## 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



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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**

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#### **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
-/	A) Scientific Knowledge (these themes are applied across the conceptual SLOs)	Elaborations on (A) Scientific Knowledge):
Science	1. Patterns	
Science	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.	1. Patterns: Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.
	<ul> <li>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.</li> </ul>	<ol> <li>Cause and Effect: Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and</li> </ol>
	<ul> <li>iii) Patterns of performance of designed systems can be analyzed and interpreted to reengineer and improve the system.</li> <li>iv) Mathematical representations are needed to identify some patterns.</li> </ul>	the mechanisms by which they are mediated, is a major activity of science and engineering.
	v) Empirical evidence is needed to identify patterns	<ol> <li>Scale, Proportion and Quantity: In considering phenomena, it is critical to recognize what is relevant at different size, time,</li> </ol>
	2. Cause and Effect: Mechanism and Prediction	and energy scales, and to recognize proportional relationships between different quantities as scales change.
	<ul> <li>i) Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.</li> <li>ii) Cause and effect relationships can be suggested and predicted for complex natural and</li> </ul>	<ol> <li>Systems and System Models: A system is an organized group of related objects or components; models can be used</li> </ol>
	human designed systems by examining what is known about smaller scale mechanisms within the system.	for understanding and predicting the behavior of systems.
	<ul> <li>iii) Systems can be designed to cause a desired effect.</li> <li>iv) Changes in systems may have various causes that may not have equal effects.</li> </ul>	<ol> <li>Energy and Matter. Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior</li> </ol>
	3. Scale, Proportion, and Quantity	6. Structure and Function: The way an object is shaped or
	i) The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.	structured determines many of its properties and functions.
	<li>ii) Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.</li>	<ol> <li>Stability and Change: For both designed and natural systems, conditions that affect stability and factors that control</li> </ol>
	<ul> <li>iii) Patterns observable at one scale may not be observable or exist at other scales.</li> <li>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.</li> </ul>	rates of change are critical elements to consider and understand.
	<ul> <li>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).</li> </ul>	
	4. Systems and System Models	Elaborations on (B) Scientific Practices:
	i) Systems can be designed to do specific tasks.	1. Asking Questions and Defining Problems: A practice of science is to ask and refine questions that lead to descriptions
	<ul> <li>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.</li> <li>iii) Models (e.g., physical, mathematical, computer models) can be used to simulate systems</li> </ul>	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
	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	solutions and identify constraints to solve problems about the designed world. Both scientists and engineers also ask questions to clarify ideas.
	precision and reliability due to the assumptions and approximations inherent in models.	2. Developing and Using Models: A practice of both science

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#### 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

 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 analysisto 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

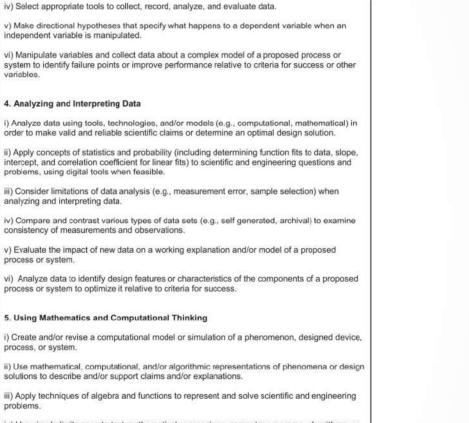
i) Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate 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.



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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

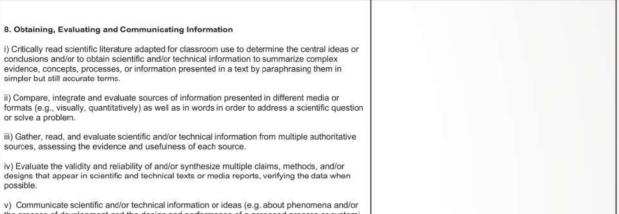
i) Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.

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). 

iii) Gather, read, and evaluate scientific and/or technical information from multiple authoritative

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).

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## 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.

 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.

 Design a solution to a complex real-world problem, based on scientific knowledge, studentgenerated 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.

 Evaluate a solution to a complex real-world problem, based on scientific knowledge, studentgenerated sources of evidence, prioritized criteria, and trade off considerations.

iii) 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

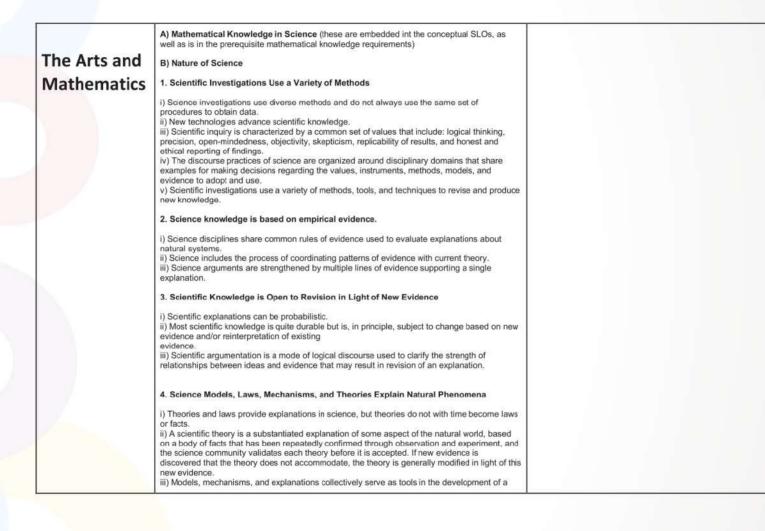
#### real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem. i) Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. ii) Both physical models 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.





#### 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.

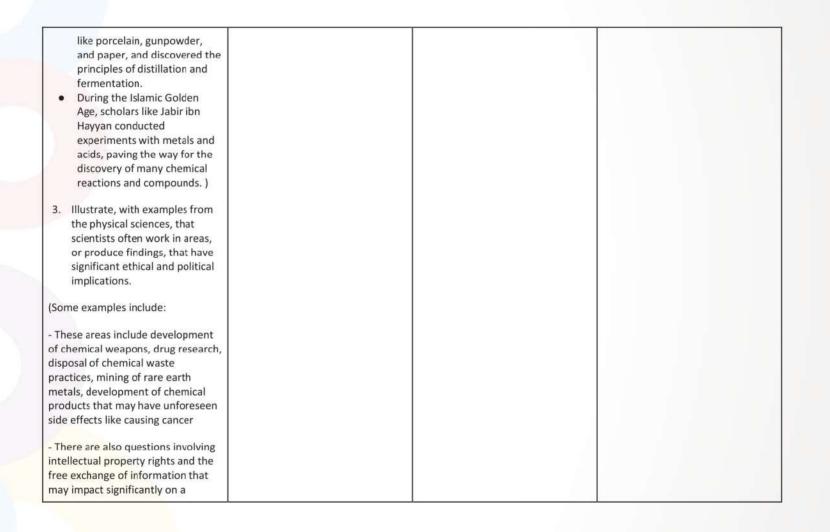
ii) Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions.

 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.
 Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues.

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

## Cross Cutting Theme

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#### 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**

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#### **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.

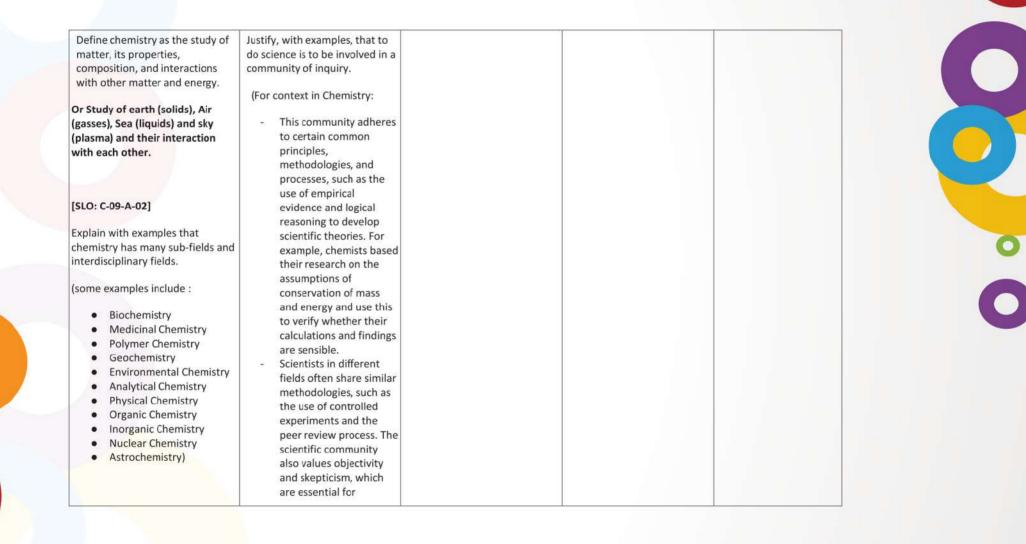
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#### Assessment Criterion for Domain A

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
	of Science in Chemistry		
Benchmark 1: Students can des	understanding, skill and attitude to deal in the areas of ch cribe the history of chemistry, d key developments in the field.	M/A	
The Science of Chemistry: [SLO: C-09-A-01]	History of Chemistry [SLO: C-10-A-01]	N/A	

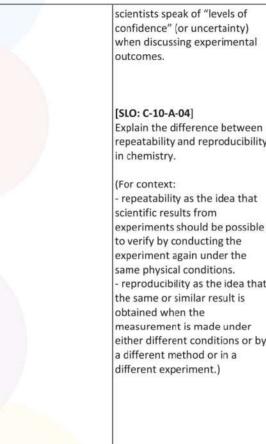


SLO: C-09-A-03]	ensuring the accuracy and validity of scientific		
Formulate examples of essential questions that are important for the branches of Chemistry	findings).		
e.g. for Analytical Chemistry a question would be 'how can we	[SLO: C-10-A-02]		
accurately determine the chemical			
compositi <mark>on of a sam</mark> ple?')	that a 'scientific		
	paradigm' is a		
The Practice of Science:	theoretical model of how nature works		
	now nature works		
	(Some examples include:		
	- The belief that materials		
SLO: C-09-A-04]	that burn do so because a		
Differentiate between 'science',	material called 'phlogiston'		
technology' and 'engineering' by	was the paradigm in chemistry in the 18th		
making reference to examples	century		
rom the physical sciences.	<ul> <li>Historical models of the</li> </ul>		
	atom are paradigms, such		
Science is a process of exploring	as the 'plum-pudding' and		
new knowledge methodically	the Rutherford models of		
hrough observation and experiments, technology refers to	the atom		
the process of applying scientific	- The periodic table of		
nowledge in practical applications	elements, and belief in the		
or various purposes. Engineering	'periodicity' of atoms based on the arrangements of		
s the application of knowledge in	their electrons is a		
order to design, build and			
maintain a product or a process			

(18)

