of degree of unsaturation (DU) or index of hydrogen deficiency (IHD).
- Explain that DU is a value calculated from the molecular formula of an organic compound and provides information about the presence of rings or multiple bonds.
- Emphasize that DU is particularly useful for identifying aromatic compounds and compounds with double or triple bonds.

Stage 2 - Handout with Molecular Structures

- Divide the students into small groups (3-4 students per group).
- Provide each group with handouts containing molecular structures of various organic compounds (with their molecular formulas).
- Instruct the groups to calculate the degree of unsaturation for each compound using the given molecular formulas.

Stage 3 - Calculating Degree of Unsaturation

- Guide the groups to calculate the degree of unsaturation using the formula: $DU = (2 * C + 2 + N - H - X) / 2$, where C is the number of carbon atoms, N is the number of nitrogen atoms, H is the number of hydrogen atoms, and X is the number of halogen atoms.
- Instruct the students to record their calculated values and ensure they understand the process.

Stage 4 - Group Discussions and Presentations

- Ask each group to present their calculated degrees of unsaturation for the compounds to the class.
- Encourage other students to ask questions and engage in discussions about the concept of degree of unsaturation and its applications.

Stage 5 - Conclusion and Wrap-up

- Summarize the key points about degree of unsaturation and its significance in determining the number of rings or multiple bonds in a molecule.
- Emphasize the practical applications of DU in organic chemistry and structure determination.

Note for Teachers:

- Facilitate student interactions and discussions during the degree of unsaturation calculations.
- Provide guidance and support as needed, especially in understanding the concept and applying the formula.

Note for Students:

- Work collaboratively with your group during the degree of unsaturation calculations.
- Prepare to present your calculated values and explanations to the class during the group discussions.
- Engage actively in discussions to understand the concept of degree of unsaturation and its use in determining molecular structure.

Domain F: Empirical Data Collection and Analysis

Standard: (Spectroscopy)
The students will be able to:
Analyze spectra to determine the presence and concentration of chemical species.
Use spectroscopic techniques to identify unknown compounds in a mixture.

Student Learning Outcomes:

- Deduce possible structures for organic compounds using IR spectrum and molecular formula (Examples: phenol, acetone, ethanol)
- **I**nterpret an infrared (IR) spectrum of a simple molecule to identify functional groups

Knowledge:	**Skills:**
Students will learn to, ▪ interpret infrared (IR) spectra of organic compounds ▪ deduce possible structural features.	Students will be able to, ▪ interpret infrared (IR) spectra of organic compounds ▪ deduce possible structural features.

Perspectives:

- introducing the concept of infrared (IR) spectroscopy and its application in identifying organic compounds.

Interpret infrared (IR) spectra of organic compounds and deduce possible structural features

- IR spectroscopy provides information about the functional groups present in a compound based on the absorption of infrared radiation by specific chemical bonds.
- functional groups and their characteristic peaks in the IR spectrum.
- deduce possible structural features of the organic compounds based on the identified functional groups.

- instruct the students to consider the types of bonds and functional groups present in each compound.
- encourage the groups to collaborate and discuss their deductions of possible structures.

Activity # 3

Materials Needed:

- Whiteboard or blackboard
- Markers or chalk
- Handouts with IR spectra of various organic compounds
- Safety goggles and lab coats

Stage 1: Introduction to IR Spectroscopy

- Begin the activity by introducing the concept of infrared (IR) spectroscopy and its application in identifying organic compounds.
- Explain that IR spectroscopy provides information about the functional groups present in a compound based on the absorption of infrared radiation by specific chemical bonds.
- Emphasize that different functional groups exhibit characteristic peaks in the IR spectrum.

Stage 2: Handout with IR Spectra

- Divide the students into small groups (3-4 students per group).
- Provide each group with handouts containing IR spectra of various organic compounds.
- Instruct the groups to analyse the IR spectra and identify prominent peaks corresponding to specific functional groups.

Stage 3: Deduction of Possible Structures

- Guide the groups to deduce possible structural features of the organic compounds based on the identified functional groups.
- Instruct the students to consider the types of bonds and functional groups present in each compound.
- Encourage the groups to collaborate and discuss their deductions of possible structures.

Stage 4: Group Discussions and Presentations

- Ask each group to present their deductions of possible structures for the organic compounds to the class.
- Encourage other students to ask questions and engage in discussions about the interpretation of IR spectra.

Stage 5: Conclusion and Wrap-up

- Summarize the key points about interpreting IR spectra and deducing possible structures of organic compounds.
- Emphasise the importance of IR spectroscopy in characterising and identifying organic molecules.

Note for Teachers:

- Facilitate student interactions and discussions during the interpretation of IR spectra and structure deduction process.
- Provide guidance and support as needed, especially in understanding the IR peaks and functional groups.

Note for Students:

- Work collaboratively with your group during the interpretation of IR spectra and deduction of possible structures.
- Prepare to present your deductions and explanations to the class during the group discussions.
- Engage actively in discussions to understand the concept of IR spectroscopy and its applications in organic compound analysis.

Domain F: Empirical Data Collection and Analysis	
Standard: (NMR) The students should be able to: Describe the basic principles of NMR spectroscopy and explain how it is used to determine the structure of organic molecules Distinguish between the different types of NMR spectra and interpret the information they provide	
Student Learning Outcomes: • Use a ^{1}H NMR spectrum to deduce relative numbers of each type of proton present, the number of equivalent protons on the carbon atom adjacent to the one to which the given proton is attached. • Analyse the different environments of protons present in a simple molecule using a ^{1}H (proton) NMR spectrum.	
Knowledge: Students will understand,	**Skills:** Students will be able to,

▪ the basic principles of NMR spectroscopy a how NMR is used to determine the structure of organic molecules ▪ interpretation of NMR spectrum ▪ the concept of chemical shift and splitting patterns of protons in a given molecule.	▪ describe the basic principles of NMR spectroscopy and explain how it is used to determine the structure of organic molecules ▪ distinguish between the different types of NMR spectra and interpret the information they provide ▪ use a H^{1} NMR spectrum to deduce relative numbers of each type of proton present.

Perspectives:

- concept of nuclear magnetic resonance (NMR) the basic principles of NMR spectroscopy a how NMR is used to determine the structure of organic molecules
- interpretation of NMR spectrum
- NMR spectroscopy provides information about the local environments of hydrogen atoms (protons) in a compound
- the concept of chemical shift and splitting patterns of protons in a given molecule

Activity # 4

Materials Needed:

- Whiteboard or blackboard
- Markers or chalk
- Handouts with molecular structures of various organic compounds
- NMR spectra charts or tables
- Safety goggles and lab coats

Stage 1: Introduction to NMR Spectroscopy

- Begin the activity by introducing the concept of nuclear magnetic resonance (NMR) spectroscopy and its application in studying organic molecules.
- Explain that NMR spectroscopy provides information about the local environments of hydrogen atoms (protons) in a compound.
- Emphasize that the chemical shift and splitting pattern of proton signals in the NMR spectrum can reveal valuable information about the molecular structure.

Stage 2: Handout with Molecular Structures

- Divide the students into small groups (3-4 students per group).
- Provide each group with handouts containing molecular structures of various organic compounds.

- Instruct the groups to analyze the given structures and predict the chemical shift and splitting patterns for the protons in each compound.

Stage 3: NMR Spectra Charts and Tables

- Provide NMR spectra charts or tables with typical chemical shift ranges for different types of protons (e.g., alkyl, alkene, aromatic, etc.) and their corresponding splitting patterns (e.g., singlet, doublet, triplet, etc.).
- Guide the groups to use these charts or tables to predict the chemical shifts and splitting patterns based on the local environments of the protons in the compounds.

