National Curriculum of Pakistan
2022-23

CHEMISTRY

Grades 9-12

NATIONAL CURRICULUM COUNCIL SECRETARIAT
MINISTRY OF FEDERAL EDUCATION AND
PROFESSIONAL TRAINING, ISLAMABAD
GOVERNMENT OF PAKISTAN

بسم الله الرحمن الرحيم

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It is with great pride that we, at the National Curriculum Council Secretariat, present the first core curriculum in Pakistan's 75-year history. Consistent with the right to education guaranteed by Article 25-A of our Constitution, the National Curriculum of Pakistan (2022-23) aspires to equip every child with the necessary tools required to thrive in and adapt to an ever-evolving globalized world.

The National Curriculum is in line with international benchmarks, yet sensitive to the economic, religious, and social needs of young scholars across Pakistan. As such, the National Curriculum aims to shift classroom instruction from rote learning to concept-based learning.

Concept-based learning permeates all aspects of the National Curriculum, aligning textbooks, teaching, classroom practice, and assessments to ensure compliance with contemplated student learning outcomes. Drawing on a rich tapestry of critical thinking exercises, students will acquire the confidence to embark on a journey of lifelong learning. They will further be able to acknowledge their weaknesses and develop an eagerness to build upon their strengths.

The National Curriculum was developed through a nationwide consultative process involving a wide range of stakeholders, including curriculum experts from the public, private, and non-governmental sectors. Representatives from provincial education departments, textbook boards, assessment departments, teacher training departments, deeni madaris, public and private publishers, private schools, and private school associations all contributed their expertise to ensure that the National Curriculum could meet the needs of all Pakistani students.

The experiences and collective wisdom of these diverse stakeholders enrich the National Curriculum, fostering the core, nation-building values of inclusion, harmony, and peace, making the National Curriculum truly representative of our nation's educational aspirations and diversity.

I take this opportunity to thank all stakeholders, including students, teachers, and parents who contributed to developing the National Curriculum of Pakistan (2022-23)

Dr. Mariam Chughtai
Director
National Curriculum Council Secretariat
Ministry of Federal Education and Professional Training

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 analyzed 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. 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 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 analyzed 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 behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.	**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 behavior of systems. 5. Energy and Matter: Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior 6. Structure and Function: The way an object is shaped or structured determines many of its properties and functions. 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

	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. 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. ii) Change and rates of change can be quantified and modeled 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. iii) Ask questions that can be investigated within the scope of the school laboratory, research	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. Modeling tools are used to develop questions, predictions and explanations; analyze 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. 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. Analyzing and Interpreting Data: Scientific investigations produce data that must be analyzed 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. 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 behavior of systems and test the validity of such predictions.

	facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory. iii) 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. iv) 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, analyze 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.	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 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.

	iv) Select appropriate tools to collect, record, analyze, 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. Analyzing and Interpreting Data** i) Analyze 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 analyzing 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) Analyze 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/m3 , 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. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.** i) Analyze complex real-world problems by specifying criteria and constraints for successful solutions. 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. 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**	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 Develop solutions: Break a major problem into smaller problems that can be solved separately Optimize: Prioritize criteria, consider tradeoffs, and assess social and environmental impacts as a complex solution is tested and refined

	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 int 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, skepticism, 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 skeptical 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 Endeavor** i) Scientific knowledge is a result of human endeavor, 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 endeavor 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	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)		

like 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, defense 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.)			

Theoretical Concepts Progression Grid

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, 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 take 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-centered 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 to chemistry.			
Benchmark 1: Students can describe the history of chemistry, including major contributors and key developments in the field.		**N/A**	
The Science of Chemistry: **[SLO: C-09-A-01]**	History of Chemistry **[SLO: C-10-A-01]**	**N/A**	

Define chemistry as the study of matter, its properties, composition, 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.** **[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)	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. 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 skepticism, which are essential for			

[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?') The Practice of Science: **[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	ensuring the accuracy and validity of scientific findings). **[SLO: C-10-A-02]** Explain, with examples, that a '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 - 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			

that solves a problem and fulfills a need. Science provides the foundational knowledge and understanding while engineering applies that knowledge to develop practical solutions) Scientific Method:	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 behavior 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: - identify common sources of argumentative fallacies - explain the broad schools of thought about the relationship between chemistry and the nature of knowledge - give examples of ethical dilemmas that emerge from research and practice of science - explain the broad schools of thought about how science is distinguished from other fields of inquiry			**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 and processes	
Philosophy of Science:	**[SLO: C-10-A-03]** Explain, with examples, how		Thought Experiments **[SLO: C-11-A-01]**	Ethics and Values in Chemistry:

	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.)		Describe how Al Ghazali's burning cotton thought experiment highlight the challenges of inductive reasoning examples of deductive reasoning with respect to Chemistry)	**[SLO: C-12-A-01]** Identify common cognitive biases/fallacies that can hinder sound scientific reasoning in physical sciences (Some examples include: • the confirmation bias • 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 (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-11-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.** **Describe the structure of atoms and their role in the properties of matter.** **Classify matter as elements, compounds, or mixtures, and explain the characteristics that define each type.** **Discuss the behavior of matter at the macroscopic and microscopic levels, including the kinetic molecular theory and phase changes.** **Apply the mole concept to chemical calculations, including stoichiometry and chemical reactions.**				
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]**				N/A

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) **[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			**N/A**	

pressure on matter.				
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. **[SLO: C-10-B-02]** Distinguish between evaporation and boiling. **[SLO: C-10-B-03]** Interpret heating and cooling curves in terms of kinetic 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]**		N/A	N/A

	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 **[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*			

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.

Benchmark 1: Students can describe the structure of atoms, including the protons, neutrons, and electrons and using these concepts to discuss Isotopes.			**Benchmark 1: The student will be able to explain the energy levels and electron configurations of atoms, and use these models to predict and interpret trends in the periodic table, such as atomic radius and electron shielding.**	
[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 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	N/A		**[SLO: C-11-B-01]** Describe that, each atomic shell and subshell 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 **[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 and nucleon number represent the same concept **[SLO: C-11-B-05]**	N/A

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 charge and relative masses of a subatomic particles (an electron, proton and neutron) **[SLO: C-09-B-14]** Interpret the relationship between a subatomic particle, their mass and charge. **[SLO: C-09-B-15]** Illustrate the path that positively and negatively charged particles would take under the influence of a uniform electric field.			Describe the behavior 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-11-B-08]** Determine the electronic configuration of elements and their ions with proton numbers. (Some examples include: a. simple configuration	

[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/atomic mass 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]			e.g. 2,8, b. subshells e.g. $1s^2$, $2s^2$, $2p^6$, $2s^1$ c. Students should be able to determine both of these from periodic table and are not required to memorize these d. students should understand that chemical properties of an atom are governed by valence electrons)	

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, and relate electronic configuration to patterns in ionization energy**	
N/A	N/A		**[SLO: C-11-B-09]** Define terms related to electronic configuration (Some examples include shells, subshells, orbitals, principal quantum number (n), ground state), **[SLO:C-11-B-10]**	N/A

			Relate Quantum Numbers to Electronic distribution of elements. **[SLO: C-11-B-11]** 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-12]** Apply aufbau principle, pauli exclusion principle and hunds rule to write the electronic configuration of elements **[SLO: C-11-B-13]** Describe the order of increasing energy of the subshells(s,p,d and f) **[SLO: C-11-B-14]** Describe the electronic configurations to include the number of electrons in each shell, subshell and orbital. **[SLO: C-11-B-15]** Explain the electronic configurations in terms of energy of the electrons and inter-electron repulsion	

			[SLO: C-11-B-16] Determine the electronic configuration of atoms and ions given the proton or electron number and charge, **[SLO: C-11-B-17]** *Illustrate the importance of electronic configurations 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-18]** Describe the shapes of s, p and d orbitals **[SLO: C-11-B-19]** Describe a free radical as a species with one or more unpaired electrons *[SLO: C-11-B-20]* Explain that ionization	

			energies are due to the attraction between the nucleus and the outer electron *[SLO: C-11-B-21]* Explain how ionization energy helps account for the trends across a period and down a group of the Periodic Table *[SLO: C-11-B-22]* Account for the variation in successive ionization energies of an element **[SLO: C-11-B-23]** 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-24]** Deduce the electronic configurations of elements using successive ionization	

			energy data **[SLO: C-11-B-25]** Deduce the position of an element in the Periodic Table using successive ionization energy data **[SLO: C-11-B-26]** 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-27]** Perform calculations involving non-integer relative atomic masses and abundance of isotopes from given data, including mass spectra. ***[SLO: C-11-B-28]*** *Explain the concept of emission spectra* *Use the concept of emission spectra to deduce the electronic configuration of elements.*	