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 t	o explain and evaluate, with exa	mples, what philosophical assum	ptions underpin the practice of	science
Benchmark I: Students should able t - identify common sources of argum - explain the broad schools of though between chemistry and the nature of - give examples of ethical dilemmas practice of science - explain the broad schools of though distinguished from other fields of ind	entative fallacies ht about the relationship of knowledge that emerge from research and ht about how science is		<ul> <li>Benchmark I: Students should be explain the role of thou chemical theory</li> <li>consider the ethical aspusing chemical substance</li> </ul>	ght experiments in ects of developing and
	<b>[SLO: C-10-A-03]</b> Explain, with examples, how		Thought Experiments [SLO: C-11-A-01]	Ethics and Values in Chemistry:

(19)



repeatability and reproducibility

- repeatability as the idea that experiments should be possible - reproducibility as the idea that either different conditions or by

20

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

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#### (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



#### assumptions

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#### **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

Benchmark 2: Students can understand to phase changes, and can explain the impa	See States and Second and Marcal	N/A	
Explain the effect of temperature on solubility and formation of unsaturated and saturated solutions			
[SLO: C-09-B-07]			
suspensions as mixtures and give an example of each			
[SLO: C-09-B-06] Identify solutions, colloids, and			
[SLO: C-09-B-05] Explain the differences between elements, compounds and mixtures			
Explain the allotropic forms of solids (some examples may include diamond, graphite, and fullerenes)			
(examples could include familiarity with plasma, intermediate states and exotic states e.g. BEC or liquid crystals) [SLO: C-09-B-04]			
[SLO: C-09-B-03] Identify that state is a distinct form of matter			
State the distinguishing macroscopic properties of commonly observed states of solids, liquids and gasses in particular density, compressibility, and fluidity.			

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	N/A	N/A
	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]		

#### 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

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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]     N/A       Explain the structure of the atom as a central nucleus containing neutrons and protons surrounded by electrons in shells     Image: Containing neutrons and protons surrounded by a su	[SLO: C-11-B-01] N/A Describe that, each atomic shell and subshell are further divided into degenerate orbitals having the same energy.
[SLO: C-09-B-09] State that, orbits (shells) are energy levels of electrons and a larger shell implies higher	[SLO: C-11-B-02] describe protons, neutrons and electrons in terms of their relative charges and relative masses
energy and greater average distance from nucleus [SLO: C-09-B-10] State that electrons are	[SLO: C-11-B-03] Recognize that the terms atomic and proton number represent the same concept
quantum particles with probabilistic paths whose exact paths and locations cannot be mapped (with reference to the uncertainty principle)	[SLO: C-11-B-04] Recognize the terms mass and nucleon number represent the same concept
[SLO: C-09-B-11] Explain that a nucleus is made	[SLO: C-11-B-05]

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

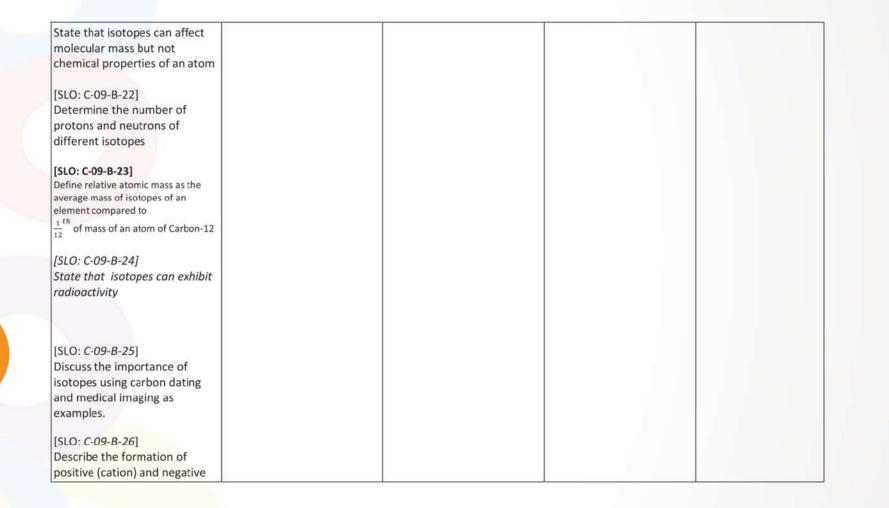
#### [SLO: C-11-B-08]

Determine the electronic configuration of elements and their ions with proton numbers. (Some examples include:

a. simple configuration

[SLO: C-09-B-16]	e.g. 2,8,
Define proton number/atomic	b. subshells e.g. 1s <sup>2</sup> , 2s <sup>2</sup> ,
number as the number of	2p <sup>6</sup> , 2s <sup>1</sup>
protons in the nucleus of an	c . Students should be
atom.	able to determine
	both of these from
[SLO: C-09-B-17]	periodic table and are
Explain that the proton number	not required to
is unique to each element and	memorize these
used to arrange elements in	d. students should
periodic table	understand that
	chemical properties of
[SLO: C-09-B-18]	an atom are governed
State that radioactivity can	by valence electrons)
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]	

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(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			
masses and abundance of			
isotopes,			
[SLO: C-09-B-29] calculate the relative mass of			
an isotope given relative atomic	c		
mass and abundance of all stable isotopes.			
N/A		Benchmark 2: Students can des configuration of atomic shells a and relate electronic configura ionization energy	and subshells in detail,
N/A	N/A	[SLO: C-11-B-09] Define terms related to	N/A
		electronic configuration	
		(Some examples include	
		shells, subshells, orbitals, principal quantum	
		number (n), ground state),	
		[SLO:C-11-B-10]	





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#### [SLO: C-11-B-16] Determine the electronic configuration of atoms

configuration of atoms and ions given the proton or electron number and charge, 6

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#### [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

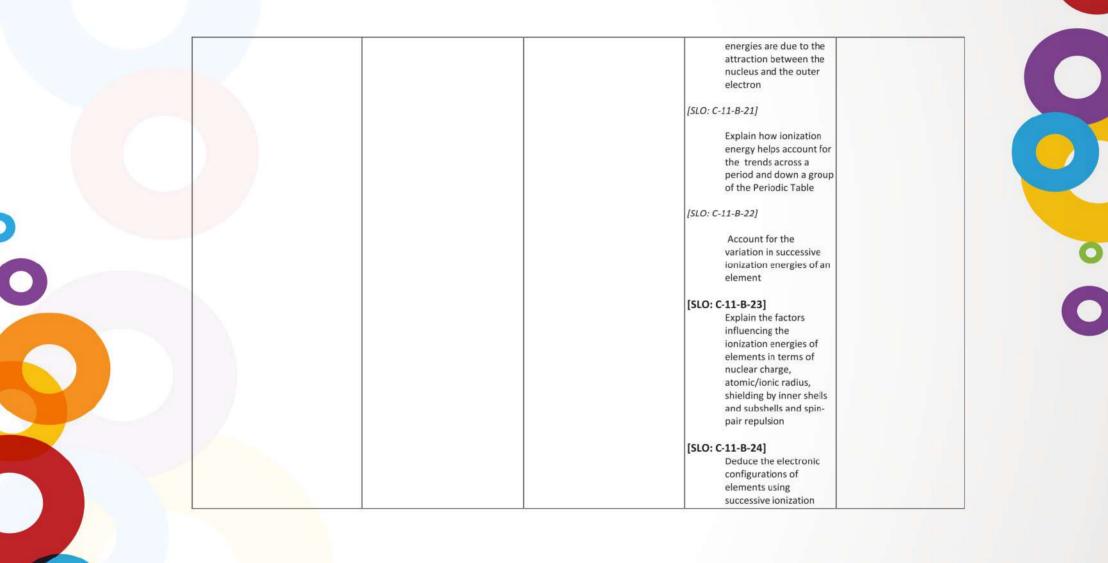
Describe the shapes of s, p and d orbitals

#### [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



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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 propert of molecules, including molecular geometry, and polarity	
<ul> <li>[SLO: C-09-B-30] Describe that noble gas electronic configuration, octet and duplet rules help predict chemical properties of main group elements</li> <li>[SLO: C-09-B-31] Compare between the formation of cations and anions</li> <li>[SLO: C-09-B-32] Account for the electropositive and electronegative nature of metals and non metals.</li> </ul>	N/A	[SLO: C-11-B-29]       N/A         • Define electronegativity as the power of an atom to attract electrons to itself       Image: State of the state of	
[SLO: C-09-B-33] Define ionic, covalent, coordinate covalent and metallic bonds		[SLO: C-11-B-31] • Explain the trends in electronegativity across a period and down a	

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[SLO: <i>C-09-B-34</i> ]	group of the Periodic Table
Differentiate between ionic	
a service and the service of the ser	
compounds and covalent	
compounds.	
(The following points need to be	
included in the respective	
definitions:	
a. Ionic Bond as strong	
electrostatic attraction	
between oppositely	[SLO: C-11-B-32]
charged ions	Use the differences in
b. Covalent bond as strong	Pauling electronegativity
electrostatic attraction	values to predict the formation of ionic and
between shared electrons	covalent bonds
and two nuclei	covalent bonds
c. Metallic bond as strong	[SLO: C-11-B-33]
electrostatic attraction	Describe covalent
between cloud/sea of	bonding in molecules
delocalized electrons and	using the concept of
positively charged cations)	hybridization to describe
	sp, sp2 and sp3 orbitals
[SLO: C-09-B-35]	
Explain the properties of	[SLO: C-11-B-34]
compounds in terms of bonding	
and structure	Use bond energy values
and structure	and the concept of bond
(CLO, C. 00, P. 36)	length to compare the
[SLO: C-09-B-36]	reactivity of covalent molecules
Compare uses and properties of	molecules
materials such as strength and	[SLO: C-11-B-35]
conductivity as determined by the	• Describe the shapes
type of chemical bond present	and bond angles in
	and boild 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 lonic 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-andcross diagrams and Lewisdot structures
- simple molecules including H<sub>2</sub>, Cl<sub>2</sub>, O<sub>2</sub>, N<sub>2</sub>, H<sub>2</sub>O, CH<sub>4</sub>, NH<sub>3</sub>, HCl, CH<sub>3</sub>OH, C<sub>2</sub>H4, CO<sub>2</sub>, HCN, and similar molecules using dot-andcross diagrams and Lewisdot 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

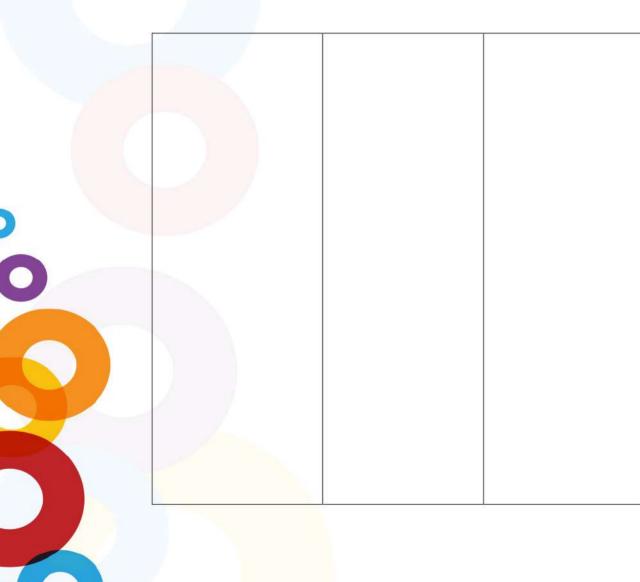
# (Including:

- instantaneous dipole induced dipole (id-id) force, also called London dispersion forces
- 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,

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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<sub>2</sub>O (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

			H₃O <sup>+</sup> ion (resonance structure not required)	
Standard: (Stoichiometry) Student	s should be able to:			
Explain the mole concept and its a	pplication in chemical calculations	, including stoichiometry.		
Apply the law of conservation of n	nass to predict the quantities of re	actants and products in chemical i	reactions.	
Constructing chemical equations a	nd understanding the balancing o	f these chemical equations.		
Use stoichiometry to calculate the	amount of reactants and product	s in a chemical reaction.		
Describe the relationship betweer	moles, mass, and volume, and ap	ply this relationship to stoichiome	tric 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]				N/A
State the formulae of common elements and compounds. [SLO: <i>C-09-B-43</i> ] Define molecular formula of a	[SLO: C-10-B-10] Use the molar gas volume, 24 dm <sup>3</sup> at room temperature and pressure, in calculations involving gases		[SLO: C-11-B-50] Express balanced chemical equations in terms of moles, representative particles, masses, and volumes of gases (at STP).	
compound as the number and type of different atoms in one molecule [SLO: C-10-B-11] Define concentration, use both g/dm <sup>3</sup> and mol/dm <sup>3</sup> , and convert			[SLO: C-11-B-51] Explain the concept of limiting reagents	
Define empirical formula of a compound as the simplest whole number ratio of different atoms in a molecule	between them		[SLO: C-11-B-52] Calculate the maximum amount of product and amount of any	

# [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<sup>23</sup>) 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<sup>3</sup> or mol/dm<sup>3</sup>, including conversion between cm and dm<sup>3</sup>)

# [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

# using moles. [SLO: C-11-B-58] [SLO: C-09-B-51] Deduce the symbol equation with state symbols for a chemical reaction Calculate the quantities of given relevant information. 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:

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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.

symbols.

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.

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[SLO: C-09-B-52]	[SLO: C-10-B-16]	N/A	[SLO: C-12-B-01]
Define redox reactions as simultaneous oxidation and reduction in terms of oxyge hydrogen, electrons and changes in oxidation state	n, compound, in molten or aqueous solution, by		Apply the concept of oxidation numbers in identifying oxidation and reduction reactions
[SLO: C-09-B-53] Use roman numerals to indicate oxidation number	passage of electric current		
an element in a compound			[SLO: C-12-B-02]
[SLO: C-09-B-54] Identify oxidizing and reducing agents in a redox reaction	<ul> <li>[SLO: C-10-B-17]</li> <li>Identify and label in simple electrolytic cells, the anode (+), cathode (- ), electrolyte and direction of flow of</li> </ul>		Apply the concept of changes in oxidation numbers to balance chemical equations
[SLO: C-09-B-55]	electrons in external		[SLO: C-12-B-03]
Recognize that the oxidation number of elements in their free sta is zero	circuit,		Define the terms redox, oxidation, reduction, and disproportionation
[SLO: C-09-B-56] Derive the formula of ionic compounds from ionic charges and oxidation numbers	[SLO: C-10-B-18] • Describe the transfer of charge in external circuit, movement of ions in the electrolyte		(in terms of electron transfer and changes in oxidation number)
[SLO: C-09-B-57] Identify that the oxidation number of	and transfer of electrons at electrodes		[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 hydrogenoxygen 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. 0

# [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

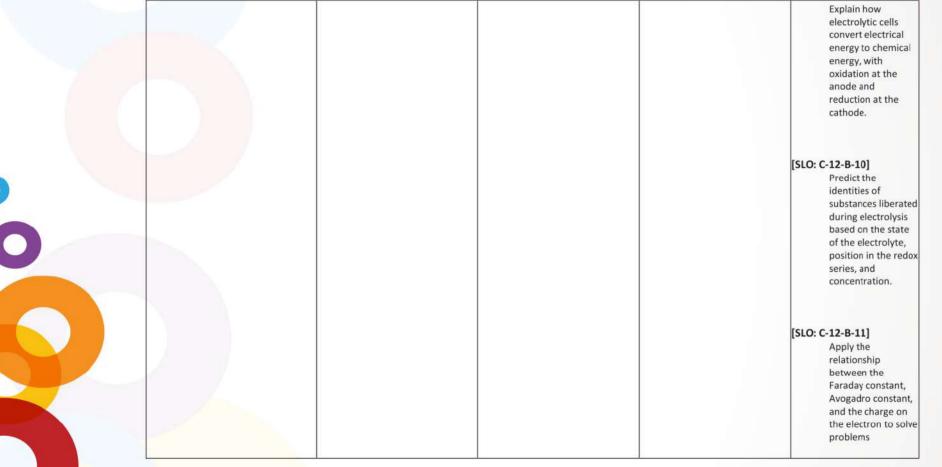
# [SLO: C-12-B-07]

Deduce the feasibility of redox reactions from activity series or reaction data.

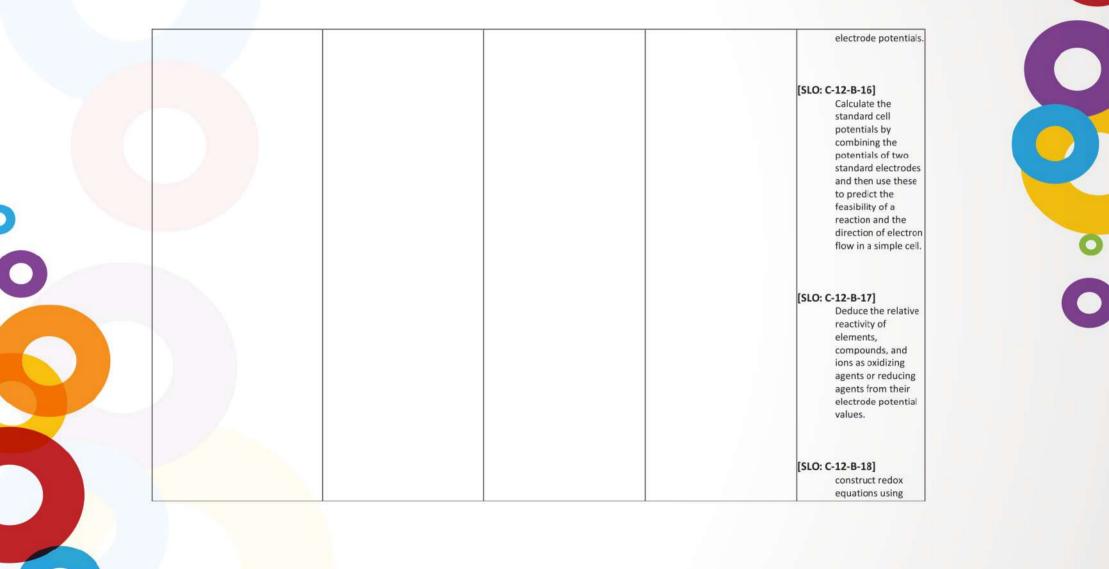
# [SLO: C-12-B-08]

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]







		equations.	
		[SLO: C-12-B-19] Explain hov electrode p vary with ti concentrat aqueous io use the Ne equation to this quantit	ootentials he ions of ns and rnst o predict
Benchmark 2: Students can apply to explain and predict the behavior transfer of electrons in chemical r the role of electrochemistry in rea batteries, corrosion, and electrop	or of electrochemical cells and the eactions. They also understand al-world applications, such as	Benchmark 2: Students should be able to explain voltaic or galvanic cells convert chemical energy 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	[SLO: C-10-B-22] Identify the products formed at electrodes and describe the observations made during the electrolysis of dilute	[SLO: C-10-B-60][SLO: C-12-B-20]Explain the merits of photovoltaic cells as sustainable ways of meeting energy demands by making reference to the photovoltaic principleExplain ho convert en spontaneoi processes to processes to	ells ergy from us, c chemica

relevant half-

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electrical energy	
[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 chemica processes to electrical energy, with oxidation at the anode and reduction at the

# halide compound in dilute or concentrated solution [SLO: C-10-B-21] [SLO: C-10-B-24] Construct ionic halfequations 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