Stage 4: Group Discussions and Presentations

- Ask each group to present their predictions of chemical shifts and splitting patterns for the protons in the given compounds to the class.
- Encourage other students to ask questions and engage in discussions about NMR spectroscopy principles and proton analysis.

Stage 5: Conclusion and Wrap-up

- Summarize the key points about predicting proton chemical shifts and splitting patterns using NMR spectroscopy.
- Emphasize the importance of NMR spectroscopy in structural elucidation and compound analysis.

Note for Teachers:

- ➢ Facilitate student interactions and discussions during the proton analysis and NMR spectroscopy principles.
- ➢ Provide guidance and support as needed, especially in understanding chemical shifts and splitting patterns.

Note for Students:

- ➢ Work collaboratively with your group during the proton analysis and NMR spectroscopy predictions.
- ➢ Prepare to present your predictions and explanations to the class during the group discussions.
- ➢ Engage actively in discussions to understand the concept of NMR spectroscopy and its applications in proton analysis.

Domain F: Empirical Data Collection and Analysis

Standard: (NMR)
The students should be able to:
Distinguish between the different types of NMR spectra and interpret the information they provide

Student Learning Outcomes:
- Describe the identification of O–H and N–H protons by proton exchange using D_2O

Knowledge:	**Skills:**
Enable will understand ▪ the proton exchange method to distinguish different protons in an organic compound.	Enable students to distinguish ▪ different protons of organic compounds (i.e. O–H and N–H protons) by proton exchange using D_2O.

Perspectives:
- introducing the concept of proton exchange and its significance in distinguishing between O-H and N-H protons in organic compounds.
- the Proton exchange method to distinguish different protons in an organic compound
- D_2O, exchange of labile (easily exchangeable) protons with deuterium (D) occurs.
- rate of proton exchange varies depending on the nature of the proton and its chemical environment.
- identify the peaks corresponding to O-H and N-H protons and discuss their observations.

Activity # 5
Materials Needed:

- Whiteboard or blackboard
- Markers or chalk
- Organic compounds with O-H and N-H protons (e.g., ethanol and methylamine)
- Deuterium oxide (D_2O)
- NMR spectrometer (optional but recommended)
- Safety goggles and lab coats

Stage 1: Introduction to Proton Exchange Experiment
- Begin the activity by introducing the concept of proton exchange and its significance in distinguishing between O-H and N-H protons in organic compounds.
- Explain that when a compound is dissolved in D_2O, exchange of labile (easily exchangeable) protons with deuterium (D) occurs.
- Emphasize that the rate of proton exchange varies depending on the nature of the proton and its chemical environment.

Stage 2: Experimental Setup

- Divide the students into small groups (3-4 students per group).
- Provide each group with organic compounds containing O-H and N-H protons (e.g., ethanol and methylamine).
- Instruct the groups to dissolve a small amount of each compound in D_2O and observe the changes in the NMR spectra.

Stage 3: NMR Spectroscopy Analysis

- If available, guide the groups to analyse the NMR spectra of the dissolved compounds before and after proton exchange using an NMR spectrometer.
- Instruct the students to identify the peaks corresponding to O-H and N-H protons and discuss their observations.

Stage 4: Group Discussions and Presentations

- Ask each group to present their findings and interpretations of the NMR spectra to the class.
- Encourage other students to ask questions and engage in discussions about proton exchange and NMR spectroscopy.

Stage 5: Conclusion and Wrap-up

- Summarise the key points about identifying O-H and N-H protons through proton exchange using D_2O as a solvent.
- Emphasise the practical applications of proton exchange experiments in NMR spectroscopy.

Note for Teachers:

- ➢ Facilitate student interactions and discussions during the proton exchange experiment and NMR spectroscopy analysis.
- ➢ Provide guidance and support as needed, especially in understanding the NMR spectra.

Note for Students:

- ➢ Work collaboratively with your group during the proton exchange experiment and NMR spectroscopy analysis.
- ➢ Prepare to present your findings and interpretations to the class during the group discussions.
- ➢ Engage actively in discussions to understand the concept of proton exchange and its role in NMR spectroscopy.

Domain F: Empirical Data Collection and Analysis

Standard:(Materials)
The students should be able to:
Discuss the extraction of materials from natural sources.
Assess the toxicity of materials and the effects of exposure on human health and the environment, and recommend measures to reduce these impacts.

Student Learning Outcomes:

- Explain the process of extracting metal (Cu) from ore and alloying them to achieve desired characteristics.

Knowledge:	**Skills:**
Students will**,** ▪ understand the process of extracting metals from its ores.	Students will be able to, ▪ understand the process of extracting metals from its ores.

Perspectives:

– define ore
– concept of ore extraction and its significance in obtaining metals from their ores.
– explain that ores are naturally occurring mineral deposits containing valuable metals that need to be extracted using suitable methods.
– emphasize that different metals require different extraction techniques based on their reactivity and abundance.
– extracting metals from ores and the significance of different extraction methods.

Activity # 6
Materials Needed:

- o Whiteboard or blackboard
- o Markers or chalk
- o Handouts with information on different extraction methods
- o Samples of ores (if available)
- o Safety goggles and lab coats

Stage 1: Introduction to Ore Extraction

- Begin the activity by introducing the concept of ore extraction and its significance in obtaining metals from their ores.
- Explain that ores are naturally occurring mineral deposits containing valuable metals that need to be extracted using suitable methods.
- Emphasize that different metals require different extraction techniques based on their reactivity and abundance.

Stage 2: Overview of Extraction Methods

- Divide the students into small groups (3-4 students per group).

- Provide each group with handouts containing information on different extraction methods such as smelting, roasting, leaching, and electrolysis.
- Instruct the groups to study the extraction methods and their applications for specific types of ores.

Stage 3: Hands-on Exploration

- If available, provide samples of different ores to the groups for hands-on exploration.
- Instruct the students to observe the ores' properties, discuss their compositions, and consider which extraction method would be suitable for each ore.

Stage 4: Group Discussions and Presentations

- Ask each group to present their findings and conclusions regarding the most appropriate extraction methods for the given ores.
- Encourage other students to ask questions and engage in discussions about ore extraction processes.

Stage 5: Conclusion and Wrap-up

- Summarize the key points about the process of extracting metals from ores and the significance of different extraction methods.
- Emphasize the importance of sustainable and environmentally friendly extraction practices.

Note for Teachers:

- ➢ Facilitate student interactions and discussions during the hands-on exploration and group presentations.
- ➢ Provide guidance and support as needed, especially in understanding the extraction methods and their applications.

Note for Students:

- ➢ Work collaboratively with your group during the hands-on exploration and discussions about ore extraction.
- ➢ Prepare to present your findings and conclusions to the class during the group discussions.
- ➢ Engage actively in discussions to understand the concept of ore extraction and the various extraction methods used in metallurgy.

Domain E: Organic Chemistry

Standard: (Hydroxy Compounds) Students should be able to:
Explain the reaction mechanisms and products of alcohol reactions, including oxidation, esterification, and dehydration.

Student Learning Outcomes:

- Describe the reaction of alcohol with acyl chlorides to form esters (ethyl ethanoate)

Knowledge:	**Skills:**
Students will get knowledge to, ▪ explain the reaction mechanisms and products ▪ oxidation reaction esterification, and dehydration.	Students will be able to**,** ▪ explain the reaction mechanisms and products ▪ oxidation reaction esterification, and dehydration.

Perspectives:

- by introducing the concept of acyl chlorides and their importance in organic synthesis.
- explain that acyl chlorides are reactive compounds containing the functional group -COCl.
- emphasize that acyl chlorides undergo various reactions with nucleophiles, alcohols, amines, and water.