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.**				
Benchmark 1: Students can describe the types of chemical bonds, including ionic, covalent coordinate covalent,and metallic bonds.			**Benchmark 1: Students can apply the concepts of chemical bonding to predict the structure and properties of molecules , including molecular geometry, and polarity**	
[SLO: *C-09-B-30*] Describethat 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 **[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	N/A		**[SLO: C-11-B-29]** • Define electronegativity as the power of an atom to attract electrons to itself **[SLO: C-11-B-30]** • Explain the factors influencing the electronegativities of elements in terms of nuclear charge, atomic radius, shielding by inner shells and subshells **[SLO: C-11-B-31]** • Explain the trends in electronegativity across a period and down a	N/A

[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-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*			group of the Periodic Table **[SLO: C-11-B-32]** • Use the differences in Pauling electronegativity values to predict the formation of ionic and covalent bonds **[SLO: C-11-B-33]** • Describe covalent bonding in molecules using the concept of hybridization to describe sp, sp2 and sp3 orbitals **[SLO: C-11-B-34]** Use bond energy values and the concept of bond length to compare the reactivity of covalent molecules **[SLO: C-11-B-35]** • **Describe** the shapes and bond angles in	

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 dissolves in water and conduct electricity) **[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			molecules using VSEPR theory (including describing by sketching) **[SLO: C-11-B-36]** Predict the shapes , and bond angles in molecules and ions. 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 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.* *SLO:C-11-B-40* *Explain the salient features of molecular orbital theory.* *SLO:C-11-B-41*	

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, CaCl2 using dot-and-cross diagrams and Lewis-dot structures b. simple molecules including H_2, Cl_2, O_2, N_2, H_2O, CH_4, NH_3, HCl, CH_3OH, C_2H4, CO_2, HCN, and similar molecules using dot-and-cross diagrams and Lewis-dot structures).			*Explain the paramagnetic nature of Oxygen molecule in the light of MOT.* *SLO:C-11-B-42* *Calculate Bond order of N2, O2, F2& He.* **[SLO: C-11-B-43]** • Describe the types of van der Waals' force (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-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. sulfate and nitrate **[SLO: C-11-B-49]** Analyze 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 reactants and write balanced chemical equations.**	
[SLO: *C-09-B-42*] State the formulae of common elements and 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-10-B-10]** Use the molar gas volume, 24 dm^3 at room temperature and pressure, in calculations involving gases **[SLO: C-10-B-11]** Define concentration, use both g/dm^3 and mol/dm^3, and convert between them		**[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	N/A

[SLO: *C-09-B-45*] Deduce the formula and name of a 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 molecules. **[SLO:** *C-09-B-47*] 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-48*] Define mole as amount of substance containing avogadro's number ($6.02x10^{23}$) of particles **[SLO:** *C-09-B-49*] Explain the relationship between a mole and Avogadro's constant **[SLO: C-09-B-50]** Construct chemical equations and ionic equations to show reactants forming products, including state	**[SLO: C-10-B-12]** Calculate stoichiometric relationships between substances relationships (specifically: • reacting masses, limiting reactants, • volume of gasses at r.t.p., • volumes of solution and concentrations of solutions in g/dm^3 or mol/dm^3, including conversion between cm 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-10-B-15]** Calculate percentage yield, percentage composition by mass and percentage purity from appropriate data		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 gram molecular mass of a gas from density measurements at STP. **[SLO: C-11-B-57]** Derive measurements of mass, volume, and number of particles	

symbols. **[SLO: C-09-B-51]** Deduce the symbol equation with state symbols for a chemical reaction given relevant information.			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 behavior of batteries, fuel cells, and other electrochemical devices.				
Benchmark 1: Students should be able to describe the principles of electricity and electrochemistry, including redox reactions, oxidation and reduction, and the behavior 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 **[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	**[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]** • Identify and label in simple electrolytic cells, the anode (+), cathode (-), electrolyte and direction of flow of electrons in external circuit, **[SLO: C-10-B-18]** • Describe the transfer of charge in external circuit, movement of ions in the electrolyte and transfer of electrons at electrodes		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

a monatomic ion is 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) or aqueous potassium iodide	**[SLO: C-10-B-19]** • Identify the products formed at electrodes and describe the observations made during the electrolysis of molten lead(II) chloride, concentrated aqueous sodium chloride, dilute sulfuric acid using inert electrodes (platinum or carbon/graphite) [SLO: C-10-B-20] State that hydrogen-oxygen fuel cell uses hydrogen and oxygen to produce electricity with water as the only chemical product [SLO: C-10-B-21] Describe the advantages and disadvantages of using hydrogen–oxygen fuel cells in comparison with gasoline /petrol engines in vehicles			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 **[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, compounds, and ions 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 behavior 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-22]** • Identify the products formed at electrodes and describe the observations made during the electrolysis of dilute copper(II) sulfate using inert electrode or copper electrode **[SLO: C-10-B-23]** • Predict the identity of		[SLO: C-10-B-60] Explain the merits of photovoltaic cells as sustainable ways of meeting energy demands by making reference to the photovoltaic principle	**[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

	products of electrolysis of a halide compound in dilute or concentrated solution | **[SLO: C-10-B-24]** • Construct ionic half-equations for reaction at either electrode. **[SLO: C-10-B-25]** Describe electroplating and its applications. **[SLO: C-10-B-26]** Sketch a schematic diagram for a voltaic cell e.g. Daniel cell **[SLO: C-10-B-27]** Use the voltage data given for voltaic cells to determine order of reactivity of any two metals			cathode [SLO: C-10-B-21] Explain how voltaic cells convert chemical energy from redox reactions to electrical energy using Cu-Zn galvanic cell as an example

Standard: (States and Phases of Matter)

The students will be able to:

Identify and explain the physical properties of solids, liquids, and gasses in terms of their chemical compositions.

Compare and contrast intermolecular forces, including hydrogen bonding, and explain how they affect the states and phases of matter.

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 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 types of intermolecular forces. **[SLO: C-11-B-63]** Explain the strength and applications of dipole-dipole forces, hydrogen bonding and London forces. **[SLO: C-11-B-64]** Describe physical properties of liquids such as evaporation, vapor	N/A

			pressure, boiling point, viscosity and surface tension. **[SLO: C-11-B-65]** Apply the concept of hydrogen bonding to explain the properties of water (specifically high surface tension, high specific heat, low vapor pressure, high heat of vaporization, and high boiling point) **[SLO: C-11-B-66]** Define molar heat of fusion and molar heat of vaporization. **[SLO: C-11-B-67]** Describe how heat of fusion and heat of vaporization affect the particles that make up matter. [SLO: C-11-B-68] 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-69]** Describe the **physical** properties of gases (including compressibility, expandability and pressure exerted by gases) ***[SLO: C-11-B-70]*** *Describe liquid crystals and give their uses in daily life.* ***[SLO: C-11-B-71]*** *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-72]** • Describe simple properties of solids e.g. compression, expansion, motion of molecules, inter particle space, intermolecular forces	N/A

			and kinetic energy based on kinetic molecular theory. **[SLO: C-11-B-73]** • Differentiate between amorphous and crystalline solids. ***[SLO: C-11-B-74]*** • *Describe properties of crystalline solids like geometrical shape, melting point, cleavage planes, habit of a crystal, crystal growth.*	
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.** **Describe the laws of thermodynamics and their application in chemical systems.** **Discuss the relationship between energy and work, and apply this relationship to thermodynamic processes.**				
Benchmark 1: Students should be able to define and use energy concepts, including energy change, internal energy, enthalpy, and thermochemistry, in chemical reactions.			**Benchmark 1: Students should be able to apply the laws of thermodynamics to analyze and predict energy changes in chemical systems, including exothermic and endothermic reactions, enthalpy and entropy changes**	
[SLO: C-09-B-622] Explain the idea of a chemical system and its	N/A		**[SLO: C-11-B-75]** Describe that chemical reactions are	N/A

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 and recognize its sign as negative for exothermic and positive for endothermic reactions **[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			accompanied by enthalpy changes and these changes can be exothermic (ΔH is negative) or endothermic (ΔH is positive) **[SLO: C-11-B-76]** interpret a reaction pathway diagram, in terms of the enthalpy change of the reaction and of the activation energy **[SLO: C-11-B-77]** Define terms such as standard conditions, enthalpy change, reaction, formation, combustion, neutralization **[SLO: C-11-B-78]** Explain that energy transfer occurs during chemical reactions because of the breaking and making of bonds **[SLO: C-11-B-79]** Calculate the bond energies for the enthalpy change of reaction, ΔH	

for exothermic and endothermic reaction which includes enthalpy change, activation energy (uncatalyzed and catalyzed), 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 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-80]** Describe that some bond energies are exact and some bond energies are approximate **[SLO: C-11-B-81]** 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-82]** Define terms such as enthalpy change of atomization, ΔH, lattice energy, ΔH, first electron affinity, EA **[SLO: C-11-B-83]** Use terms such as enthalpy change of atomization, ΔH, lattice energy, ΔH, first electron affinity, EA **[SLO: C-11-B-84]** Explain the factors affecting the electron affinities of elements	