# 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.

products of electrolysis of a

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

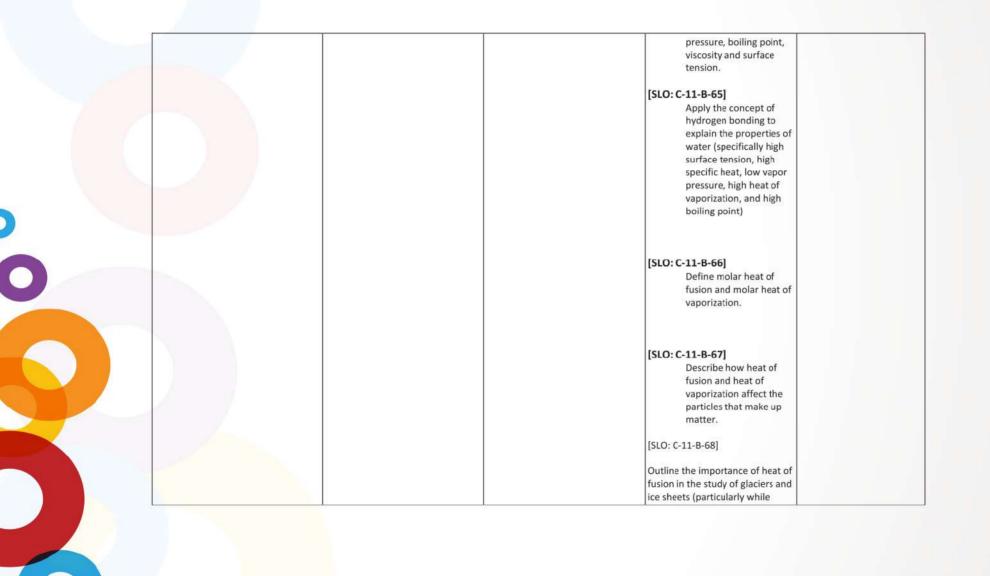
# cathode

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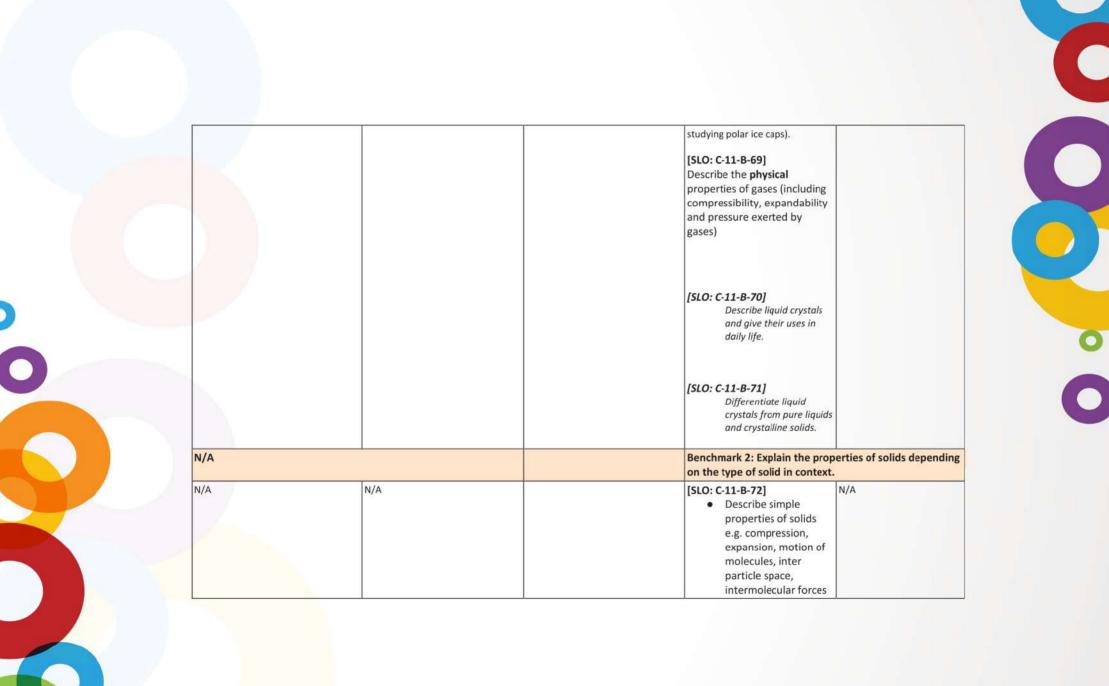
Explain how voltaic cells convert chemical energy from redox reactions to electrical energy using Cu-Zn galvanic cell as an example

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, 
		[SLO: C-11-B-64] Describe physical properties of liquids such as evaporation, vapor



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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

and kinetic energy

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 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 b concepts, including energy chang thermochemistry, in chemical re	e, internal energy, enthalpy, and	Benchmark 1: Students should of thermodynamics to analyze changes in chemical systems, i endothermic reactions, enthal	and predict energy ncluding exothermic and
[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, ∆H

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]

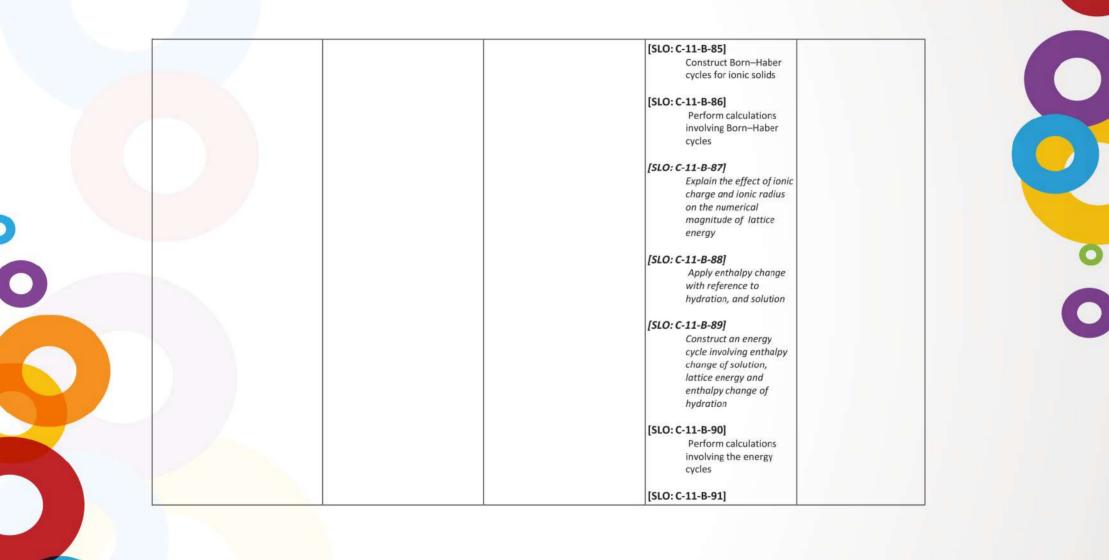
Define terms such as enthalpy change of atomization, ΔH, lattice energy, ΔH, first electron affinity, EA

# [SLO: C-11-B-83]

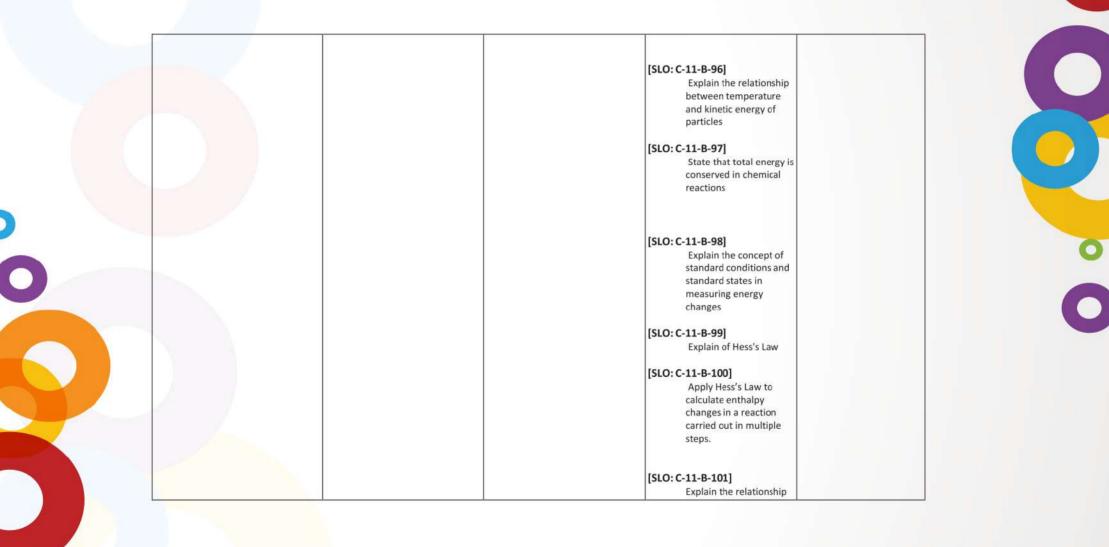
Use terms such as enthalpy change of atomization, ΔH, lattice energy, ΔH, first electron affinity, EA

#### [SLO: C-11-B-84]

Explain the factors affecting the electron affinities of elements







[SLO: C-12-B-102] Explain Gibbs free energy

between bond formation energy, and bond breaking energy C

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[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	Benchmark 1: The student will be able to calculate the
kinetics to analyze and predict the rate of chemical reactions,	rate of reaction and rate constant using the rate law
including the effect of changing conditions on reaction rate.	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.

N/A

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#### [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

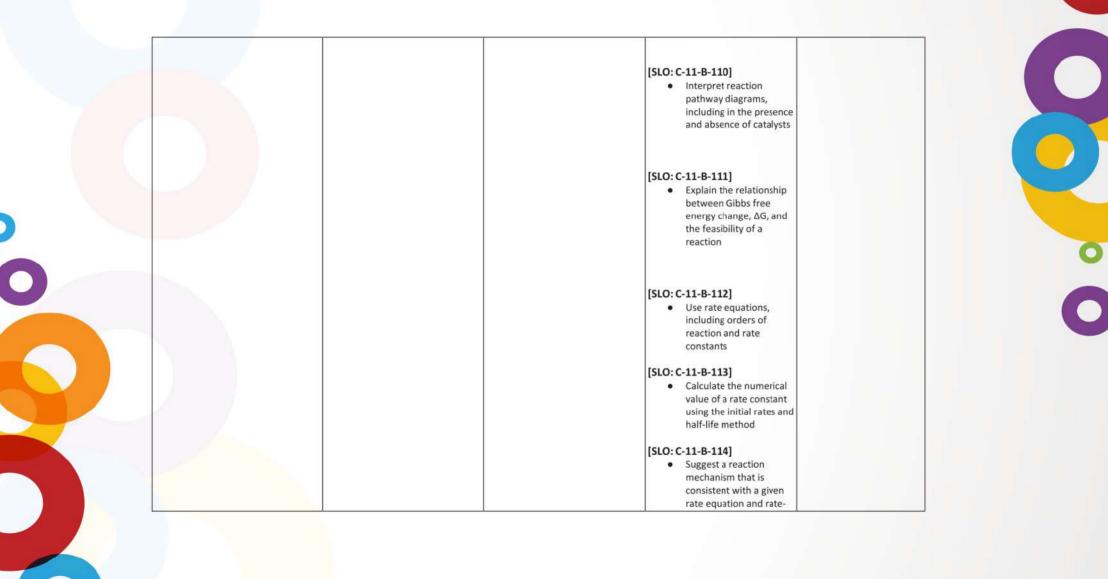
# [SLO: C-11-B-108]

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

#### [SLO: C-11-B-109]

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 Explain the concept of catalyst and how they increase the rate of a reaction by lowering the activation energy