Activity # 7

Materials Needed:

- Whiteboard or blackboard
- Markers or chalk
- Handouts with information on reactions of acyl chlorides
- Acyl chloride samples (e.g., acetyl chloride, benzoyl chloride)
- Reagents for various reactions (e.g., alcohols, amines, water, etc.)
- Safety goggles and lab coats

Stage 1: Introduction to Acyl Chlorides

- Begin the activity by introducing the concept of acyl chlorides and their importance in organic synthesis.
- Explain that acyl chlorides are reactive compounds containing the functional group -COCl.
- Emphasize that acyl chlorides undergo various reactions with nucleophiles, alcohols, amines, and water.

Stage 2: Overview of Acyl Chloride Reactions

- Divide the students into small groups (3-4 students per group).
- Provide each group with handouts containing information on different reactions of acyl chlorides.
- Instruct the groups to study the reactions and their mechanisms.

Stage 3: Hands-on Exploration

- Provide acyl chloride samples and various reagents (alcohols, amines, water, etc.) to the groups.
- Instruct the students to perform simple reactions between acyl chlorides and the given reagents and observe the outcomes.

Stage 4: Group Discussions and Presentations

- Ask each group to present their experimental results and observations to the class.
- Encourage other students to ask questions and engage in discussions about the reactivity of acyl chlorides.

Stage 5: Conclusion and Wrap-up

- Summarize the key points about the reactions of acyl chlorides and their importance in organic synthesis.
- Emphasize the practical applications of acyl chloride reactions in various industries.

Note for Teachers:

- ➢ Facilitate student interactions and discussions during the hands-on exploration and group presentations.
- ➢ Provide guidance and support as needed, especially in understanding the reaction mechanisms.

Note for Students:

- ➢ Work collaboratively with your group during the hands-on exploration and discussions about acyl chloride reactions.
- ➢ Prepare to present your experimental results and observations to the class during the group discussions.
- ➢ Engage actively in discussions to understand the concept of acyl chloride reactions and their applications in organic chemistry.

Domain E: Organic Chemistry	
Standard: (Nitrogen Compounds) Students should be able to: Describe the structure and properties of Nitrogen Compounds, including their characteristic functional groups.	
Student Learning Outcomes: • Explain why amides are much weaker bases than amines	
Knowledge: Students will get knowledge about, ▪ amides ▪ properties of amide i.e. basic properties.	**Skills:** Enable students to investigate, ▪ the functional group Amides ▪ basic properties of amide.

Perspectives:

- amide & amine functional group
- amides and amines and their differences in basicity.
- amides and amines are both nitrogen-containing compounds, but their functional groups influence their basicity.
- lone pair of electrons on the nitrogen atom in amines is more available for accepting protons, making them stronger bases than amides.

Activity # 8
Materials Needed:

- Whiteboard or blackboard
- Markers or chalk
- Handouts with information on the basicity of amides and amines
- Samples of amides (e.g., acetamide) and amines (e.g., methylamine)
- pH indicator strips or pH meters
- Safety goggles and lab coats

Stage 1: Introduction to Amides and Amines

- Begin the activity by introducing the concept of amides and amines and their differences in basicity.
- Explain that amides and amines are both nitrogen-containing compounds, but their functional groups influence their basicity.
- Emphasize that the lone pair of electrons on the nitrogen atom in amines is more available for accepting protons, making them stronger bases than amides.

Stage 2: Comparison of Basicity

- Divide the students into small groups (3-4 students per group).
- Provide each group with handouts containing information on the basicity of amides and amines.
- Instruct the groups to compare the basicity of amides and amines based on the provided information.

Stage 3: Experimental Investigation

- Provide samples of amides (e.g., acetamide) and amines (e.g., methylamine) to the groups.
- Instruct the students to test the basicity of the samples using pH indicator strips or pH meters by measuring the pH of their aqueous solutions.

Stage 4: Group Discussions and Presentations

- Ask each group to present their findings and conclusions regarding the basicity of amides and amines to the class.
- Encourage other students to ask questions and engage in discussions about the factors influencing basicity.

Stage 5: Conclusion and Wrap-up

- Summarize the key points about the basicity of amides and amines and the reasons behind their differences.
- Emphasize the importance of understanding basicity in the context of organic chemistry and chemical reactivity.

Note for Teachers:

- Facilitate student interactions and discussions during the comparison of basicity and experimental investigation.
- Provide guidance and support as needed, especially in understanding the factors affecting basicity.

Note for Students:

- Work collaboratively with your group during the comparison of basicity and experimental investigation.
- Prepare to present your findings and conclusions to the class during the group discussions.
- Engage actively in discussions to understand the concept of basicity and the differences between amides and amines.

Domain E: Organic Chemistry

Standard: (Polymer) Students should be able to:
Describe the structure and properties of polymers, including homopolymers and copolymers.

Student Learning Outcomes:

- Explain the chemical processes and properties of PVC and nylon, and the applications of these polymers in the industry.

Knowledge:	**Skills:**
Students will get information about, ▪ the structure and properties of polymers PVC and Nylon.	Students will be able to, ▪ explain the chemical processes and properties of PVC and nylon, ▪ describe the applications of these polymers in the industry.

Perspectives:

- introduction of PVC and Nylon. Chemical formula

- the chemical processes and properties of PVC and nylon,
- the applications of these polymers in the industry.

Activity # 9

Materials Needed:

- Whiteboard or blackboard
- Markers or chalk
- Handouts with information on the process and properties of PVC and Nylon
- PVC and Nylon samples (if available)
- Safety goggles and lab coats

Stage 1: Introduction to PVC and Nylon

- Begin the activity by introducing the concept of PVC (Polyvinyl Chloride) and Nylon and their significance in the polymer industry.
- Explain that PVC is a synthetic polymer derived from vinyl chloride monomers, and Nylon is a synthetic polyamide.
- Emphasize the importance of these polymers in various applications due to their unique properties.

Stage 2: Overview of Manufacturing Process

- Divide the students into small groups (3-4 students per group).
- Provide each group with handouts containing information on the manufacturing process of PVC and Nylon.
- Instruct the groups to study the processes and the chemical reactions involved in their production.

Stage 3: Hands-on Exploration

- If available, provide samples of PVC and Nylon to the groups.
- Instruct the students to observe the physical properties of the samples and discuss their characteristics.

Stage 4: Group Discussions and Presentations

- Ask each group to present their understanding of the manufacturing process and properties of PVC and Nylon to the class.
- Encourage other students to ask questions and engage in discussions about the applications and significance of these polymers.

Stage 5: Conclusion and Wrap-up

- Summarize the key points about the manufacturing process and properties of PVC and Nylon.
- Emphasize the importance of these polymers in our daily lives and their contributions to various industries.

Note for Teachers:

- Facilitate student interactions and discussions during the exploration of PVC and Nylon.
- Provide guidance and support as needed, especially in understanding the manufacturing processes.

Note for Students:

- Work collaboratively with your group during the exploration of PVC and Nylon.
- Prepare to present your findings and explanations to the class during the group discussions.
- Engage actively in discussions to understand the concept of PVC and Nylon properties and their applications.

Domain E: Organic Chemistry

Standard: (Organic Synthesis)
The students should be able to:
Identify and name common organic functional groups and their physical and chemical properties.

Student Learning Outcomes: Enable students to

- Describe the use of Artificial Intelligence tools in designing organic molecules, which may have the potential to be used as medicine. (Halicin can be used as an example)

Knowledge:	**Skills:**
Students will get information of, ▪ artificial intelligence tools ▪ the applications of artificial intelligence tools in the field of organic chemistry.	Students will enable to understand, ▪ artificial intelligence tools ▪ the applications of artificial intelligence tools in the field of organic chemistry.