			[SLO: C-11-B-85] Construct Born–Haber cycles for ionic solids **[SLO: C-11-B-86]** Perform calculations involving Born–Haber cycles ***[SLO: C-11-B-87]*** *Explain the effect of ionic charge and ionic radius on the numerical magnitude of lattice energy* ***[SLO: C-11-B-88]*** *Apply enthalpy change with reference to hydration, and solution* ***[SLO: C-11-B-89]*** *Construct an energy cycle involving enthalpy change of solution, lattice energy and enthalpy change of hydration* **[SLO: C-11-B-90]** Perform calculations involving the energy cycles **[SLO: C-11-B-91]**	

			Explain the effect of ionic charge and ionic radius on the numerical magnitude of an enthalpy change of hydration **[SLO: C-11-B-92]** 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-93]** 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-94]** Calculate the entropy change for a reaction, ΔS, given the standard entropies, S, of the reactants and products **[SLO: C-11-B-95]** Explain the concept of heat as a form of energy	

			[SLO: C-11-B-96] Explain the relationship between temperature and kinetic energy of particles **[SLO: C-11-B-97]** State that total energy is conserved in chemical reactions **[SLO: C-11-B-98]** Explain the concept of standard conditions and standard states in measuring energy changes **[SLO: C-11-B-99]** Explain of Hess's Law **[SLO: C-11-B-100]** Apply Hess's Law to calculate enthalpy changes in a reaction carried out in multiple steps. **[SLO: C-11-B-101]** Explain the relationship	

			between bond formation energy, and bond breaking energy **[SLO: C-12-B-102]** Explain Gibbs free energy **[SLO: C-12-B-103]** Apply the concept of Gibbs free energy to solve problems **[SLO: C-12-B-104]** *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 catalysts.** **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 analyze and predict the rate of chemical reactions, including the effect of changing conditions on reaction rate.			**Benchmark 1: The student will be able to 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-28]** • 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-29]** • State that catalyst increases the rate of reaction, provides alternate pathway with lower activation energy, and remains unchanged at the end of a reaction **[SLO: C-10-B-30]** • Describe the physical parameters that may be affected by the rate of, reaction including change in mass, temperature, and formation of gas **[SLO: C-10-B-31]** • Interpret data, including graphs, for investigating rate of reaction		**[SLO: C-11-B-105]** • Explain the rate of reaction and rate constant. **[SLO: C-11-B-106]** • Use experimental data to calculate the rate of a reaction **[SLO: C-11-B-107]** • Explain the concept of activation energy and its role in chemical reactions **[SLO: C-11-B-108]** • Use the Boltzmann distribution curve to explain the effect of temperature on the rate of a reaction **[SLO: C-11-B-109]** • Explain the concept of catalyst and how they increase the rate of a reaction by lowering the activation energy	N/A

			[SLO: C-11-B-110] • Interpret reaction pathway diagrams, including in the presence and absence of catalysts **[SLO: C-11-B-111]** • Explain the relationship between Gibbs free energy change, ΔG, and the feasibility of a reaction **[SLO: C-11-B-112]** • Use rate equations, including orders of reaction and rate constants **[SLO: C-11-B-113]** • Calculate the numerical value of a rate constant using the initial rates and half-life method **[SLO: C-11-B-114]** • Suggest a reaction mechanism that is consistent with a given rate equation and rate-	

			determining step **[SLO: C-11-B-115]** • Describe the effect of temperature change on the rate constant and rate of a reaction.	
Benchmark 2: Students can describe the factors that influence the rate of chemical reactions, including concentration, temperature, and catalysts, and how these factors affect the activation energy.			**N/A**	
N/A	**[SLO: C-10-B-32]** explain the effect on rate of reaction of changing concentration of a reactant, pressure of gases, surface area of solids, temperature, presence of catalyst (including enzymes) using collision theory *[SLO: C-10-B-33]* *Justify the importance of chemical kinetics in the food industry to determine ideal harvesting and transportation times for produce.*		N/A	N/A
Standard: (Equilibria) Students should be able to: Describe the concept of chemical equilibrium and the dynamic nature of chemical reactions. **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 will be able to describe the concept of chemical equilibrium and how reversible reactions can be influenced by the adjustment of physical parameters			**Benchmark 1: Students can apply the principles of chemical equilibrium to analyze 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 reaction 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) sulfate and cobalt (II) chloride **[SLO: C-09-B-74]** State that reversible reactions can achieve equilibrium in a closed system when rate of forward	N/A		**[SLO: C-11-B-116]** 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-117]** Define dynamic equilibrium between two physical states. **[SLO: C-11-B-118]** State the necessary conditions for equilibrium and the ways that equilibrium can be recognized. **[SLO: C-11-B-119]** Describe the microscopic events that occur when a chemical system is in	**[SLO: C-12-B-22]** explain common ion effects giving suitable examples. **[SLO: C-12-B-23]** Use the extent of ionization and the acid dissociation constant, K_a, to distinguish between strong and weak acids. **[SLO: C-12-B-24]** Use the extent of ionization and the base dissociation constant, K_b, to distinguish

and backward reactions are equal.			equilibrium Define with examples. **[SLO: C-11-B-120]** Deduce the equilibrium constant expression [Kc] from an equation for homogeneous reaction. **[SLO: C-11-B-121]** Determine the relationship between different equilibrium constants (Kc) for the same reaction at the same temperature. **[SLO: C-11-B-122]** Write the equilibrium expression for a given chemical reaction in terms of concentration, K_c, partial pressure, number of moles and mole fraction. **[SLO: C-11-B-123]** Differentiate between Microscopic and Macroscopic events in a chemical reaction. **[SLO: C-11-B-124]**	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

			Propose microscopic events that account for observed macroscopic changes that take place during a shift in equilibrium. **[SLO: C-11-B-125]** Determine if the equilibrium constant will increase or decrease when temperature is changed, given the equation for the reaction. **[SLO: C-11-B-126]** State Le Chatelier's Principle and be able to apply it to systems in equilibrium with changes in concentration, pressure, temperature, or the addition of catalyst. **[SLO: C-11-B-127]** Explain industrial applications of Le Chatelier's Principle using Haber's process and the Contact Process as an example. [SLO: C-11-B-128] Discuss the industrial applications	solutions, 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, K_{pc} **[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

			of chemical equilibria and how it can be used to optimize chemical reactions to maximize yields and minimize waste products. **[SLO: C-11-B-129]** Use the concept of hydrolysis to explain why aqueous solutions of some salts are acidic or basic.	affecting the numerical value of a partition coefficient in terms of the polarities of the solute and the solvents used
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 behavior, and their definition using Brønsted-Lowry theory.			**Benchmark 1: Students will be able to calculate pH values for dissolved acids and alkalis, including in titration experiments**	
[SLO: C-09-B-75] Define Bronsted-Lowry acids as	N/A		Acid-Base Theory **[SLO: C-11-B-130]**	The pH scale

proton donors and Bronsted-Lowry bases as proton acceptors **[SLO: C-09-B-76]** **Recognize** that 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 bases 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. **[SLO: C-09-B-78]** Formulate dissociation equations 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			define conjugate acid–base pairs **[SLO: C-11-B-131]** identify conjugate acid-base paris in reactions **[SLO: C-11-B-132]** Apply the concept of conjugate acid and conjugate base on salt hydrolysis **[SLO: C-11-B-133]** define mathematically the terms pH, K_a, pK_a and K_w and use them in calculations (K_b and the equation $K_w = K_a \times K_b$ will not be tested) **[SLO: C-11-B-134]** calculate $[H^+(aq)]$ and pH values for: (a) strong acids (b) strong alkalis (c) weak acids (d) weak alkalies **[SLO: C-11-B-135]** Distinguish that Lewis acids accept lone pair, and Lewis bases donate lone pair to make a coordinate covalent bond.	**[SLO: C-12-B-30]** State that $pH = -\log[H^+(aq)]$ and $[H^+] = 10$(to the power)−pH. **[SLO: C-12-B-31]** State that change of one pH unit represents a 10-fold change in the hydrogen ion concentration $[H^+]$. **[SLO: C-12-B-32]** Use the ionic product constant, $K_w = [H^+][OH^-] = 10^{-14}$ at 298 K to solve problems **SLO: C-12-B-33]** sketch the pH titration curves of titrations using combinations of strong and weak acids with strong and weak alkalis