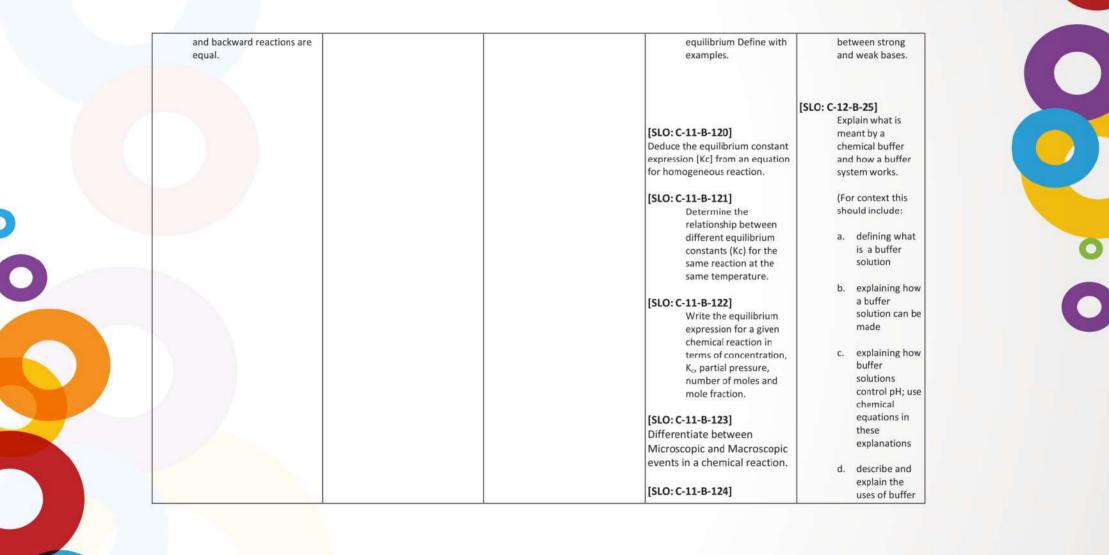


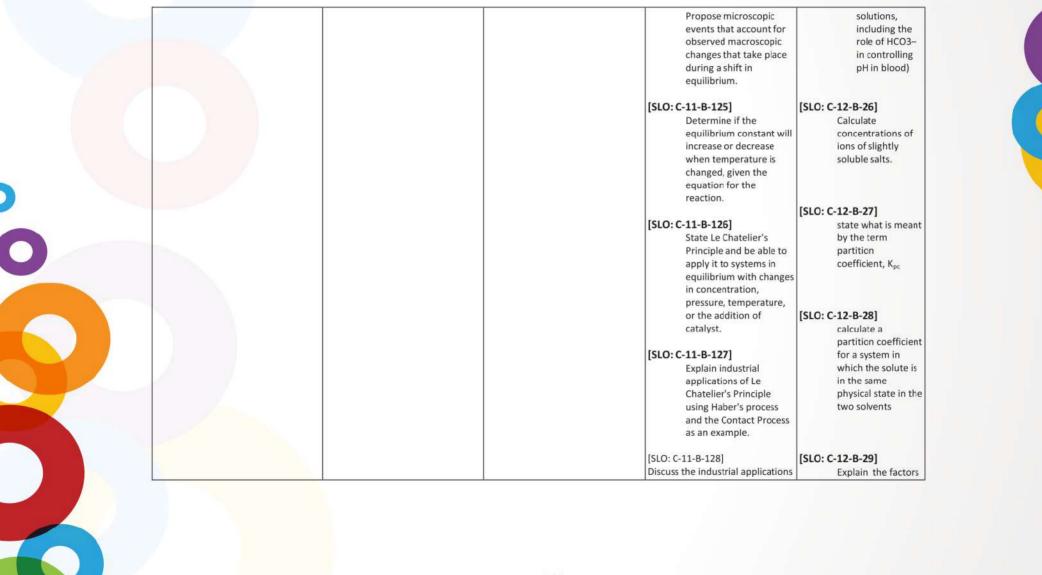
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		determining step [SLO: C-11-B-115]  Describe the effect of temperature change on the rate constant and rate of a reaction.
rate of chemical reaction	can describe the factors that influence the ons, including concentration, temperature, these factors 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
Explain the relationship	tudents should be able to: Describe the conce b between concentration of reactants or prod action to predict the position of chemical equi	nical equilibrium and the dynamic nature of chemical reactions. the position of equilibrium.
Discuss the effect of ter	mperature and pressure 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 or adjustment of physical parameters	
[SLO: C-09-B-72] Recognize that reversible reaction are shown by symbol ⇒ and may no go to completion [SLO: C-09-B-73] Describe how changing the physical conditions of a chemical equilibrium syster can redirect reversible		[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-12-B-22] explain common ion effects giving suitable examples.
reactions (Some examples can includ a. effect of heat on hydrate compounds		<b>[SLO: C-11-B-117]</b> Define dynamic equilibrium between two physical states.	[SLO: C-12-B-23] Use the extent of ionization and the acid dissociation constant, K <sub>a</sub> , to
<ul> <li>addition of water to anhydrous substances in particular copper(II) sulfate and cobalt (II) chloride</li> </ul>		[SLO: C-11-B-118] State the necessary conditions for equilibrium and the ways that equilibrium can be recognized.	distinguish between strong and weak acids.
SLO: C-09-B-74] State that reversible reactions can achieve equilibrium in a closed system when rate of forwar	d		[SLO: C-12-B-24] Use the extent of ionization and the base dissociation constant, K <sub>b</sub> , to distinguish





reactions to maximize yields and a partition minimize waste products. coefficient in terms of the polarities of the solute and the solvents used [SLO: C-11-B-129] Use the concept of hydrolysis to explain why aqueous solutions of some salts are acidic or basic. Standard: (Acid-Base Chemistry and pH) Students should be able to: Define acids and bases and describe their properties. Explain the concept of pH and describe the relationship between pH and the concentration of hydrogen ions in a solution. Describe the different types of acid-base reactions, including neutralization and proton transfer. Discuss the use of buffers to control pH, including the relationship between buffer capacity and the concentration of buffer components. Benchmark 1: Students will be able to identify and distinguish Benchmark 1: Students will be able to calculate pH between acids and bases based on their properties, chemical values for dissolved acids and alkalis, including in behavior,

of chemical equilibria and how it

can be used to optimize chemical

affecting the

numerical value of

C

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behavior, and their definition using Brønsted-Lowry theory.		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<sup>+</sup>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
hese 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-[SLO: C-12-B-30] base pairs [SLO: C-11-B-131] identify conjugate acidbase 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<sub>a</sub>, pK<sub>a</sub> and 10<sup>-14</sup> at 298 K to solve K<sub>w</sub> and use them in calculations (K<sub>b</sub> and the equation  $K_w = K_a \times K_b$  will not be tested)

#### [SLO: C-11-B-134]

calculate [H<sup>+</sup>(ag)] 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.

State that  $pH = -\log[H^{+}(aq)]$ and  $[H^{\dagger}] = 10$ (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<sup>+</sup>]. [SLO: C-12-B-32]

Use the ionic product constant,  $K_w = [H^+][OH^-] =$ 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

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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 0

[SLO: C-11-B-137] Demonstrate the ability to comprehend and

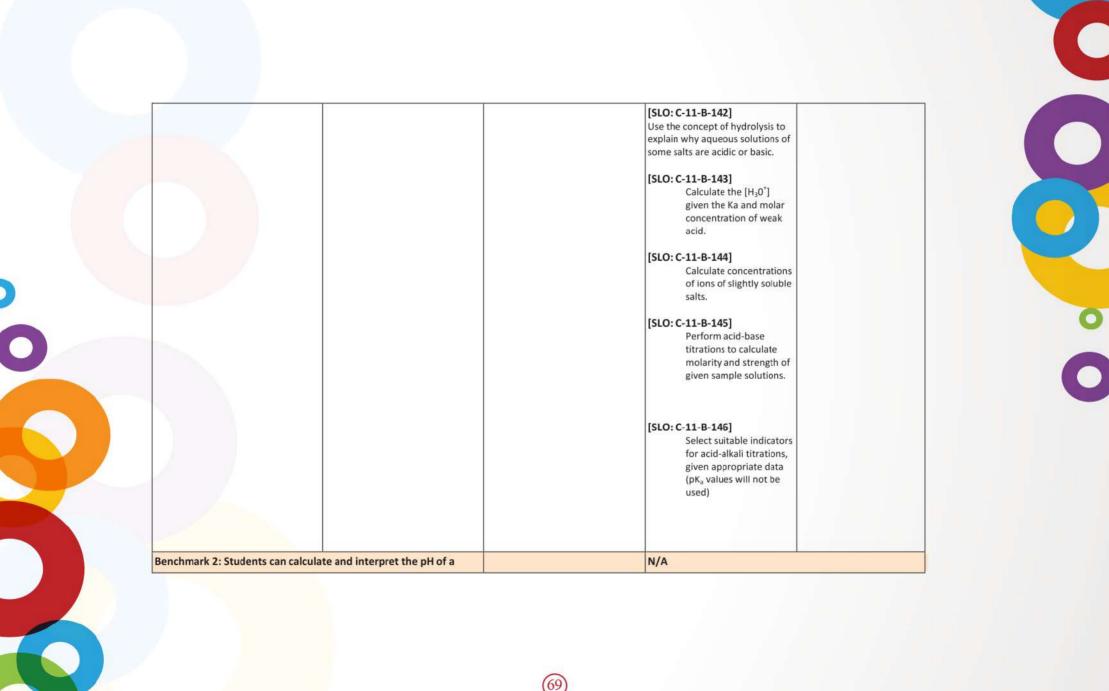
effectively apply the concept of solubility product. (K<sub>sp</sub>)

[SLO: C-11-B-138] Construct an expression for K<sub>sp</sub>

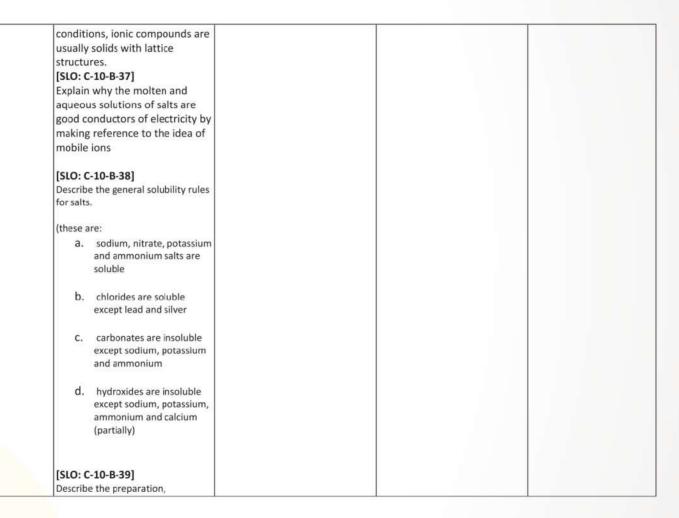
[SLO: C-11-B-139] calculate K<sub>sp</sub> from concentrations and vice versa

> [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<sub>sp</sub> values and concentration of a common ion



	d the relationship between pH, strength of acids and bases.		
	N/A	N/A	
tandard: (Salts) Studer	nts should be able to: Describe the nature of salts, including t	heir formation from the reaction of	acids and bases.
xplain the concept of i	onic compounds, including the arrangement of ions in a cryst	tal lattice.	
issues the properties o	fasts including solubility conductivity and malting point		
iscuss the properties o	of salts, including solubility, conductivity, and melting point.		
pply the principles of o	chemical bonding to explain the behavior of salts in different	physical states.	
escribe the role of salt	s in chemical reactions, including their effect on acid-base ed	juilibria.	
	will be able to differentiate between based on their properties and solubility.	N/A	
I/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	N/A	N/A
	from bases and negative ions come from acids) [SLO: C-10-B-35] Explain why at STP salts are solids with high melting points.		



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.

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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.		explain the periodic trends of ionization energy, electron aff predict the properties and read on their position in the period properties to classify elements	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		

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 sublevelss, p, d, and f. 6

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# [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. 0

# [SLO: C-11-C-07]

Recognize that trends in metallic and nonmetallic behavior are due to the trends in valence electrons.