Perspectives

- introducing the concept of artificial intelligence (AI) and its growing impact on various industries, including chemistry.
- explain that AI tools are being increasingly used in organic chemistry to aid in the design and optimization of new molecules with specific properties.
- importance of AI in accelerating the drug discovery process and materials science.

Activity # 10

Materials Needed:

- Whiteboard or blackboard
- Markers or chalk
- Handouts with information on AI tools in organic molecule design
- Computers or tablets with internet access (optional but recommended)
- Safety goggles and lab coats

Stage 1: Introduction to AI Tools in Organic Molecule Design

- Begin the activity by introducing the concept of artificial intelligence (AI) and its growing impact on various industries, including chemistry.
- Explain that AI tools are being increasingly used in organic chemistry to aid in the design and optimization of new molecules with specific properties.
- Emphasize the importance of AI in accelerating the drug discovery process and materials science.

Stage 2: Overview of AI Applications in Organic Molecule Design

- Divide the students into small groups (3-4 students per group).
- Provide each group with handouts containing information on AI tools and their applications in organic molecule design.
- Instruct the groups to study the applications of AI in different areas of organic chemistry.

Stage 3: Hands-on Exploration

- If possible, provide access to computers or tablets with internet access.
- Instruct the students to explore online resources or AI platforms that demonstrate the use of AI tools in designing organic molecules.
- Encourage them to perform virtual experiments, visualize how AI algorithms can predict molecular properties, and optimize structures.

Stage 4: Group Discussions and Presentations

- Ask each group to present their findings and insights on the use of AI tools in organic molecule design to the class.
- Encourage other students to ask questions and engage in discussions about the potential benefits and limitations of AI in this context.

Stage 5: Conclusion and Wrap-up

- Summarize the key points about the applications of AI in designing organic molecules and its impact on the field of organic chemistry.
- Emphasize the importance of keeping up with advancements in technology to stay informed about cutting-edge tools in the scientific community.

Note for Teachers:

- Facilitate student interactions and discussions during the exploration of AI tools in organic molecule design.

- ➢ Provide guidance and support as needed, especially in understanding the AI applications.

Note for Students:

- ➢ Work collaboratively with your group during the exploration of AI tools in organic molecule design.
- ➢ Prepare to present your findings and insights to the class during the group discussions.
- ➢ Engage actively in discussions to understand the concept of AI applications in organic chemistry and its potential implications.

Domain F: Empirical Data Collection and Analysis

Standard: (NMR)
The students will be able to:
Explain how carbon-13 NMR spectra provide unique information about the structure of organic molecules.
Analyse carbon-13 NMR spectra to deduce the structure of simple organic compounds and recognize common spectral patterns in the spectra of different types of compounds.

Student Learning Outcomes:

- Predict the number of peaks in a C-13 NMR spectrum for a given molecule.
- Use a C-13 NMR spectrum to deduce possible structures of a simple molecule.

Knowledge:	**Skills:**
Students will get knowledge to, ▪ understand C-13 NMR ▪ the use of C-13 NMR to predict structure of molecules.	Students will be able to, ▪ use a C-13 NMR spectrum to describe the structure of molecule.

Perspectives:

- NMR and C-13 NMR chemical shift values
- C-13 NMR spectroscopy and its application in organic compound analysis
- The use of C-13 NMR to predict structure of molecules
- Use a C-13 NMR spectrum to describe the structure of molecule
- NMR spectra its interpretation

Activity # 11

Materials Needed:

- o Whiteboard or blackboard
- o Markers or chalk
- o Handouts with information on 13C NMR spectroscopy and chemical shift values

- Molecular models or drawings of organic compounds (if available)
- Safety goggles and lab coats

Stage 1: Introduction to 13C NMR Spectroscopy

- Begin the activity by introducing the concept of 13C NMR spectroscopy and its application in organic compound analysis.
- Explain that 13C NMR spectroscopy provides information about the carbon environments in a molecule, and each unique carbon environment gives rise to a distinct peak in the spectrum.
- Emphasize that the number of peaks in a 13C NMR spectrum is determined by the different types of carbon atoms present in the compound.

Stage 2: Overview of Carbon Environments

- Divide the students into small groups (3-4 students per group).
- Provide each group with handouts containing information on different carbon environments and their corresponding chemical shift values in 13C NMR spectra.
- Instruct the groups to study the different types of carbon atoms and their characteristic chemical shifts.

Stage 3: Hands-on Exploration

- Provide molecular models or drawings of organic compounds to the groups.
- Instruct the students to identify the different types of carbon environments in the given molecules and predict the number of peaks they would expect to see in the 13C NMR spectrum.

Stage 4: Group Discussions and Presentations

- Ask each group to present their predictions of the number of peaks in the 13C NMR spectrum for the given molecules to the class.
- Encourage other students to ask questions and engage in discussions about the factors influencing the chemical shifts and peak numbers.

Stage 5: Conclusion and Wrap-up

- Summarize the key points about predicting the number of peaks in a 13C NMR spectrum based on carbon environments.
- Emphasize the importance of 13C NMR spectroscopy in identifying carbon connectivity and functional groups in organic compounds.

Note for Teachers:

- Facilitate student interactions and discussions during the exploration of 13C NMR spectroscopy.
- Provide guidance and support as needed, especially in understanding the different carbon environments.

Note for Students:

- Work collaboratively with your group during the exploration of 13C NMR spectroscopy and carbon environments.
- Prepare to present your predictions and explanations to the class during the group discussions.
- Engage actively in discussions to understand the concept of 13C NMR spectroscopy and its applications in organic compound analysis.

Grade 9 & 10

Domain: Atomic Structure

Standard: Students should be able to:

- Describe the arrangement of electrons in the electron shells and explain how this arrangement affects the chemical properties of an atom.

Benchmark I:

Students can describe the structure of atoms, including the protons, neutrons, and electrons and using these concepts to discuss Isotopes.

Knowledge:	Skills:
Students will know, ▪ how an atom is structured and the subatomic particles it contains. ▪ arrangement of electrons in the subshells and the electronic configurations of the elements. ▪ the quantum theory understanding of atomic orbitals and radius. Students will understand ▪ terms like quantization, isotopes, orbitals, and ionization.	Students will be able to, ▪ describe atoms as the fundamental particles of elements and their structures. ▪ understand the phenomena of ionization and its relation with the atomic number and atomic size. ▪ evaluate the forces involved at subatomic levels and estimate their relative magnitudes. ▪ explain the stability of an atomic structure. ▪ discuss the theory of atomic structure starting from Rutherford, continuing through Bohr and explaining the modern quantum theory.

Perspectives

- **Evolution of atomic theory:** This perspective highlights the historical development of atomic theory, from ancient Greek philosopher Democritus' idea of atoms to John

Dalton's law of definite proportions and atomic theory. For example, students can learn about how the discovery of electrons by J. J. Thomson, and the subsequent development of atomic models by Niels Bohr and Ernest Rutherford, led to a deeper understanding of the structure of atoms.

- **Atom-molecule interaction:** This perspective focuses on how the properties of atoms and molecules interact and affect the properties of materials. For example, students can learn about the effect of electronic configuration on the reactivity of elements, and how the arrangement of atoms in a molecule affects its shape and reactivity.

- **Modern applications:** This perspective emphasizes the practical applications of atomic theory and its impact on fields such as medicine, energy, and technology. For example, students can learn about the role of atomic theory in the development of X-ray crystallography and its use in determining the structures of biological molecules, as well as the use of nuclear reactions in nuclear power plants and medical imaging.

Learning Activities

1. **Creating a Trending Periodic Table**

Objective: To understand the trends in the periodic table and their relation to the electronic configuration of elements.