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 **[SLO: C-09-B-82]** Define acid rain. **[SLO: C-09-B-83]** Discuss effects of acid rain and relate them with properties of acids.			**[SLO: C-11-B-136]** calculate the pH of buffer solutions in given appropriate data **[SLO: C-11-B-137]** Demonstrate the ability to comprehend and effectively apply the concept of solubility product. (K_{sp}) **[SLO: C-11-B-138]** Construct an expression for K_{sp} **[SLO: C-11-B-139]** calculate K_{sp} from concentrations and vice versa *[SLO: C-11-B-140]* 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-141]* perform calculations using K_{sp} values and concentration of a common ion	

			[SLO: C-11-B-142] Use the concept of hydrolysis to explain why aqueous solutions of some salts are acidic or basic. **[SLO: C-11-B-143]** Calculate the $[H_30^+]$ given the Ka and molar concentration of weak acid. **[SLO: C-11-B-144]** Calculate concentrations of ions of slightly soluble salts. **[SLO: C-11-B-145]** Perform acid-base titrations to calculate molarity and strength of given sample solutions. **[SLO: C-11-B-146]** Select suitable indicators for acid-alkali titrations, given appropriate data (pK_a values will not be used)	
Benchmark 2: Students can calculate and interpret the pH of a			**N/A**	

solution and understand the relationship between pH, concentration, and the strength of acids and bases.				
	N/A		N/A	
Standard: (Salts) Students should be able to: Describe the nature of salts, including their formation from the reaction of acids and bases. **Explain the concept of ionic compounds, including the arrangement of ions in a crystal lattice.** **Discuss the properties of salts, including solubility, conductivity, and melting point.** **Apply the principles of chemical bonding to explain the behavior of salts in different physical states.** **Describe the role of salts in chemical reactions, including their effect on acid-base equilibria.**				
Benchmark 1: Students will be able to differentiate between different types of salts based on their properties and solubility.			**N/A**	
N/A	**[SLO: C-10-B-34]** 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-35]** Explain why at STP salts are solids with high melting points. **[SLO: C-10-B-36]** Describe that under normal		N/A	N/A

	conditions, ionic compounds are usually solids with lattice structures. **[SLO: C-10-B-37]** 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-38]** Describe the general solubility rules for salts. (these are: a. sodium, nitrate, potassium and ammonium salts are soluble b. chlorides are soluble except lead and silver c. carbonates are insoluble except sodium, potassium and ammonium d. hydroxides are insoluble except sodium, potassium, ammonium and calcium (partially) **[SLO: C-10-B-39]** Describe the preparation,			

	separation and purification of soluble salts by reactions of acids with alkali (titration), excess metal, excess insoluble base, excess insoluble carbonate			
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, electron 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 behavior.**				
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 periods (horizontal row) of the periodic table, including the demarcation of elements into s and p blocks based on their electron configurations.			**Benchmark 1: The student will be able to interpret and explain the periodic trends of electron configuration, ionization energy, electron affinity, 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.**	
[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 **[SLO: C-09-C-02]**	N/A		**[SLO: C-11-C-01]** Explain the arrangement of elements in the periodic table **[SLO: C-11-C-02]** Explain that the periodic	N/A

Identify the group or period or block of an element using its electronic configuration (only 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 periods, 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 **[SLO: C-09-C-07]**			table is arranged into four blocks associated with the four sublevels—s, p, d, and f. **[SLO: C-11-C-03]** Recognize that the period number (n) is the outer energy 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, nonmetals 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,	

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			electron affinity and electronegativity. **[SLO: C-11-C-07]** Recognize that trends in metallic and non-metallic behavior are due to the trends in valence electrons. **[SLO: C-11-C-08]** Deduce the electron configuration of an atom from the element's position on the periodic table, and vice versa (based on s,p,d and f subshells). **[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 behavior of the oxides and the hydroxides NaOH, $Mg(OH)_2$ including, where relevant, amphoteric behavior in reactions with acids and bases (sodium 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. **[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 1 and Group 17 elements	
Standard: (Group Properties and Elements) Students should be able to: Describe the group properties of elements, including their electron configurations and reactivity. **Explain the trends in reactivity, size, and electronegativity of elements within a group.** **Discuss the chemical behavior of elements in different oxidation states and their role in chemical reactions.** **Apply the concepts of electron configuration and electron transfer to explain the reactivity of elements.** **Describe the properties and applications of elements in different groups, including the alkali metals, alkaline earth metals, halogens, and noble gases.**				
Benchmark 1: Students can 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 I Alkali metals as relatively soft metals with general trends down the group limited to	Nitrogen and Sulfur ***[SLO: C-10-C-01]*** *Recognize that atmospheric oxides*			

decreasing melting point, increasing density and increasing reactivity **[SLO: C-09-C-10]** Predict properties of other elements in group I, given information about the elements. **[SLO: C-09-C-11]** Predict properties of elements in group 1 in order of reactivity given relevant information. Group VII Properties **[SLO: C-09-C-12]** Define group VII 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 flourine 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 halide ions and also as reducing agents **[SLO: C-09-C-15]** Predict the properties of elements in	*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 the oxidation of atmospheric sulfur 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 /20 atm and an iron catalyst **[SLO: C-10-C-06]** State the symbol equation for the conversion of sulfur dioxide to sulfur trioxide in the Contact process, $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$ **[SLO: C-10-C-07]**			

group VII, given information about the elements **[SLO: C-09-C-16]** Analyze 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 colored 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) Noble gases **[SLO: C-09-C-18]** Define the Group 18 noble gases as unreactive, monatomic gases **[SLO: C-09-C-19]** explain this in terms of electronic configuration Properties of metals **[SLO: C-09-C-20]**	State the sources of the sulfur dioxide (burning sulfur or roasting sulfide ores) and oxygen (air) in the Contact process **[SLO: C-10-C-08]** State the typical conditions for the conversion of sulfur dioxide to sulfur trioxide in the Contact process as 450°C, 200kPa /atm 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 a 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_2O3 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, coldwater,steam and oxygen.			

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)	**[SLO: C-10-C-12]** Arrange metals in order of reactivity given relevant information			
Standard: (Group 2) **The students will be able to:** **Identify and classify Group 2 elements based on their position in the periodic table** **Explain the reactivity trends of Group 2 elements based on their electron configuration and oxidation state** **Describe the industrial and everyday uses of Group 2 elements, such as magnesium in alloys, calcium in construction, and barium in flame retardants** **Explain the methods for extraction and purification of Group 2 elements, such as thermal reduction and electrolysis** **Discuss the solubility and other properties of Group 2 compounds, such as the high solubility of Group 2 hydroxides in water and the low reactivity of Group 2 carbonates.**				
N/A			**Benchmark 1: Describe the trend of atomic properties in Group and their chemical reactivity with the other elements. These include the trends of reactivity and solubility, and reactions to form oxides and carbonates.**	
N/A	N/A		N/A	**[SLO: C-12-C-01]** Describe the

				properties and trends of Group 2 elements, including their electron configurations, reactivity, and common compounds such as oxides, hydroxides and carbonates **[SLO: C-12-C-02]** Explain the chemical reactivity of Group 2 elements, including their reactions with oxygen, water, and acids (Be, Mg, Ca). **[SLO: C-12-C-03]** Explain the reactivity of Group 2 elements in terms of their electron configuration and valence electrons. **[SLO: C-12-C-04]** Describe the industrial and everyday uses of Group 2 compounds, including their role in medicine and

				agriculture. **[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]** use the term reactivity series and its application in predicting the outcome of chemical reactions. ***[SLO: C-12-C-07]*** *Explain the extraction and purification process of Group II elements and their compounds.* **[SLO: C-12-C-08]** Understand the term thermal decomposition and its application in the analysis of Group 2 compounds especially carbonates and nitrates. **[SLO: C-12-C-09]**

				use the term thermal decomposition and its application in the analysis of Group 2 compounds especially carbonates and nitrates. **[SLO: C-12-C-10]** Explain the trend in solubility of group 2 sulfates and hydroxides using terms enthalpy of hydration and enthalpy of solution **[SLO: C-12-C-11]** Compare the properties and reactivity of Group 2 elements with group 1 in the periodic table. **[SLO: C-12-C-12]** Explain the term complex ion and its application in the formation of Group2 compounds. **[SLO: C-12-C-13]** Explain the term

				basic oxide and its application in the formation of Group 2 compounds. Solubility **[SLO: C-12-C-14]** 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-15]** describe qualitatively the variation in solubility and of enthalpy change of solution, ΔH sol, of the hydroxides and sulfates in terms of relative magnitudes of the enthalpy change of hydration and the lattice energy
Standard: (Group 17)				