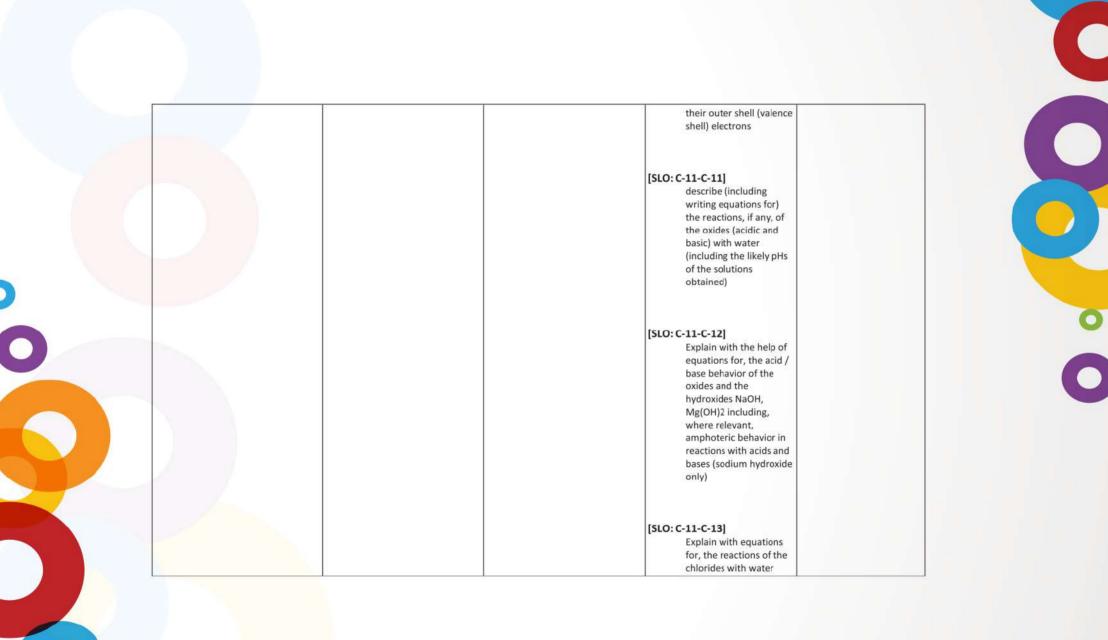
[SLO: C-11-C-08]

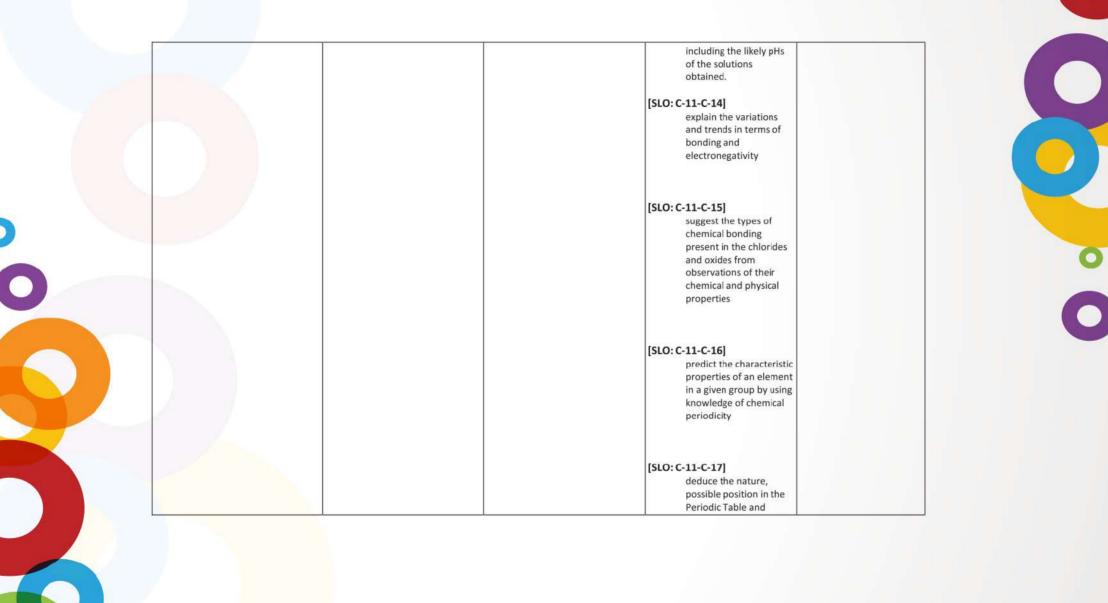
Deduce the electron configuration of an atom from the element's position on the periodic table, and vice versa (based on s,p,d and f subshells).

[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<sub>2</sub> in terms of





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identity of unknown elements from given information about physical and chemical properties C

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[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 describ properties of elements in different including their reactivity and their	t groups of the periodic table,	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 greyblack 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<sub>2</sub>) 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<sub>2</sub> 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

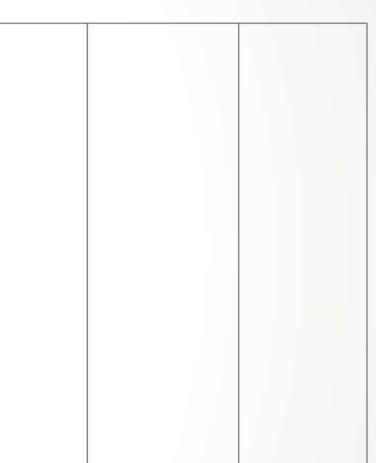
#### [SLO: C-10-C-05]

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,  $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$ 

ts in [SLO: C-10-C-07]



group VII, given information about the elements State the sources of the sulfur dioxide (burning sulfur or roasting sulfide ores) and oxygen (air) in the Contact process

# [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]

# [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<sub>2</sub> and CO<sub>2</sub>, basic, including CuO and CaO, or amphoteric, limited to Al<sub>2</sub>O3 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.



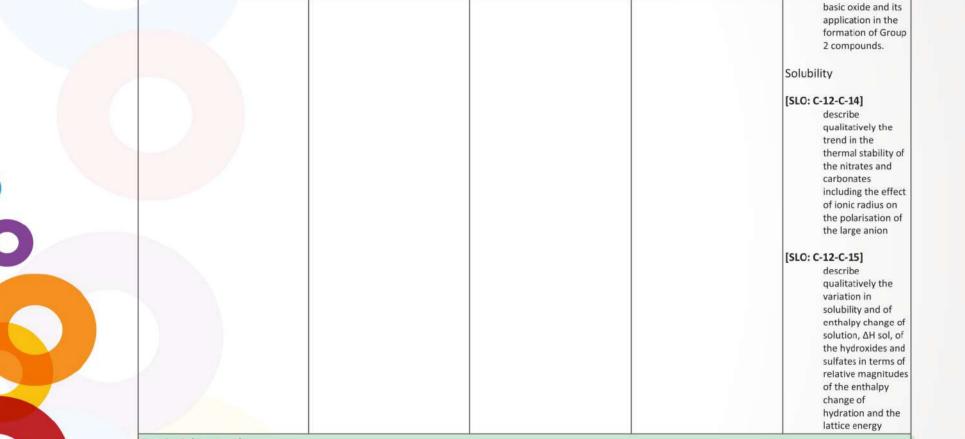
	e general physical f metals and non-metals.	[SLO: C-10-C-12] Arrange metals in order of reactivity given relevant information			
b. c.	in terms of: thermal conductivity electrical conductivity malleability and ductility melting points and boiling points)				
Standard: ( The studen	Group 2) its will be able to:				
		ents based on their position in the oup 2 elements based on their elec		n state	
Explain the Describe th Explain the	e reactivity trends of Gro ne industrial and everyd e methods for extraction e solubility and other pro		tron configuration and oxidation as magnesium in alloys, calcium ents, such as thermal reduction a	in construction, and ba and electrolysis	
Explain the Describe th Explain the Discuss the	e reactivity trends of Gro ne industrial and everyd e methods for extraction e solubility and other pro	oup 2 elements based on their elec ay uses of Group 2 elements, such and purification of Group 2 eleme	tron configuration and oxidation as magnesium in alloys, calcium ents, such as thermal reduction a	in construction, and ba and electrolysis p 2 hydroxides in water Benchmark 1: Describe Group and their chem elements. These include	

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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.

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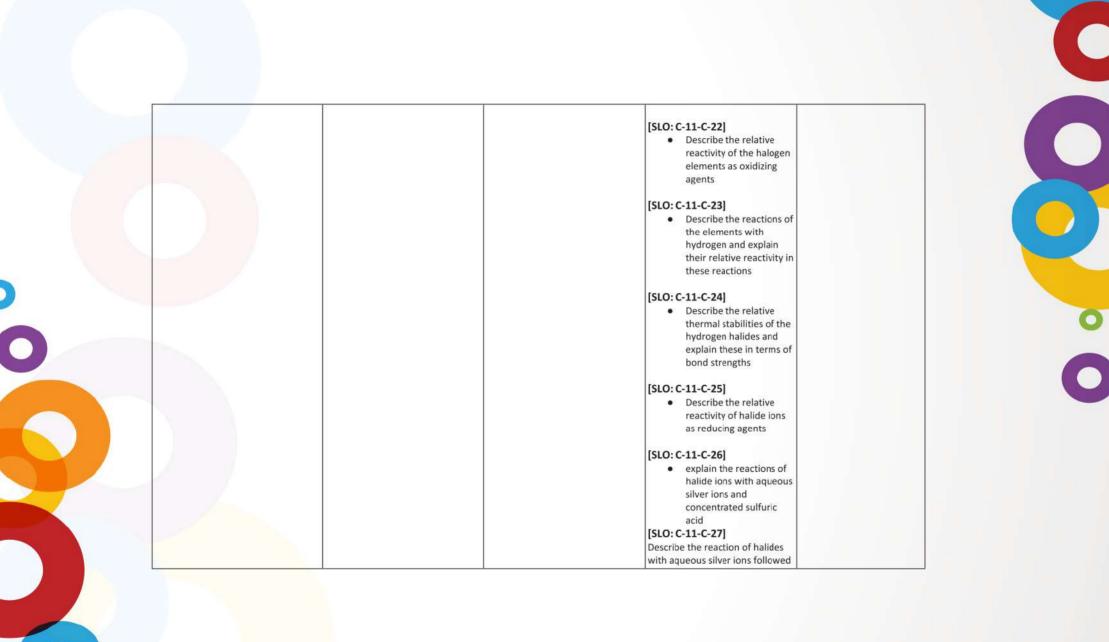
Explain the industrial and everyday uses of Group 17 elements and their compounds, such as the production of refrigerants and disinfectants.