Materials:
- 18 elements with their atomic number, symbol, and electronegativity
- 18 blank periodic table sheets for each student or group
- Coloured pens or markers

Procedure:
- Give each student or group a set of data for 18 elements, including their atomic number, symbol, and electronegativity.
- Instruct students to use the data to create their own periodic table, organizing the elements based on their electronegativity trend.
- Encourage students to use different colours or symbols to represent the trends and make their periodic table visually appealing.
- Once they have finished creating their periodic table, have them present their work to the class and discuss their reasoning behind their arrangements.
- As a class, compare the different periodic tables and discuss the similarities and differences in the arrangements.
- Facilitate a discussion on the trends in electronegativity and their relationship to the electronic configuration of elements.

Assessment:

- Observe student participation and engagement during the presentation and discussion of their periodic tables.
- Evaluate their periodic table for accuracy and the use of colour or symbols to represent the trends in electronegativity.
- Assess their understanding of the relationship between electronegativity and electronic configuration through class discussions and questions.

Expected Results:
Students will have a clear understanding of the trends in electronegativity in the periodic table.
Students will have the ability to apply their understanding of electronic configuration to explain the trends in electronegativity.
Students will have engaged in higher-order thinking skills through the creation and presentation of their periodic table.

Demonstration:
Students can observe the spectra of different elements and compare the patterns to determine the elements' electronic configurations. The teacher can lead a discussion about how spectroscopy is used in real-world chemistry applications. In case a laser and grating are not available, spectroscopic data can be used.

Grade 11 & 12

Domain: Physical Chemistry

Standard: Students should be able to:
Discuss the factors that affect bond strength, including bond length and bond energy.

Benchmark I: Students can apply the concepts of chemical bonding and bond theories to predict the structure and properties of molecules, including molecular geometry, and polarity.

Knowledge:	Skills:
Students will know, ▪ The concept of chemical bonding and the various types of bonds atoms form. ▪ The relative strengths of atomic bonds and the forces involved in each of them. ▪ The concept of covalent bonds and the different theories that explain the shapes, strengths, and lengths of these bonds. ▪ The concept of Hydrogen Bonding and its involvement in maintaining the	Students will be able to, ▪ Explain the structure of different compounds formed as a result of chemical bonding and compare their relative strengths and characteristics. ▪ Explain the geometry of molecules and understand different shapes the atoms can arrange in based on the kind of bond involved.

structure of molecules like water and ammonia. Students will understand, ● Terms like Electronegativity, Van der Waals' forces, Dipoles, and Hybridization.	▪ Compare the theories concerning the formation of covalent bonds and their postulates and predictions about the bond length and strength. ▪ Evaluate the involved intermolecular forces between molecules and their role in determining the physical and chemical properties of the compounds.

Perspectives:

- **The development of chemical bonding theories:** From early bonding theories like the ionic and covalent models to more recent developments like orbital hybridization and molecular orbitals, understanding the evolution of chemical bonding theories can provide a deeper appreciation for how our understanding of chemical bonds has changed over time.
- **The role of chemical bonding in determining the properties of matter:** Chemical bonding plays a key role in determining the properties of matter, such as melting and boiling points, reactivity, and solubility. Understanding how different bonding types can lead to different properties can help students understand why different materials behave in unique ways.
- **The interplay between chemical bonding and the environment:** Chemical bonding can play a role in environmental issues, such as air and water pollution, soil contamination, and climate change. Understanding the mechanisms behind chemical bonding reactions can help students appreciate the impact of these reactions on the environment and the potential for human actions to mitigate these effects.

Learning Activities

Trend in electronegativity across period 3

Materials:

- Sodium (Na), Magnesium (Mg), Aluminium (Al), Silicon (Si), Phosphorus (P), Sulphur (S), Chlorine (Cl), Argon (Ar)
- Beaker of distilled water
- Litmus paper
- Test tubes
- Pipettes

Procedure:

- Prepare 10 test tubes, one for each element in the list above.
- Label each test tube with the name of the element.

- Using a pipette, add 1 mL of distilled water to each test tube.
- Add a small piece of each element to each test tube, starting with Sodium and ending with Calcium.
- Observe the reaction of each element with water and record the results in a data table.
- Use the results to create a periodic table with the elements arranged in order of increasing electronegativity.

Element	**Reaction with water**	**Electronegativity**
Na	Releases hydrogen gas, forms a basic solution	Lowest by using isolated wooden box and gloves
Mg	Releases hydrogen gas, forms a basic solution	Low
Al	No reaction	Moderate
Si	No reaction	Moderate
P	Reacts to form a neutral solution	Moderate
S	Reacts to form an acidic solution	High
Cl	Reacts to form an acidic solution	Highest
Ar	No reaction	N/A
K	Releases hydrogen gas, forms a basic solution	Low
Ca	No reaction	Moderate

Expected Results:

- Sodium and Potassium will react with water to release hydrogen gas, forming a basic solution.
- Magnesium will also release hydrogen gas, but to a lesser extent than Sodium and Potassium.
- Aluminium and Silicon will not react with water.
- Phosphorus will react with water to form a neutral solution.
- Sulphur will react with water to form an acidic solution.
- Chlorine will react with water to form an acidic solution, showing the highest electronegativity.
- Argon is an inert gas and will not react with water.

Conclusion:

The trend in electronegativity of period 3 elements can be observed by their behaviour in aqueous solutions. The electronegativity of the elements increases from Sodium to Chlorine, with Sodium having the lowest electronegativity and Chlorine having the highest. This activity demonstrates the relationship between electronegativity and the ability of an element to attract electrons from other atoms in a chemical bond.

Grade - 09

Domain: Environmental Chemistry
Topic: Atmosphere

Standard: Students should be able to:
Describe the role of Sulphur in the formation of acid rain and its impact on the environment. Describe the role of NO and NO_2 in the formation of acid rain, both directly and through their catalytic role in the oxidation of atmospheric sulphur dioxide.

- **Benchmark I:** Demonstrate an understanding of the composition and structure of the Earth's atmosphere, including the role of atmospheric gases, pollutants and greenhouse effect.

Knowledge:	Skills:
Students will know, ▪ composition of air and the leading sources of air pollutants in the atmosphere. ▪ the sources of these pollutants and their effects on human and atmospheric health. ▪ chemical reactions between the pollutants and the atmospheric gases to produce smog and acid rain. ▪ economic and environmental issues underlying changing air quality.	Students will be able to, ▪ make suggestions about fighting climate change. ▪ discuss the main sources of air pollution and make recommendations for fixing them. ▪ explain the harmful effects of smog and acid rain and present precautionary measures to avoid these effects. ▪ provide suggestions on making energy sources renewable.

Perspectives

- **Understanding the composition and structure of the Earth's atmosphere:**
  - Discuss how the composition of the Earth's atmosphere changes with altitude, including the presence of trace gases such as ozone and carbon dioxide.
  - In the context of Pakistan, mention the impact of increasing industrialization and urbanization on air quality, specifically in cities such as Karachi and Lahore.
- **Exploring the role of the atmosphere in the Earth's climate:**
  - Discuss how the atmosphere plays a crucial role in regulating the Earth's temperature through the greenhouse effect.
  - Mention the impact of climate change on the monsoon patterns in Pakistan, and its effects on agriculture and water availability.

- **Examining the sources and effects of atmospheric pollutants:**
  - Discuss the sources of air pollutants, including industrial emissions, vehicular emissions, and natural sources.
  - In the context of Pakistan, mention the air pollution crisis in cities like Lahore, which is caused by the high levels of vehicular and industrial emissions.
- **Applying the principles of chemical reactions to explain the formation and removal of atmospheric pollutants:**
  - Discuss the chemical reactions that lead to the formation of air pollutants, such as the reaction of nitrogen oxides and volatile organic compounds to form ground-level ozone.
  - Mention the efforts being made to combat air pollution, such as the installation of scrubbers in power plants and the promotion of alternative modes of transportation.