The students will be able to: **Describe the trends in the properties of Group 17 elements (fluorine, chlorine, bromine, iodine, and astatine) including volatility, reactivity, and electronegativity.** **Explain the industrial and everyday uses of Group 17 elements and their compounds, such as the production of refrigerants and disinfectants.** **Identify the halide ions (chloride, bromide, and iodide) and predict their reactivity based on the trends in Group 1 elements.** **Demonstrate an understanding of the reactions of Group 17 elements and their compounds with other elements, including redox reactions and halide exchange reactions.** **Discuss the environmental impacts of the use of Group 17 elements and their compounds, including ozone depletion and halogenated organic compound pollution.**				
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 colors 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 elements in terms of instantaneous dipole-induced dipole forces	N/A

			[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 elements 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 **[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 sulfuric acid **[SLO: C-11-C-27]** Describe the reaction of halides 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 Sulfur) The students will be able to: **Describe the reactivity of nitrogen and sulfur compounds.** **Describe the major chemical reactions and products involving nitrogen and sulfur.** **Discuss the environmental effects of nitrogen and sulfur compounds.** **Explain the differences between nitrification and denitrification.** **Describe the industrial processes for the production of nitrates and sulfates.**				
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	N/A

			[SLO: C-11-C-30] Explain the lack of reactivity of nitrogen due to its triple bond strength and lack of polarity **[SLO: C-11-C-31]** Describe the basicity of ammonia using the Brønsted–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 **[SLO: C-11-C-35]** Explain the role of NO and NO_2 in the formation of photochemical smog, specifically in the reaction with unburned hydrocarbons to form peroxyacetyl nitrate (PAN) **[SLO: C-11-C-36]** Differentiate between nitrification and denitrification Sulfur **[SLO: C-11-C-37]** Explain the lack of reactivity of sulfur, with reference to its bonding and stability of its compounds.	

			[SLO: C-11-C-38] Describe the different oxidation states of sulfur and their relative stability. **[SLO: C-11-C-39]** Describe the properties and uses of sulfuric acid, including its production and industrial applications. ***[SLO: C-11-C-40]*** *describe the chemical reactions and processes involving sulfur, such as combustion and oxidation.* ***[SLO: C-11-C-41]*** *Explain the uses of sulfur 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 will 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-16]** Identify the general physical and chemical properties of the first row of transition elements, titanium to copper **[SLO: C-12-C-17]** define a transition element as a d-block element which forms one or more stable ions with incomplete d orbitals **[SLO: C-12-C-18]** sketch the shape of

				a $3d_{xy}$ orbital and $3d_{z2}$ orbital **[SLO: C-12-C-19]** 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-20]** 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-21]** 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-22]** explain why transition elements form complex ions in terms of vacant d orbitals that are energetically accessible
N/A				
N/A	N/A		•	**[SLO: C-12-C-23]** • 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-24] • 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-25]** • Use the term monodentate ligand including as examples H_2O, NH_3, Cl^- and CN^- **[SLO: C-12-C-26]** 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-27]** • 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-28] Describe the geometry (shape and bond angles) of transition element complexes which are linear, square planar, tetrahedral or octahedral **[SLO: C-12-C-29]** state what is meant by coordination number **[SLO: C-12-C-30]** 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-31]** • 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-32] • predict, using E^0 values, the feasibility of redox reactions involving transition elements and their ions **[SLO: C-12-C-33]** • Analyse reactions involving MnO_4^- / $C_2O_4^-$ in acid solution given suitable data (including describing the reaction and doing calculations) **[SLO: C-12-C-34]** Analyse reactions involving MnO_4^- / Fe^{2+} in acid solution given suitable data ((including describing the reaction and doing calculations) **[SLO: C-12-C-35]** Analyse reactions involving Cu^{2+} / I– given suitable data (including describing the reaction and doing calculations) **[SLO: C-12-C-36]** • perform calculations involving other

				redox systems given suitable data
N/A	N/A		•	Colour of complexes **[SLO: C-12-C-37]** • use the terms degenerate and non-degenerate d orbitals **[SLO: C-12-C-38]** • describe the splitting of degenerate d orbitals into two non-degenerate sets of d orbitals of higher energy,and use of Δ E 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-39] • 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-40]** • 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-41]** • 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	N/A			Stereoisomerism in transition element complexes **[SLO: C-12-C-42]** • 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-43]** • deduce the overall polarity of complexes Stability constants, K_{stab} **[SLO: C-12-C-44]** • 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-45]** • write an expression for a K_{stab} of a complex ($[H_2O]$ should not be included) **[SLO: C-12-C-46]** • use K_{stab} expressions to perform

				calculations **[SLO: C-12-C-47]** • 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 atmospheric chemistry in environmental chemistry and its impact on air quality and climate.**				
Benchmark 1: Demonstrate an understanding of the composition, structure and functions 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	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	N/A

[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 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. sulfur dioxide from the combustion of fossil fuels which contain sulfur 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			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 (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*	

pollutants (Some examples include: 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. sulfur 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: a. the absorption, reflection and emission of thermal energy b. reducing thermal energy loss to space) **[SLO: C-11-D-05]** Describe the role of sulfur in the formation of acid rain			*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 and deforestation **[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 measures used to control air pollution* **[SLO: C-11-D-08]** *analyze data and interpret air quality measurements and trends* **[SLO: C-*11-D-09]*** *Explain the link between air*	

and its impact on the environment. **[SLO: C-09-D-06]** Describe the strategies to reduce the effects of major environmental issues (Some examples include: a. climate change: planting trees, reduction in 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 sulfur dioxide by using low sulfur fuels and flue gas desulfurization with calcium oxide) **[SLO: C-11-D-07]** Describe the role of NO and NO $2(subscript)$ in the formation of acid rain, both directly and through their catalytic role in the oxidation of atmospheric sulfur dioxide.			*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. **[SLO: C-11-D-14]** *Analyze the economic, social and political issues related to air*	

[SLO: C-09-D-08] Explain how oxides of nitrogen form in car engines and describe their removal by catalytic converters, e.g. $CO + 2NO \rightarrow 2CO + N_2$ **[SLO: C-09-D-09]** 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-10]** *Analyze how to use tools to reduce personal exposure to harmful pollutants* *(some examples include the usage of masks, air quality indices and CO detectors)* **[SLO: C-09-D-11]** Identify high risk situations in life including those where long-term exposure to these pollutants can lead to respiratory issues and reduction in quality and longevity of life			*pollution and air quality management and demonstrate through answers.*	
Standard: (Water) Students should be able to: Describe the properties and composition of water, including its chemical and physical properties. **Explain the sources and recycling of water on Earth, including the water cycle and groundwater.** **Discuss the effects of pollutants on water quality, including acid rain, chemical pollutants, and eutrophication.**				

Apply the principles of chemical reactions to explain the formation and removal of water pollutants. **Describe the role of water in environmental chemistry and its impact on water resources and aquatic ecosystems.**				
Benchmark: Explain how to measure the purity of water and evaluate the role of water in various natural and industrial processes (like making fertilizers), and describe the impact of human activities on the quality and availability of freshwater resources.			**N/A**	
[SLO: C-09-D-12] Investigate chemical tests for the presence of water using anhydrous copper(II) sulfate **[SLO: C-09-D-13]** Explain how to test the purity of water using melting point and boiling point **[SLO: C-09-D-14]** Distinguish between Distilled water and tap water with their applications in practical chemistry. **[SLO: C-09-D-15]** State that water from natural sources may contain useful and harmful substances. (Some examples include: a. dissolved oxygen b. metal compounds c. plastics	N/A		***[SLO: C-11-D-15]*** *Identify 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 and explain the sources and effects of water pollution on human health and the environment* ***[SLO: C-11-D-18]*** *Identify and explain water treatment methods and technologies, such as filtration and purification* ***[SLO: C-11-D-19]*** *Explain the laws and*	N/A

d. sewage e. harmful microbes f. nitrates from fertilizers g. phosphates from fertilizers and detergents) **[SLO: C-09-D-16]** Recognize that some naturally occuring 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-17]** Recognize that some naturally occuring substances in water are potentially harmful (some examples include: a. some metal compounds that are toxic b. some plastics that harm aquatic life c. sewage that contains			*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 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.*	

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 are not required) **[SLO: C-09-D-18]** 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 odors (c) chlorination to kill microbes) **[SLO: C-09-D-19]** Describe various water-borne diseases and the steps that can be taken to avoid them **[SLO: C-09-D-20]** Identify the negative effects of water pollutants on life and the ways to avoid them **[SLO: C-09-D-21]**				