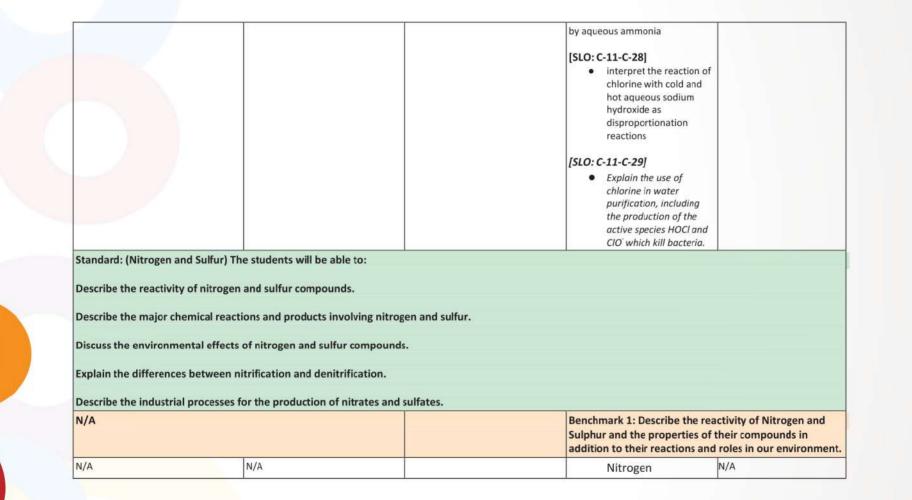
Identify the halide ions (chloride, bromide, and iodide) and predict their reactivity based on the trends in Group 1 elements.

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 ha and their tendency to form compounds with vario elements in the periodic table.	
N/A	N/A	<ul> <li>[SLO: C-11-C-19]</li> <li>Describe the colors and trend in volatility of chlorine, bromine and iodine</li> </ul>	N/A
		<ul> <li>[SLO: C-11-C-20]</li> <li>Describe the trend in bond strength of halogen molecules</li> </ul>	
		<ul> <li>[SLO: C-11-C-21]</li> <li>Interpret the volatility of the elements in terms of instantaneous dipole- induced dipole forces</li> </ul>	





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man-made occurrences of oxides of nitrogen and their catalytic removal from exhaust gases of internal combustion engines 0

[SLO: C-11-C-35]

Explain the role of NO and NO<sub>2</sub> 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.



and in the Synthetic organic chemistry, including the synthesis of dyes, drugs and fragrances. 0

# 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 th periodic table and understand their general properties.
N/A	N/A	[SLO: C-12-C-16] Identify the gener physical and chemical properti of the first row of transition elements, titaniur to copper [SLO: C-12-C-17] define a transitior element as a d- block element which forms one more stable ions with incomplete of orbitals
		[SLO: C-12-C-18] sketch the shape



			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







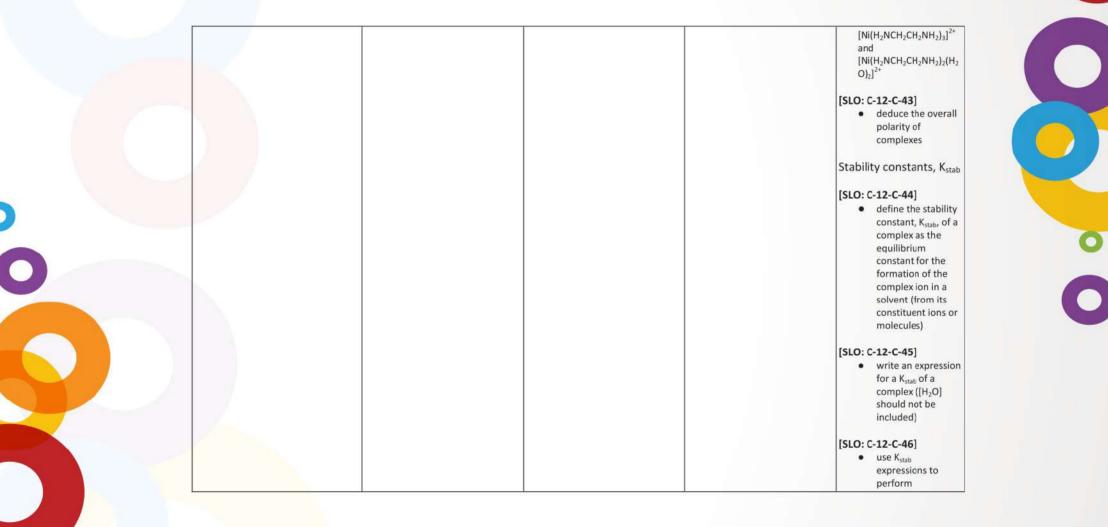
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		redox systems given suitable data
N/A	N/A	Colour of complexes
		[SLO: C-12-C-37] • use the terms degenerate and non-degenerate d orbitals
		[SLO: C-12-C-38] • describe the
		splitting of degenerate d orbitals into two non-degenerate
		sets of d orbitals of higher energy, and use of ∆ E in:
		(a) octahedral complexes, two higher and three lower d orbitals
		(b) tetrahedral complexes, three high and two lower d orbitals



		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
		<ul> <li>[SLO: C-12-C-42]</li> <li>describe the types of stereoisomerism shown by complexes, including those associated with bidentate ligands:</li> <li>(a) geometrical (cistrans) isomerism, e.g. square planar such as [Pt(NH<sub>3</sub>)<sub>2</sub>Cl<sub>2</sub>] and octahedral such as [Co(NH<sub>3</sub>)<sub>4</sub>(H<sub>2</sub>O)<sub>2</sub>]<sup>2+</sup> and [Ni(H<sub>2</sub>NCH<sub>2</sub>CH<sub>2</sub>NH<sub>2</sub>)<sub>2</sub>(H<sub>2</sub>O)<sub>2</sub>]<sup>2+</sup></li> </ul>
		(b) optical isomerism, e.g.

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			calculations [SLO: C-12-C-47] • explain ligand exchanges in terms of K <sub>stab</sub> values and understand that a large K <sub>stab</sub> is due to the formation of a stable complex ion
Domain D: Environmental Chemistry			
Apply the principles of chemical re-	atmospheric pollutants, including	the greenhouse effect. greenhouse gases and air pollutants. and removal of atmospheric pollutants. stry and its impact on air quality and cli	
Benchmark 1: Demonstrate an und	erstanding of the composition,	Bend	hmark 1: Evaluate the impact of various pollutants
structure and functions of the Eart role of atmospheric gases, pollutar			ne environment and life and describe possible ions to mitigate these impacts.
[SLO: C-09-D-01] State that composition of clean, dry air is approximately 78% nitrogen, N <sub>2</sub> , 21% oxygen, O <sub>2</sub> , and the remainder as a mixture of noble gasses and carbon dioxide, CO <sub>2</sub>	N/A	ldent comp (Inclu	: C-11-D-01] N/A ify the properties and position of the atmosphere. Ide the concepts of 4 layers mosphere and their

(101)

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# [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
- 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 6

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[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<sub>3</sub>), 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
- 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

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# [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:

- 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 6

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#### [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

			pollution and air quality management and demonstrate		
[SLO: C-09-D-08]			through answers.		
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					
Standard: (Water) Students should	be able to: Describe the propertie	es and composition of water, inclu	uding its chemical and physical	properties.	

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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.

(105)

Apply the principles of chemical reactions to explain the formation and removal of water pollutants.

Benchmark: Explain how to measu		N/A	
evaluate the role of water in varior processes (like making fertilizers), human activities on the quality and resources.	and describe the impact of		
[SLO: C-09-D-12]	N/A	[SLO: C-11-D-15]	N/A
Investigate chemical tests for the		Identify different types of water	
presence of water using anhydrous		pollution, (some examples include	
copper(II) sulfate		point source and nonpoint source pollution	
[SLO: C-09-D-13]			
Explain how to test the purity of		[SLO: C-11-D-16]	
water using melting point and boiling		Identify common water pollutants	
point		(Some examples include oil,	
		pesticides, and heavy metals	
[SLO: C-09-D-14]			
Distinguish between Distilled water		[SLO: C-11-D-17]	
and tap water with their applications		Identify and explain the sources	
in practical chemistry.		and effects of water pollution on	
		human health and the	
[SLO: C-09-D-15]		environment	
State that water from natural sources			
may contain useful and harmful		[SLO: C-11-D-18]	
substances.		Identify and explain	
(Some examples include:		water treatment	
alizzation of any man		methods and	
a. dissolved oxygen		technologies, such as filtration and purification	
b. metal compounds			
		[SLO: C-11-D-19]	
c. plastics		Explain the laws and	

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- 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
- 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 C

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### [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.



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 C

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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	Benchmark 1: Analyze the chemical and physical
their functional groups, nomenclature, isomerism, and homologous	properties of organic compounds based on their

series.		functional groups and be acqua and terminology of different co mechanisms.	
[SLO: C-09-E-01] Describe organic molecules as either straight-chained, branched or cyclic	[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-	[SLO: C-11-E-01] • Recognize that hydrocarbons are compounds made up of C and H atoms only	[SLO: C-12-E-01] Explain stereoisomerism and its division into geometrical (cis/trans) and
[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 <sub>2</sub> =CH <sub>2</sub> , CH <sub>3</sub> CH <sub>2</sub> OH, cut coordina	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 -	[SLO: C-11-E-02] • Recognize that alkanes are simple hydrocarbons	optical isomerism [SLO: C-12-E-02] Describe
CH <sub>3</sub> COOCH3 [SLO: C-09-E-03] Identify and draw structural formulae for molecules.	ane, -ene, -yne, -ol, or -oic acid or from a molecular, structural or displayed formula [SLO: C-10-E-03]	with no functional group	geometrical (cis/trans) isomerism in alkenes, and
[SLO: C-09-E-04] interpret general formulae of compounds in the same homologous	Name and draw the displayed formulae of the unbranched esters which can be made from unbranched alcohols and carboxylic	Recognize that compounds contain a functional group which dictates their physical and chemical properties	explain its origin in terms of restricted rotation due to the presence of $\pi$ bonds
series including alkanes, alkenes, alkynes, alcohols and carboxylic acids. [SLO: C-09-E-05]	acids, each containing up to four carbon atoms	[SLO: C-11-E-04]	
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		Interpret the general, structural, displayed and skeletal formulae of the classes of compounds	[SLO: C-12-E-03] Describe the shape of benzene and other aromatic molecules, including sp <sup>2</sup>
CH <sub>3</sub> CH=CHCH <sub>3</sub>		[SLO: C-11-E-05]	hybridisation, in terms of $\sigma$ bonds

(110)

### [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<sub>2</sub>- unit (d) displaying a trend in physical properties (e) sharing similar chemical properties)