Learning Activities

1. **Measuring the Amount of Oxygen in the Air**

Objective: To measure the amount of oxygen in the air using common household materials.

Materials:

- Small, clear plastic bottle with a lid
- Water
- Alka-Seltzer/Aspirin tablet
- Scale
- Ruler

Procedure:

- Fill the bottle with water, leaving about 1 inch of air space at the top.
- Measure the initial volume of air in the bottle using the ruler. Record the volume in millilitres.
- Crush an Alka-Seltzer/Aspirin tablet into a fine powder and add it to the water in the bottle.
- Quickly screw the lid on the bottle, making sure it is tightly sealed.
- Observe the reaction of the Alka-Seltzer with the water, which will produce carbon dioxide gas. The carbon dioxide gas will displace the air in the bottle, increasing the volume of the bottle.
- Measure the final volume of the bottle using the ruler. Record the volume in millilitres.
- Calculate the volume of air displaced by subtracting the initial volume from the final volume.

- The volume of air displaced is directly proportional to the amount of oxygen in the air. You can use the following conversion factor to determine the percentage of oxygen in the air:

(Volume of air displaced / Total volume of the bottle) * 100 = % oxygen in the air.

Precautions:
Make sure to crush the Alka-Seltzer tablet into a fine powder before adding it to the water to maximize the amount of carbon dioxide produced.
Make sure to screw the lid on the bottle tightly to prevent the carbon dioxide from escaping.
The reaction between Alka-Seltzer and water can get quite vigorous, so be careful not to spill any of the solution while measuring the final volume of the bottle.

References:

Chem1.com. (n.d.). Alka-Seltzer and the Ideal Gas Law. [online] Available at: https://www.chem1.com/acad/sci/aboutgaslaws.html [Accessed 9 Feb 2023]

Science Bob. (n.d.). How much Oxygen is in the Air? [online] Available at: https://www.sciencebob.com/how-much-oxygen-is-in-the-air/ [Accessed 9 Feb 2023].

2. **Investigating Air Pollution with Bumper Stickers**

Objective:
To study the effects of air pollution on the environment and understand the role of nitrogen oxides and sulphur dioxide in the formation of acid rain.

Materials:
- Bumper stickers or adhesive labels
- Markers
- Plastic bags
- Ruler or measuring tape

Procedure:
- Cut out a bumper sticker or adhesive label and place it inside a plastic bag. Seal the bag.
- Label the bag with the date and time it was collected.
- Place the bag in an area with high air pollution, such as near a busy road or industrial area. Leave it there for 24 hours.
- Remove the bag and examine the bumper sticker. Observe any discoloration or changes in colour.

- Repeat steps 1 to 4 in a clean air area, such as a park or a countryside.
- Compare the bumper stickers from the two different locations and discuss the differences in discoloration or colour changes.
- Measure the size of any discoloured areas on both stickers and compare the results.

Analysis:
The bumper stickers will change colour due to the presence of nitrogen oxides and sulphur dioxide in the air. The discoloration will be more pronounced in the bumper sticker from the area with high air pollution. The discoloration of the bumper sticker is a result of acid rain formation caused by the nitrogen oxides and sulphur dioxide in the air.

Conclusion:
This activity helps students understand the effects of air pollution on the environment and the role of nitrogen oxides and sulphur dioxide in the formation of acid rain. Students will appreciate the importance of reducing air pollution to protect our environment.

References:
United States Environmental Protection Agency (EPA). (2021). Air Pollution and Your Health. Retrieved from https://www.epa.gov/air-pollution-and-your-health

United States Environmental Protection Agency (EPA). (2021). What is Acid Rain? Retrieved from https://www.epa.gov/acidrain/what-acid-rain

National Center for Biotechnology Information (NCBI). (2021). Air Pollution: Types, Sources, Effects and Control. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6936902/

Lesson Plans on Conducting Experiments in the Lab

<table>
<tr><td colspan="4">Chemistry Experiment – Grade 09</td></tr>
<tr><td>Subject: Chemistry</td><td>Level: Grade 09</td><td colspan="2">Topic:
Investigating the pH of common household substances</td></tr>
<tr><td colspan="2">Name of teacher:</td><td colspan="2">Duration: 80 min.</td></tr>
<tr><td colspan="4">Objectives
By the end of this lab students will be able to;
o To understand the concept of acids and bases and the pH scale.
o To learn how to use a pH meter to measure the pH of different household substances.
o To compare and analyze the pH values of various household substances.
o To relate the pH values of the substances to their acidic or basic nature.</td></tr>
<tr><td colspan="4">Materials and Apparatus
▪ pH meter or pH indicator paper
▪ Distilled water
▪ 0.1 M Hydrochloric acid (HCl)
▪ 0.1 M Sodium hydroxide (NaOH)
▪ Vinegar
▪ Baking soda
▪ Lemon juice
▪ Soap solution
▪ Salt
▪ Tap water
▪ 10 small beakers
▪ Dropper
▪ Stirring rod</td></tr>
<tr><td colspan="3">Methodology</td><td>Duration and Resources</td></tr>
</table>

Introduction: 1. **Introduction to Acids and Bases**: The teacher will begin the lesson by introducing the concept of acids and bases to the students. They will explain the difference between acids and bases, the pH scale, and how to measure pH using indicators. 2. **Safety Procedures:** The teacher will go over the safety procedures for the lab, including wearing goggles and aprons, handling chemicals carefully, and cleaning up spills. 3. **Demonstration:** The teacher will perform a demonstration of an acid-base reaction using a universal indicator to show how the pH changes. 4. **Discussion:** The students will discuss the demonstration and predict what will happen when different acids and bases are mixed. 5. **Objective:** The teacher will explain the objective of the lab, which is to determine the pH of common household substances.	15 minutes
Main Activity: 1. **Materials:** The teacher will provide each group with a set of materials, including a pH meter or paper, various household substances, and a data sheet.	05 Minutes
2. **Procedure:** The teacher will explain the procedure for testing the pH of the substances. The students will use the pH meter or paper to test the pH of each substance and record the results on their data sheet.	25 Minutes
3. **Discussion:** As the students are testing the substances, the teacher will ask questions to encourage critical thinking and discussion. They may ask about the properties of the substances that affect pH, or the potential uses of the substances in industry or everyday life.	15 Minutes
4. **Analysis:** Once all the substances have been tested, the students will analyse the data to identify patterns and draw conclusions. They may be asked to create graphs or charts to represent the data.	10 Minutes
Wrap-up: 1. **Conclusion:** The teacher will ask the students to share their findings and discuss what they learned. They will summarize the main concepts of the lab, including the difference between acids and bases, how to measure pH, and the pH of common household substances.	10 Minutes

2. **Applications:** The teacher will discuss some real-world applications of pH testing, such as testing the pH of swimming pools, soil, or drinking water. 3. **Clean up:** The students will clean up their workstations, dispose of any materials according to safety procedures, and return any equipment to the teacher.	

Assessment	▪ Students will be assessed based on their participation in the experiment and their ability to accurately measure the pH of the substances. ▪ Students will be asked to write a short reflection on the experiment, highlighting the importance of understanding the pH of household substances.
Extensions	▪ Students can further investigate the effect of adding an acid or base to a neutral substance. ▪ Students can explore the pH values of different fruits and vegetables and their importance in nutrition. ▪ Students can also investigate the effect of pH on the growth of plants.