Explain water scarcity as an important issue faced by Pakistan and the ways in which it can be resolved Fertilizers ***[SLO: C-09-D-22]*** *State that urea, ammonium salts and nitrates are used as fertilizers* ***[SLO: C-09-D-23]*** *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 complex 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			**Benchmark 1: Analyze the chemical and physical properties of organic compounds based on their**	

series.			**functional groups and be acquainted with the structures and terminology of different compounds and organic mechanisms.**	
[SLO: C-09-E-01] Describe organic molecules as either straight-chained, branched or cyclic **[SLO: C-09-E-02]** 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, $CH_3COOCH3$ **[SLO: C-09-E-03]** Identify and draw structural formulae for molecules. **[SLO: C-09-E-04]** interpret general formulae of compounds in the same homologous series including alkanes, alkenes, alkynes, alcohols and carboxylic acids. **[SLO: C-09-E-05]** 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-10-E-01]** Name and draw the structural and displayed formulae of unbranched alkanes, alkenes, alcohols, and carboxylic acids. (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-10-E-03]** 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		**[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-11-E-04]** Interpret the general, structural, displayed and skeletal formulae of the classes of compounds **[SLO: C-11-E-05]**	**[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 sp^2 hybridisation, in terms of σ bonds

[SLO: C-09-E-06] Identify a functional group as an atom or group of atoms that determine the chemical properties of a homologous series including that for alcohols, aldehydes, ketones, phenols, carboxylic acids, amine, esters, and amide. **[SLO: C-09-E-07]** Describe the general characteristics of a homologous series (These can include: (a) having the same functional group (b) having the same general formula (c) differing from one member to the next by a $-CH_2-$ unit (d) displaying a trend in physical properties (e) sharing similar chemical properties) **[SLO: C-09-E-08]** State that a saturated compound has molecules in which all carbon–carbon bonds are single bonds **[SLO: C-09-E-09]** State that an unsaturated compound has molecules in which one or more carbon–carbon bonds are not single bonds			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,	and a delocalised π system **[SLO: C-12-E-04]** Explain what is meant by a chiral center and that such a center 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

			nucleophilic, electrophilic, addition, substitution, elimination, hydrolysis, condensation, oxidation and reduction) **[SLO: C-11-E-08]** Define catenation and explain its importance in organic chemistry. **[SLO: C-11-E-09]** Describeterminology 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'	optically active, racemic mixture and mesocompunds 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 the potential different biological activity of enantiomers, the need to separate racemic mixtures, and the use of chiral catalysts to produce a single pure optical isomer using thalidomide as an example*

			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.	
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, reactivity, and physical properties.			**Benchmark 1: Demonstrate an understanding of the formation and reactions of hydrocarbons (including aromatic compounds), their nomenclature, shapes and properties.**	

N/A **[SLO: C-09-E-10]** State that the bonding in alkanes is single covalent and that alkanes are saturated hydrocarbons **[SLO: C-09-E-11]** Describe the properties of alkanes as being generally unreactive, except in terms of combustion and substitution by chlorine **[SLO: C-09-E-12]** 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-13]** Describe the substitution reaction of alkanes with chlorine as a photochemical reaction, and draw the structural or displayed formulae of the products, limited to monosubstitution **[SLO: C-09-E-14]** Describe, using symbol equations, preparation of alkanes from cracking of larger hydrocarbons, hydrogenation of alkenes and alkynes, and reduction of alkyl halides	<u>Alkenes</u> **[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-10-E-05]** Describe the manufacture of alkenes by the cracking of large alkane 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 KMnO4 **[SLO: C-10-E-08]** Describe the properties of alkenes in terms of addition reactions with:		**[SLO: C-11-E-13]** • Classify hydrocarbons as aliphatic and aromatic. **[SLO: C-11-E-14]** • Describe nomenclature of alkanes and cycloalkanes. **[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]** • Define homolytic and heterolytic fission, free radical initiation, propagation and termination. **[SLO: C-11-E-18]** • Describe the mechanism of free radical substitution in alkanes exemplified by methane and ethane. **[SLO: C-11-E-19]**	**[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. **[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

	a. bromine or aqueous bromine b. hydrogen in the presence of a nickel catalyst c. steam in the presence of an acid catalyst and 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 and in artificially ripening fruits* [SLO: C-10-E-12] Describe separation of petroleum into useful fraction by fractional distillation		• Identify organic redox reactions. • • **[SLO: C-11-E-20]** • Explain the nomenclature of alkenes. **[SLO: C-11-E-21]** • Explain shape of ethene molecule in terms of and C-C bonds. **[SLO: C-11-E-22]** • Describe the structure and reactivity of alkenes as exemplified by ethene. **[SLO: C-11-E-23]** • explain with suitable examples the terms isomerism, stereoisomerism and structural isomerism. **[SLO: C-11-E-24]** • Explain dehydration of alcohols and dehydrohalogenation of RX for the preparation of ethene.	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. **[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]**

	[SLO: C-10-E-13] Describe how the properties of fractions obtained from petroleum change from the bottom to the top 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		**[SLO: C-11-E-25]** • Describe the chemistry of alkenes by the following reactions of ethene: hydrogenation, hydrohalogenation, hydration, halogenation, halohydration, epoxidation, ozonolysis, polymerization. **[SLO: C-11-E-26]** • Explain the concept of conjugation in alkenes having alternate double bonds. **[SLO: C-11-E-27]** • Use the IUPAC naming system for alkenes. **[SLO: C-11-E-28]** • Describe the mechanism of electrophilic addition in alkenes, using bromine / ethene and hydrogen bromide /propene as examples **[SLO: C-11-E-29]** • explain the inductive effects of alkyl groups on the stability of primary, secondary and tertiary cations formed during	• 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.

	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		electrophilic addition (this should be used to explain Markovnikov addition)	
Standard: (Halogenoalkanes) **The students will be able to:** **Explain the Synthesis of halogenoalkanes and their classifications 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.** **Analyze the mechanisms and products of halogenoalkane reactions, using retro-synthesis to deduce the starting materials.**				
N/A			**Benchmark 1: Explain the reactions by which Halogenoalkanc and halogenoarenes are produced and the chemical reactions of these compounds.**	
N/A	N/A		**[SLO: C-11-E-30]** • Classify halogenoalkanes based on the type of halogen atom and its position in the carbon chain, and explain how	**[SLO: C-12-E-18]** • Describe production of halogenoarenes i.e. reaction of

			the molecular structure affects their reactivity. **[SLO: C-11-E-31]** • Explain the organic functional groups involved in a simple halogenoalkane synthesis, and predict the major product(s) based on the reaction conditions. (this includes: a) the free-radical substitution of alkanes by Cl or Br 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-32]** • describe nucleophilic substitution reactions (specifically:	benzene with Cl2 and Br2 in the presence of catalyst **[SLO: C-12-E-19]** • compare the reactivity of halogenoalkane and halogenoarene using chloroethane and chlorobenzene as examples . **[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]** • Analyze the mechanism and products of a reaction pathway involving a halogenoalkane, and use retro-synthesis to deduce the starting materials.

			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 of identifying the halogen present as exemplified by bromoethane) **[SLO: C-11-E-33]** • 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-11-E-22]** • describe the SN1 and SN2 mechanisms of nucleophilic substitution in halogenoalkanes including the

				inductive effects of alkyl groups **[SLO: C-11-E-23]** • Identify that primary halogenoalkanes tend to react via the SN2 mechanism; tertiary halogenoalkanes via the SN1 mechanism; and secondary halogenoalkanes by a mixture of the two, depending on structure **[SLO: C-11-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: Analyze the different reactions through which different hydroxy compounds can be produced and the physical and chemical properties of corresponding alcohols.**	
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 /6 atm in the presence of an acid catalyst including a comparison of the advantages and disadvantages of the two methods)		**[SLO: C-11-E-34]** • 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	**[SLO: C-12-E-25]** • describe the reaction with acyl chlorides to form esters using ethyl ethanoate **[SLO: C-12-E-26]** • recall the reactions (reagents and conditions) by which phenol can be produced: reaction of phenylamine with HNO_3 or $NaNO_3$ and dilute acid below 1°C to