Teacher's Reflections	
What went as planned?	**What needs Improvements?**

Chemistry Experiment – Grade 10		
Subject: Chemistry	**Level: Grade 10**	**Topic:** Acid-base Titration
Name of teacher:		**Duration:** 80 min.

Objectives

By the end of this lab students will be able to;

- To learn the principles of acid-base titration
- To practice the technique of titration
- To determine the concentration of an unknown acid or base
- Practice recording and analyzing data.
- Develop teamwork and communication skills.

Materials and Apparatus

- 0.1 M sodium hydroxide (NaOH)
- 0.1 M hydrochloric acid (HCl)
- Phenolphthalein indicator
- Burette
- Pipette
- Conical flask
- Distilled water

Methodology	Duration and Resources
Introduction: • The teacher will begin by introducing the concept of acid-base titration to the students. • The teacher will explain the importance of titration in various fields of chemistry and its significance in determining the concentration of a solution. • The teacher will also explain the basic principles of acid-base titration, including the use of indicators, burettes, and conical flasks.	15 minutes
Main Activity: **Phase 01:** 1. The teacher will provide each student with a burette, pipette, and conical flask. 2. The teacher will demonstrate the proper technique for filling a burette and how to properly dispense the titrant into the solution. 3. Each student will be provided with a solution of either 0.1 M NaOH or 0.1 M HCl. 4. The student will use a pipette to measure a specific volume of the unknown solution into a conical flask.	25 Minutes

5. The student will then add a few drops of phenolphthalein indicator to the solution. **Phase 02:** 6. The student will begin the titration process by slowly adding the titrant (NaOH or HCl) to the solution while stirring the solution. 7. The student will continue adding the titrant until the endpoint is reached (the point at which the indicator changes colour). 8. The student will record the volume of the titrant used to reach the endpoint. 9. The student will repeat the process three times to ensure accurate results.	25 Minutes
Wrap-up: **1.** The teacher will lead a discussion on the results obtained by the students and the importance of accuracy in titration. **2.** The teacher will provide a brief explanation of how to calculate the concentration of the unknown solution using the data collected during the titration. **3.** The students will be asked to calculate the concentration of the unknown solution using the data collected. **4.** The teacher will explain the importance of using standardized solutions in titration and the consequences of not doing so.	15 Minutes

Assessment	Assessment of student learning can be conducted through the following means: • The teacher will evaluate the accuracy and completeness of the data collected by the students. • The teacher will assess the students' ability to correctly calculate the concentration of the unknown solution. • The teacher will ask follow-up questions to assess the students' understanding of the principles of acid-base titration.
Extensions	If time permits, the following extension activities can be used to further enhance student's knowledge and skills: • The teacher can provide additional challenges to the students by using more complex titrations or unknown solutions of varying concentrations. • The students can explore the use of different indicators in acid-base titrations and their effect on the accuracy of results.

	• The students can explore the use of different types of titrations, such as redox or precipitation titrations, and their applications in various fields of chemistry.

Teacher's Reflections	
What went as planned?	**What needs Improvements?**

Chemistry Experiment – Grade 11		
Subject: Chemistry	**Level: Grade 11**	**Topic:** Determination of the Stoichiometry of a Chemical Reaction
Name of teacher:		**Duration:** 80 min.

Objectives

By the end of this lab students will be able to;

- To understand the concept of stoichiometry and how it is used in chemical reactions
- To determine the stoichiometry of a chemical reaction experimentally
- To develop skills in using a balance and other laboratory equipment
- To learn to write balanced chemical equations
- Practice recording and analyzing data.
- Develop teamwork and communication skills.

Materials and Apparatus

- Magnesium ribbon
- Hydrochloric acid solution (1M)
- Burette
- Graduated cylinder
- Erlenmeyer flask
- Bunsen burner
- Wire gauze
- Tripod stand
- Stopwatch
- Safety goggles
- Lab apron

Methodology	**Duration and Resources**

<table>
<tr><td>Introduction:
• The teacher will introduce the topic of stoichiometry and its importance in chemistry.
• The teacher will explain the concept of a chemical reaction and balanced chemical equations.
• The teacher will demonstrate how to write balanced chemical equations.</td><td>15 minutes</td></tr>
<tr><td>Main Activity:
Phase 01:
1. The teacher will divide the students into groups of two.
2. Each group will be provided with the necessary equipment and chemicals.
3. The students will weigh a 5 cm length of magnesium ribbon and record its mass.
4. The students will add 25 mL of 1M hydrochloric acid to an Erlenmeyer flask and place the flask on top of a wire gauze.
5. The students will carefully add the weighed magnesium ribbon to the flask and start the stopwatch.
6. The students will observe the reaction and record the time it takes for the reaction to complete (when no more bubbles are seen).</td><td>30 Minutes</td></tr>
<tr><td>Phase 02:
7. The students will carefully rinse and fill a burette with sodium hydroxide (NaOH) solution.
8. The students will titrate the excess hydrochloric acid in the flask with the NaOH solution until the reaction is neutralized.
9. The students will record the volume of NaOH solution used.
10. The students will repeat the experiment two more times to obtain an average time and volume of NaOH solution used.
11. The students will calculate the stoichiometry of the reaction using the balanced chemical equation and their experimental results.</td><td>25 Minutes</td></tr>
<tr><td>Wrap-up:
1. The teacher will guide the students through the process of calculating the stoichiometry of the reaction.
2. The students will share their results and discuss any discrepancies in their data.
3. The teacher will summarize the key concepts learned in the lab activity.</td><td>10 minutes</td></tr>
</table>

<table>
<tr><td>Assessment</td><td>Assessment of student learning can be conducted through the following means:
The students' laboratory reports will be assessed based on the completeness and accuracy of their data, calculations, and conclusions.
The students' participation in the activity and their ability to work collaboratively and safely in the laboratory will also be evaluated.</td></tr>
<tr><td>Extensions</td><td>If time permits, the following extension activities can be used to further enhance student's knowledge and skills:
The students can investigate how changing the concentration of hydrochloric acid or magnesium affects the reaction rate and stoichiometry.
The students can also explore other chemical reactions and determine their stoichiometry using the same methodology.</td></tr>
<tr><td colspan="2">Teacher’s Reflections</td></tr>
<tr><td>What went as planned?</td><td>What needs Improvements?</td></tr>
</table>

Chemistry Experiment – Grade 12		
Subject: Chemistry	**Level: Grade 12**	**Topic:** Determination of the Enthalpy Change of a Chemical Reaction
Name of teacher:		**Duration:** 80 min.

Objectives

By the end of this lab students will be able to;

- To understand the concept of enthalpy change and its significance in chemical reactions
- To learn the technique of calorimetry to measure the enthalpy change of a chemical reaction
- To apply the knowledge of enthalpy change to calculate the heat of reaction and understand its implications
- Practice recording and analysing data.
- Develop teamwork and communication skills.

Materials and Apparatus

- 2 Styrofoam cups
- Thermometer
- Weighing balance
- Stirrer
- Graduated cylinder
- Hot plate
- Magnesium ribbon
- Hydrochloric acid (HCl)
- Distilled water

Methodology	**Duration and Resources**
Introduction: • Begin by introducing the concept of enthalpy change and its significance in chemical reactions. • Explain the principle of calorimetry and its use in measuring the enthalpy change of a chemical reaction. • Discuss the difference between exothermic and endothermic reactions.	15 minutes
Main Activity: **Phase 01:** 1. Instruct the students to weigh approximately 0.2 grams of magnesium ribbon and place it in a Styrofoam cup. 2. Add 50 mL of 1.0 M hydrochloric acid to the cup and stir gently. 3. Take the initial temperature of the solution and record it. 4. Monitor the temperature for 2-3 minutes until the reaction is complete. 5. Take the final temperature of the solution and record it.	30 Minutes

Phase 02: 6. Repeat the experiment twice or more to ensure accuracy. (if possible) 7. After completing the experiment, have students calculate the enthalpy change of the reaction using the equation: $\Delta H = q/n$ Where ΔH is the enthalpy change, q is the heat absorbed or released by the reaction, and n is the number of moles of the limiting reactant. 8. Discuss the implications of the calculated enthalpy change and its relationship with the heat of reaction. **Wrap-up:** 1. Summarize the key concepts covered in the lab activity. 2. Ask students to share their observations and experiences during the experiment. 3. Emphasize the importance of understanding enthalpy change in chemical reactions and its applications in various industries.	20 Minutes 15 Minutes
Assessment	Students will be assessed on their understanding of the principles of calorimetry and their ability to calculate the enthalpy change of a chemical reaction. The accuracy and precision of their experimental data will also be evaluated.
Extensions	Students can research and present on the practical applications of enthalpy change in industries such as food, pharmaceuticals, and energy production. Students can also explore other chemical reactions and calculate their enthalpy change using the techniques learned in the lab activity.
Teacher's Reflections	
What went as planned?	**What needs Improvements?**

GUIDELINES TO TEXTBOOK AUTHORS

As the textbooks/textual material is an important teaching and learning tool to understand the subjects. Writing textbook is an extremely important, highly technical and delicate task to assist both teachers and students in earning and transmission of the life experiences. It required the translation of curriculum learning outcomes at the proper Cognitive level of learners /students. The concept to be introduced be explained informally before providing the formal definition or statement along with tangible examples from real life situation. The solved examples and the exercises should cover the whole range of variety of questions and their applications in the everyday life. Before writing textbook authors are required to understand the curriculum in letter and spirit. The following key point keep in mind:

i) Back ground knowledge of development of National Curriculum (Physics)-2023
ii) Understanding of Rationale and Format for National Curriculum Framework (NCF).
iii) Complete understanding of contents/ progression grids of curriculum
iv) Understanding of the CPA (Concrete -Pictorial- Abstract approach)
v) Realization of responsibilities as Textbook Author

Keeping above strategy in view, the author should observe the following guidelines while writing the textbooks.

1. Learning objectives expected to be achieved in each chapter/unit should be prominently stated at the beginning of the chapter/unit.
2. The contents should be authentic, updated and well organize in sequential order throughout the books.
3. Headings and sub headings should be clearly indicated.
4. Key words, terms and definitions should be highlighted in the text.
5. Concepts, application and relationships should be developed from concrete to abstract or simple to complex.
6. The intended level and scope of treatment of each content/concept is defined by the desired learning outcomes identifying learning abilities, Investigation Skills/ Laboratory work and relevance with Science, Technology , Engineering, the Arts and Mathematics (STEAM). STEAM integrate these disciplines into cohesive learning paradigm based on real life application.
7. Concepts, information and examples should match the sequence and content of learning outcomes.

8. The scientific language used in the text should be concise and simple, consisting of short sentences using active tone and should be understandable to the students independently.
9. Ensure gender equity, textual matter urban/rural oriented and relevant to daily life.
10. The text should be supported with art i.e. illustrations, diagrams and photographs possibly in colour which should be clear, properly labelled and captioned to make the substance interesting and stimulating.
11. The textual material (text, images, illustration, pictures, figure etc.) are equally acceptable by students of either gender and should be from the local /Pakistan environment.
12. The text should be free from material repugnant to Islamic and Pakistani Ideology**.**
13. Examples and applications from local environment should be preferred.
14. SI units and terminology should be used all over in the text. However, conversion tables with other units can be given as additional information. Uniformity be maintained in symbolic representation of physical quantities and values of constants throughout in the text and in numerical problems.
15. Answers to the numerical problems should be quoted in scientific notation with correct number of significant figures and units, the answers of numerical may be given below the numerical problems.
16. Solved numerical examples and end of chapter numerical problems should be based on variety of situations in novel manner and be related to local environment, culture and real-life situations.
17. Boxed "Tid bits", "interesting information", "do you know", and "point of ponder" may be given to highlight additional information along with the description of concepts particularly related to STEAM connection through inquiry process.
18. Interesting sidelights such as case studies, discoveries, related technologies etc. may be given in the form of "boxed essays".
19. The textual material may be presented as in dynamic, challenging, stimulating and user friendly.
20. The contributions of Muslim and Pakistani Scientists may be highlighted appropriately wherever related.
21. Tables, flow charts/diagrams and concept maps may be given wherever appropriate.
22. Developing thematic/concept map may be given at the start of each chapter/unit
23. Reference of the experiments /practical activities may be made with the related topics in text.
24. Coherent and precise summary should be given at the end of each chapter.

25. Several forms of questions/activities should be given at the end of each chapter/unit.
26. Pose challenging task/assignments for students to deal with problems solving situations in real life may include.
27. Include an appropriate assessment exercise which should not only knowledge but particularly the higher abilities such as understanding, handling information, analyzing, application of ideas and solving problems and relevant Investigation Skills/ Laboratory work and processes, for this purpose, there may be: 'Self Quiz' MCQs', Review question, 'Short questions', assignments, projects etc. and thought /free response questions but all items reflect the SLOs given in the unit/chapter.
28. Some of the thought-provoking questions may also be given within the chapter/unit.
29. All questions should be very appropriately and clearly worded/constructed to test varying abilities and Investigation Skills on the basis of Bloom's taxonomy.
30. The amount of information to be covered by the chapter must match the number of hours of instructional time.
31. A comprehensive glossary of terms and subjects index, references and authors' profiles may be given at the end of the book.
32. A practical manual for the students should also be written to support practical work.

GUIDELINES FOR WRITING A UNIT/CHAPTER

To make the learning of Chemistry books interesting and exciting and to provide a strong foundation for higher learning, each chapter/unit in the physics textbooks must have, among others, but not limited the following features:

- A unit/chapter should start as continuation of the previous unit/chapter or even domain and author should start unit with the facts which highlight the need for contents/unit (it may be from daily -life situation, previous knowledge etc.)
- Chapter opener to introduce the chapter with title, full page coloured photographs, trigger questions and SLOs
- Name of unit/chapter may be written in single/combine words after thoroughly study the contents/SLOs.
- Concept map maybe included before starting domain/unit (not necessary)
- Keywords terms and definitions be to be highlighted in the text.
- Headings and sub-heading may be highlighted
- Divided into unit/chapters with headings and sub-headings where required.
- Text/Content in unit should be learner friendly and supporting information is added in information boxes, quizzes and brain teasers etc. to enhance curiosity to help understand and apply mathematical concepts
- variety of activities are included to promote higher order thinking abilities and problem-solving skills
- Font size is appropriate to age, level, and easily readable.
- Color scheme for pictures/illustrations in each unit/chapter should be close to real life and enhances the academic value of the text.
- All the relevant and supportive diagrams, pictures, tables, graphs, illustrations with captions.
- Content should be accurate (scientifically, historically, factually etc.), comprehensive, and based on updated knowledge.
- Content should be observing gender equity
- Content/text in unit/chapter should be Stimulate interest and curiosity of students.
- Uniform pattern of exercises questions (where possible) may be adapted in all chapter/unit.
- Websites and online learning centers/resources should be mentioned at the end of each unit/chapter, so that the learners and teachers can get up-to-date information about the concepts. The material should reflect the role of technology to promote learning with

understanding. Beware that the referred websites or centers should not include material contrary to our religious, moral, ethical, cultural, and social values.

- Teacher tips should include at relevant places in unit/chapters to explain different concepts and to use a variety of tools/materials, and activities.

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