	[SLO: C-10-E-16] Describe the combustion of alcohols **SLO: C-10-E-17]** Discuss the applications of alcohols as fuels, including their advantages and disadvantages over fossil fuels. **SLO: C-10-E-18]** explain the role of alcohols in various industries such as pharmaceuticals, cosmetics, and fuel production. **SLO: C-10-E-19]** Discuss the impact of alcohols on daily life, including their use as solvents and disinfectants.		c) substitution of a halogenoalkane using NaOH (aq) and heat d) reduction of an aldehyde or ketone using $NaBH_4$ or $LiAlH_4$ e) reduction of a carboxylic acid using $LiAlH_4$ f) hydrolysis of an ester using dilute acid or dilute alkali and heat describe the reaction with oxygen (combustion) of organic hydroxy compounds **[SLO: C-11-E-35]** Describe substitution 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-36]** Describe the reaction of hydroxy organic compounds with Na(s) **[SLO: C-11-E-37]** 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,	produce the diazonium salt; further warming of the diazonium salt with H_2O to give phenol **[SLO: C-12-E-27]** • recall the chemistry of phenol, as exemplified by the following reactions: • with bases, for example NaOH (aq) to produce sodium phenoxide • with Na(s) to produce sodium phenoxide and $H_2(g)$ in 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]**

			secondary alcohols give ketones, tertiary alcohols cannot be oxidized) **[SLO: C-11-E-38]** 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-39]** 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-40]** • classify alcohols as primary, secondary and tertiary alcohols, to include examples with more than one alcohol group **[SLO: C-11-E-41]** • state characteristic distinguishing reactions, e.g. mild oxidation with acidified $K_2Cr_2O_7$, colour change from orange to green **[SLO: C-11-E-42]** • deduce the presence of a $CH_3CH(OH)–$ group in an alcohol, $CH_3CH(OH)–R$, from its reaction with	• 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 **[SLO: C-12-E-32]** • apply knowledge of the reactions of phenol to those of other phenolic compounds, e.g. naphthol

			alkaline I_2(aq) to form a yellow precipitate of tri-iodomethane and an ion, RCO_2^- **[SLO: C-11-E-43]** • explain the acidity of alcohols compared with water	
Standard: (Carbonyl Compounds) Students should be able to: Describe the structure and 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, flavors, 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, structure, and use in industry and daily life.			**Benchmark 1: Explain the reactions by which carboxylic acids are produced and the nature, reactions and uses of these aldehydes and ketones.**	
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-44]** • 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	**[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 by methylbenzene

	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, flavors, fragrances, and 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.		b. the oxidation of secondary alcohols using acidified $K_2Cr_2O_7$ or acidified $KMnO_4$ and distillation to produce ketones **[SLO: C-11-E-45]** 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-46]** • describe the mechanism of the nucleophilic addition reactions of hydrogen cyanide with aldehydes and ketones [SLO: C-11-E-47] • describe the use of 2,4-dinitrophenylhydrazine (2,4-DNPH reagent) to	**[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 **[SLO: C-12-E-35]** • recognise that some carboxylic acids can be further oxidised: 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

			detect the presence of carbonyl compounds [SLO: C-11-E-48] • deduce the nature (aldehyde or ketone) of an unknown carbonyl compound from the results of simple tests (Fehling's and Tollens' reagents; ease of oxidation) [SLO: C-11-E-49] • 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-50] • 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	**[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 **[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: (check either bullets or add a,b,c,d)

			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-51]** describe: a. the redox reaction with reactive 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-52]** • recall the reaction (reagents and	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 **[SLO: C-12-E-41]** • describe the addition-elimination mechanism of acyl

			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-53]** • describe the hydrolysis of esters by dilute acid and by dilute alkali and heat	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-54]** • Define primary and secondary amines, and explain their basic properties and reactivity. **[SLO: C-11-E-55]** • Identify the differences between primary and secondary amines in terms of their structure and chemical properties.	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

			[SLO: C-11-E-56] • Describe the preparation methods of primary and secondary amines, including nucleophilic substitution reactions and reduction of nitro compounds. **[SLO: C-11-E-57]** • Explain the properties and reactivity of phenylamine and azo compounds, including their use as dyes and pigments.	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 H2/ 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]** Describe 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 basicities 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 CO 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 zwitterions,

				[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 biomedicine.** **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, including natural and synthetic types.			**Benchmark 1: Describe the polymerization process and factors that affect polymer properties and performance.**	
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		**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]**

	condensation polymers **[SLO: C-10-E-27]** • Deduce the structure or repeat unit of an addition polymer from a given alkene and vice versa **[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			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 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

	implications for their disposal **[SLO: C-10-E-32]** • Describe the environmental challenges caused by plastics, limited to: 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			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 present in a section of polymer, and classify them as one of the two polymers. **[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.

	along with their specific properties)			**[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]** • recognise that poly(alkenes) are chemically inert and can therefore be difficult to biodegrade **[SLO: C-12-E-67]** • recognise that some polymers can be degraded by the action of light **[SLO: C-12-E-68]** • recognise 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 will be able to:** **Identify and name common organic functional groups and their physical and chemical properties.** **Demonstrate understanding of the 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 function 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-58]** Explain the concept of organic synthesis and functional group interconversions. **[SLO: C-11-E-59]** Identify organic	**[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)

			functional groups using the reactions in this progression grid. **[SLO: C-11-E-60]** Predict properties and reactions of organic molecules based on functional group presence. **[SLO: C-11-E-61]** Devise multi-step synthetic routes for preparing organic molecules.. **[SLO: C-11-E-62]** Analyze 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-63]** Explain the concept of retro-synthesis and its application in organic synthesis.	
Standard: Biochemistry (carbohydrates, proteins, fats, DNA, vitamins) Students should be able to: Describe the structure and properties of carbohydrates, proteins, and lipids, including their classification as monosaccharides, disaccharides, polysaccharides, amino acids, peptides, and fatty acids. **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, fats, 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-15] **Explain the importance and basics of nutrition and healthy eating** **[SLO: C-09-E-16]** **Recognize the main biomolecules; carbohydrates, proteins, lipids and nucleic acids. their sources, along with the required daily intake for young adults** **[SLO: C-09-E-17]** **Identify carbohydrates as a source of energy**	**[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-10-E-37]** draw the general structure of proteins **[SLO: C-10-E-38]** Explain the sources, use and structure of proteins, lipids and carbohydrates **[SLO: C-10-E-39]** Describe the importance of nucleic acids ***[SLO: C-10-E-40]*** *explain vitamins, their sources and their importance to health*			***[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* ***[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*

	[SLO: C-10-E-41] *Identify applications of biochemistry in testing (blood test, pregnancy test, cancer screening, parental genetic testing), genetic engineering, gene therapy and cloning*			*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 catalyzed 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]*** ***repetition*** *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 (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, phoshorous 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: **Analyze 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:				**Uncertainties and errors in measurement and results** [SLO: C-12-F-01] Differentiate between Qualitative data and Quantitative Data -(Qualitative data includes

- 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 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 ounces. 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-09-F-03]** Apply the concept that units can				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.) [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

be combined with terms for magnitude, especially kilo, deci, and milli. **[SLO: C-09-F-04]** Justify why chemists use cm^3, g and s 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. **[SLO: C-09-F-08]** Calculate with values in standard form. **[SLO: C-09-F-09]**				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] Analyze the concept that experimental design and procedure usually lead to systematic errors in measurement, which 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

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				quantities. [SLO: C-12-F-06] Discuss that sketched graphs have labeled 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
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.** **Analyze 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.**				

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.			**N/A**	
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 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	N/A		N/A	N/A

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 example include: a) using a suitable solvent b) filtration c) crystallisation d) simple distillation e) fractional distillation) **[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				
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.				

Perform experimental procedures and techniques accurately and safely, using appropriate equipment and instruments. **Analyze and interpret data from experiments, using logical reasoning and inferential thinking to deduce the identity of unknown substances.** **Evaluate the reliability and validity of experimental results, and identify sources of error and uncertainty in the analysis.** **Communicate experimental results clearly and effectively, using appropriate graphical and written formats, and draw conclusions about the identity of unknown substances.**				
Benchmark 1: Demonstrate understanding of the principles and applications of various qualitative analysis techniques, including observation, precipitation, oxidation-reduction, and complexation reactions.			**N/A**	
[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 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. sulfur dioxide, SO_2, using	N/A		N/A	N/A

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+})				
			N/A	
	a.		• N/A	N/A
N/A			**Benchmark 1: Understand how mass spectrometers can help analyse different atoms including isotopes based on their e/m values and identify molecules based on their masses while looking at their mass spectra.**	
N/A	N/A		•	[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 [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 $n = \frac{}{1.1 \times abundance\ of\ M + =}$ [SLO: C-12-F-13]

				• deduce the presence of bromine and chlorine atoms in a compound using the Mpeak
Standard: (Spectroscopy) **The students will be able to:** **Describe the principles of spectroscopy and relate it to the interaction of electromagnetic radiation with matter.** **Analyze spectra to determine the presence and concentration of chemical species.** **Explain the relationship between the absorption/emission spectrum (from mass spectroscopy) 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 (1H 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, 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 color 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.** **Analyze 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] • analyze the different environments of carbon atoms present in a simple

				molecule using a 13C NMR spectrum. [SLO: C-12-F-22] • Use a C13 NMR spectrum to deduce possible structures of a simple molecule. [SLO: C-12-F-23] • Predict the number of peaks in a 13C NMR spectrum for a given molecule. [SLO: C-12-F-24] • analyze the different environments of protons present in a simple molecule using a 1H (proton) NMR spectrum. [SLO: C-12-F-25] • Use a H

				1(superscript)(proton) 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, [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 will be able to:** **Define chromatography and explain the principles of its different types including paper chromatography, column chromatography, thin layer chromatography, and gas chromatography.** **Analyze 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.**	
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 colorless substances.	N/A		N/A	[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

(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-09-F-20]** State and use the equation for R_f				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.
Standard: (Materials) **The students will 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 and the environmental impact of these processes.** **Predict the outcome of chemical reactions involving materials, including oxidation-reduction reactions, precipitation reactions, and acid-base reactions.** **Evaluate the sustainability of recycling processes for various materials, including the energy and material inputs required, as well as the environmental impacts of these processes.** **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.**				
N/A			**Benchmark 1: Explain the properties of different materials, their extraction techniques, uses and effects in the world around us**	
N/A	N/A		N/A	[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 metals from ores 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.* [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 analyzing structures.*
Standard: (Energy) **The students will be able to:** **Compare and contrast the different energy sources based on their availability, efficiency, and environmental impact.** **Analyze the extraction, 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 analyze the feasibility of its implementation.** **Analyze energy consumption patterns and develop strategies to reduce energy waste and increase energy efficiency.**				
Benchmark 1: Describe the composition and properties of various energy fuels, such as coal, oil, natural gas, and biofuels and explain the chemical reactions involved in the combustion of energy fuels.			**Benchmark 2: 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-E-01] Name fossil fuels; coal, natural gas and petroleum [SLO: C-10-E-02] Name methane as main		***[SLO: C-11-F-01]*** *differentiate between the difference between petrochemical and chemicals derived from them,*	N/A

	constituent of natural gas [SLO: C-10-E-03] State that petroleum is a mixture of hydrocarbons, compounds containing hydrogen and carbon only		***[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 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 will be able to:** **Explain the concept of therapeutic index and therapeutic window, and how it affects drug efficacy and safety.**				

Analyze 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.** **Analyze 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-40] *Recognize the concept of therapeutic index and therapeutic window in relation to drug administration* [SLO: C-12-F-41] *Explain the mechanism of action and uses of aspirin and penicillin and explain the chemical structure of the same* [SLO: C-12-F-42]

				Describe the mechanism of action of opiates and the concept of opioid receptors in the brain [SLO: C-12-F-43] *Describe the pH regulation of stomach and its relation to the concept of non-specific reactions and active metabolites* [SLO: C-12-F-44] *Recognize the challenges in treating viral infections with drugs and the concept of antiviral medications.*
Standard: (Agriculture) **The students will 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.** **Analyze 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-45] *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-46] *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-47] *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-48] *Explain the basics of genetic engineering and how it is used in agriculture, including the development of genetically modified crops and the potential benefits and risks associated with their use.* [SLO: C-12-F-49] *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.
Standard: (Industry) **The students will be able to:** **Analyze the impact of industrial processes on the environment and human health** **Evaluate the sustainability of different industrial processes based on energy consumption, waste generation and material use.** **Describe the role of chemistry in key industrial sectors such as petrochemical, pharmaceutical and materials manufacturing.** **Analyze the use of catalysts and reaction optimization in industrial processes.** **Discuss the challenges and opportunities in using renewable raw materials and alternative energy sources in industrial processes.**				
N/A			**Benchmark 1: Describe industrial use of chemical compounds for manufacturing, and elaborate on the reactions of various industrially used chemicals.**	
N/A	N/A		N/A	[SLO: C-12-F-50] *Justify the importance and*

				significance of industrial chemistry in various industries such as manufacturing, energy, healthcare, and environmental protection. [SLO: C-12-F-51] *Describe the chemical processes involved in industrial production, including addition and condensation polymerization, and the properties and uses of resulting materials.* [SLO: C-12-F-52] *Identify the raw materials and resources used in industrial chemistry, including those readily available in the context of*

				Pakistan. [SLO: C-12-F-53] *Explain the applications of industrial chemistry in industries such as petrochemical, cosmetics, cement, food production and more.* [SLO: C-12-F-54] *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 analyze 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.

Grades 9-10	Grade 11	Grade 12
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.**		
Standard: Students should be able to demonstrate knowledge of how to select and safely use techniques, apparatus and materials		
Benchmark I: **Students should be able to follow provided safety instructions in general lab settings while using appropriate apparatus, equipment and methods.**	**Benchmark 1: Students should be able to identify and take safety measures required to conduct experiments.**	**Benchmark 1: Students should be able to identify hazards and design safe experiments.**
[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	[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	[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.

[SLO: C-09-10-G-04] locate the nearest 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: 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 - fractional distillation - chromatography - electrolysis) [SLO: C-09-10-G-14] suggest the most appropriate apparatus or technique and justify the choice made [SLO: C-09-10-G-15]	[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-11-G-14] • replicate readings or observations as necessary, including where an anomaly is suspected	[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 thiosulfate 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 [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.
		Benchmark: Accurately carry out rate experiments ensuring quality of observation and appropriate presentation of results.
		[SLO: C-12-G-10] Carry out rate investigation by mixing reagents and recording the time for an observation to occur.

– 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)	[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 candidate	[SLO: C-12-G-11] Suggest experimental designs to measure the rate of a reaction. **Benchmark: Accurately carry out gravimetric experiments ensuring quality of observation and appropriate presentation of results.** [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) **Benchmark: 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 **Benchmark: 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: 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 this is 'no change' or 'remains a colourless solution' • to use excess alkali where a precipitate is produced on addition of NaOH(aq) or NH3 (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 2: Evaluate the results of qualitative analysis experiments, including interpretation of data, accuracy and precision of results, and identification of errors and sources of error.		
N/A	**Acid–base titrations** [SLO: C-11-G-18] • Describe an acid–base titration to include the use of a: a. burette b. volumetric 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 aluminum foil and aqueous sodium hydroxide and then testing for ammonia gas d. sulfate by acidifying with dilute nitric acid then adding aqueous barium nitrate e. sulfite 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: b. aluminum, Al^{3+} c. ammonium, NH(4 post script) d. calcium, Ca^{2+} e. chromium(III), Cr^{3+}	

	f. copper(II), Cu^{2+} g. iron(II), Fe^{2+} h. iron(III), Fe^{3+} i. zinc, Zn^{2+}	
Standard: **The students will be able to:** **Interpret mass spectra and identify isotopes based on their m/e values and relative abundances** **Determine the atomic mass of an element from its isotopic composition and mass spectrum** **Analyze the molecular mass of organic compounds by analyzing the molecular ion peak in a mass spectrum** **Predict the identity of fragmented molecules in a given mass spectrum** **Determine the number of carbon atoms in a compound using the M 1 peak and the formula** $n = \frac{}{1.1 \times abundance\ of\ M + ion}$		
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 and identify sources of error.**
[SLO: C-09-10-G-20] record the results of an experiment [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 expected results	[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-11-G-22] • record raw readings of a quantity to the same degree of precision and observations to	[SLO: C-12-G-21] Identify the best way to present collected and transformed data based on the experiment being performed [SLO: C-12-G-22] Interpret the collected data to draw conclusions based on the experiment being performed

[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	the same level of detail [SLO: C-11-G-23] • show working in calculations and key steps in reasoning [SLO: C-11-G-24] use the correct number of significant figures for calculated quantities [SLO: C-11-G-25] • draw an appropriate table in advance of taking readings or making observations and record all data in the table [SLO: C-11-G-26] • use the appropriate presentation method to produce a clear presentation of the data, [SLO: C-11-G-27] • plot appropriate variables on appropriate, clearly labelled x- and y-axes with carefully chosen scales [SLO: C-11-G-28] draw straight lines or smooth curves of best fit to show the trend of a graph; [SLO: C-11-G-29] describe the patterns and trends shown by data in tables and graphs [SLO: C-11-G-30] describe and summarise the key points of a set of observations	

	[SLO: C-11-G-31] • determine the gradient of a straight-line graph and extrapolate the line of a graph. [SLO: C-11-G-32] • 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-33] • draw conclusions from interpretations of observations, data and calculated values [SLO: C-11-G-34] • make scientific explanations of data, observations and conclusions that they have described.	
Standard: Students should be able to evaluate methods and suggest possible improvements.		
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 improvements based on validity, reliability and safety.**	**N/A**
[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	[SLO: C-11-G-35] Analyse intrinsic errors in measuring device [SLO: C-11-G-36] Describe systematic errors [SLO: C-11-G-37] identify the most significant sources of error in an experiment	

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-38] • state the uncertainty in a quantitative measurement and express such uncertainty in a measurement as an actual or percentage error [SLO: C-11-G-39] Analyse the limitations of the experimental design and propose appropriate modifications that will improve the accuracy of the experiment [SLO: C-11-G-40] evaluate the validity of the methods used [SLO: C-11-G-41] explain improvements or extensions to the methods used [SLO: C-11-G-42] apply scientific language effectively [SLO: C-11-G-43] document the work of others and sources of information used [SLO: C-11-G-44] suggest ways in which to extend the investigation to answer a new question. [SLO: C-11-G-45] Suggest alternate chemicals in experimental design which contribute to green chemistry	

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