### [SLO: C-09-E-08]

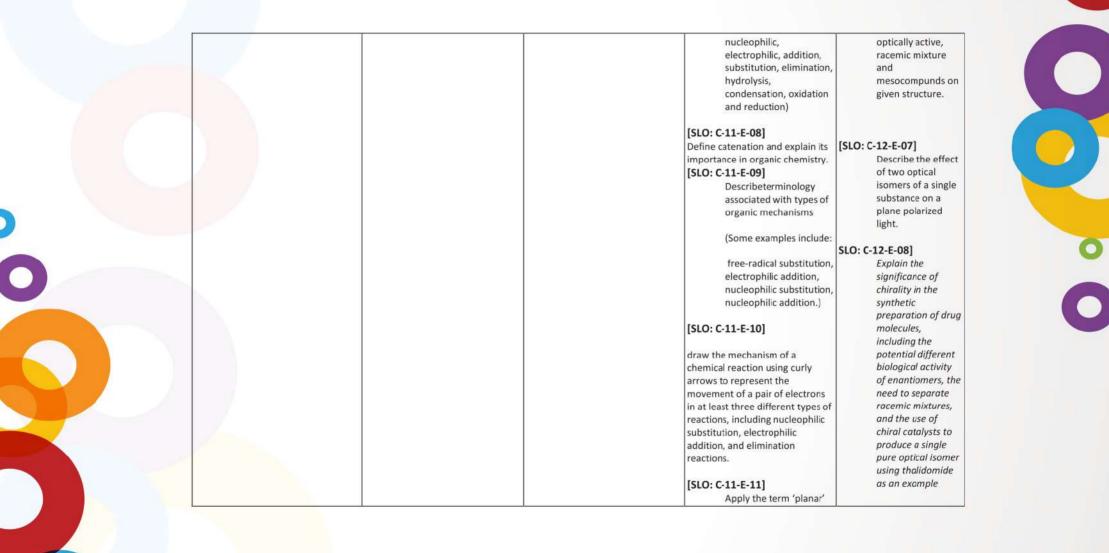
State that a saturated compound has molecules in which all carbon–carbon bonds are single bonds

### [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	and a delocalised π system
functional groups	[SLO: C-12-E-04] Explain what is meant by a chiral center and that such a center gives
Deduce the molecular	rise to two optical
and/or empirical formula	
of a compound, given its	(enantiomers)
structural, displayed or	
skeletal formula	
[SLO: C-11-E-07]	
Describe terminology	
associated with the	[SLO: C-12-E-05] Describe that
types of organic compounds and	enantiomers have
reactions	identical physical
reactions	and chemical
(Some examples include:	properties except for their ability to
homologous series,	rotate plane-
saturated and	polarized light and
unsaturated, homolytic	potential biological
and heterolytic fission,	activity.
free radical, initiation,	
propagation,	
termination,	
nucleophile,	[SLO: C-12-E-06]
electrophile,	apply the terms

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when describing the arrangement of atoms in organic molecules C

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### [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 [SLO: C-10-E-07] 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

# Alkenes

#### [SLO: C-10-E-04] State that the bonding in alkenes includes a double carbon-carbon covalent bond and that alkenes are unsaturated hydrocarbons

[SLO: C-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

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

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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
- hydrogen in the presence of a nickel catalyst
- 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.
- •

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[SLO: C-11-E-20] • Explain the nomenclature of alkenes.

#### [SLO: C-11-E-21]

 Explain shape of ethene molecule in terms of Band D 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]

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 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.

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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)

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### Standard: (Halogenoalkanes)

The students will be able to:

Explain the Synthesis of halogenoalkanes and their classifications based on their molecular structure.

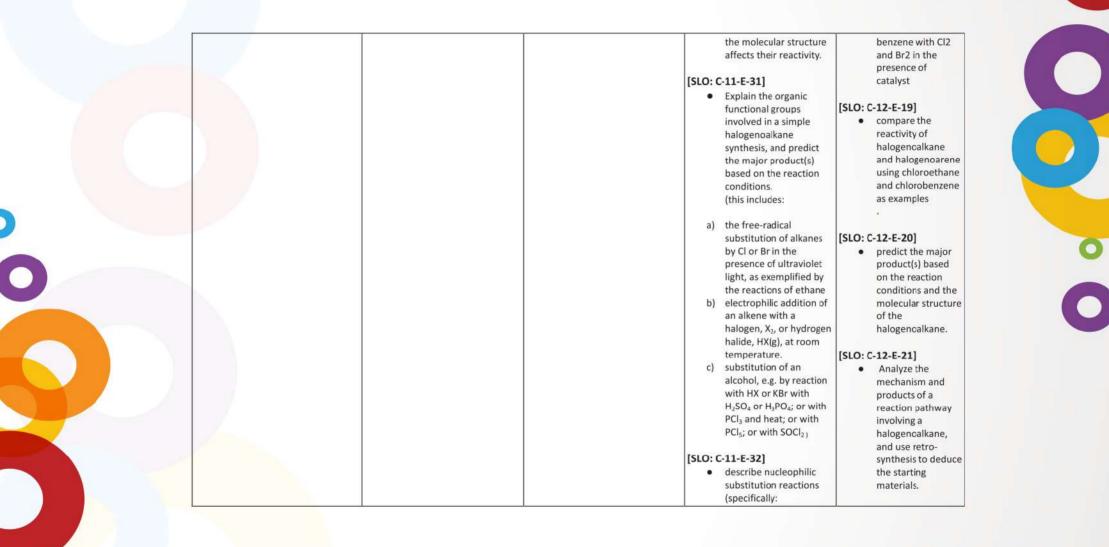
Describe the common reactions of halogenoalkanes, including elimination reactions and substitutions, with a focus on S<sub>N</sub>1 and S<sub>N</sub>2 substitution mechanisms.

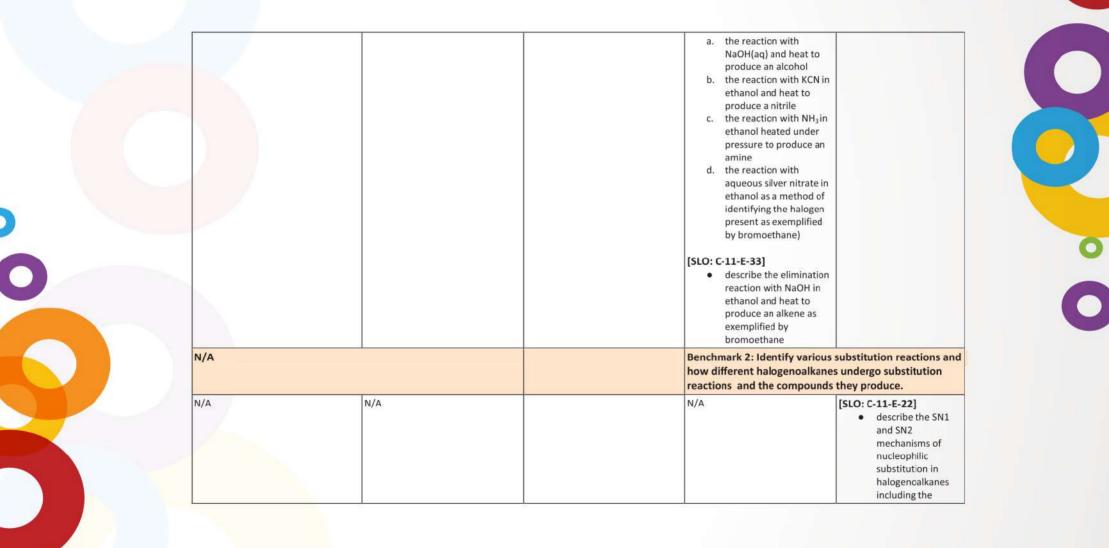
Predict the reactivity of halogenoalkanes based on their molecular structure and the reaction conditions.

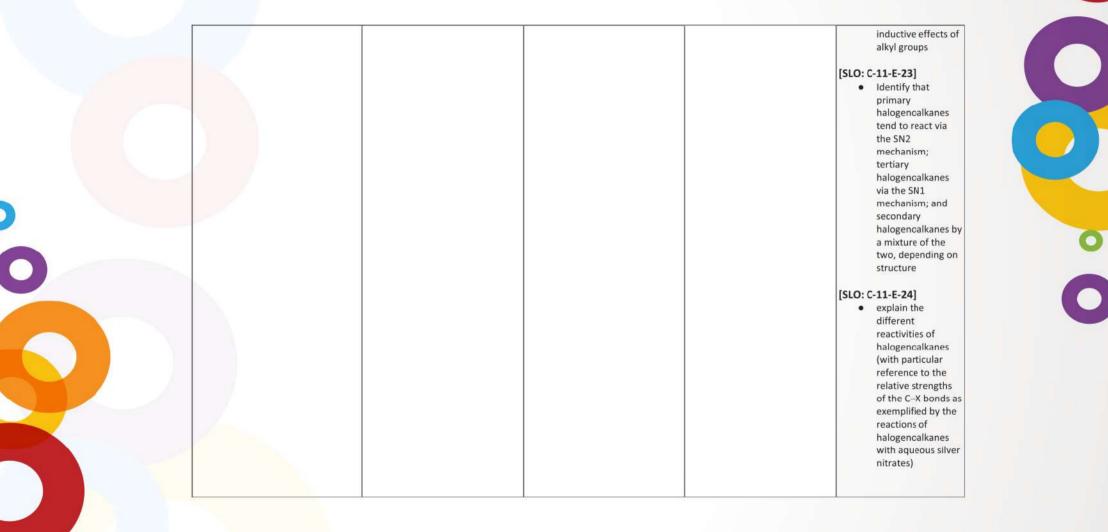
Describe simple halogenoalkane syntheses and explain the organic functional groups involved in the reactions.

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][SLO: C-12-E-18]• Classify halogenoalkanes[SLO: C-12-E-18]based on the type of halogen atom and its position in the carbon chain, and explain how• Describe production of halogencarenes reaction of	







Standard: (Hydroxy Compounds) Students should be able to: Describe the structure and properties of alcohols, including primary, secondary, and tertiary alcohols.

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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)	<ul> <li>[SLO: C-11-E-34]</li> <li>State the reactions (reagents and conditions) by which alcohols can be produced:</li> <li>a) electrophilic addition of steam to an alkene, H<sub>2</sub>O(g) and H<sub>3</sub>PO<sub>4</sub> catalyst</li> <li>b) reaction of alkenes with cold dilute acidified potassium manganate(VII) to form a diol</li> </ul>	<ul> <li>[SLO: C-12-E-25]         <ul> <li>describe the reaction with acyl chlorides to form esters using ethyl ethanoate</li> </ul> </li> <li>[SLO: C-12-E-26]         <ul> <li>recall the reactions (reagents and conditions) by which phenol can be produced: reaction of phenylamine with HNO<sub>3</sub> or NaNO<sub>3</sub> and dilute acid below 1°C to</li> </ul> </li> </ul>	

### [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<sub>4</sub> or LiAIH<sub>4</sub>
- reduction of a carboxylic acid using LiAlH<sub>4</sub>
- 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  $PCI_3$  and heat; or with PCI<sub>5</sub>; or with  $SOCI_2$ 

### [SLO: C-11-E-36]

Describe the reaction of hydroxy organic compounds with Na(s)

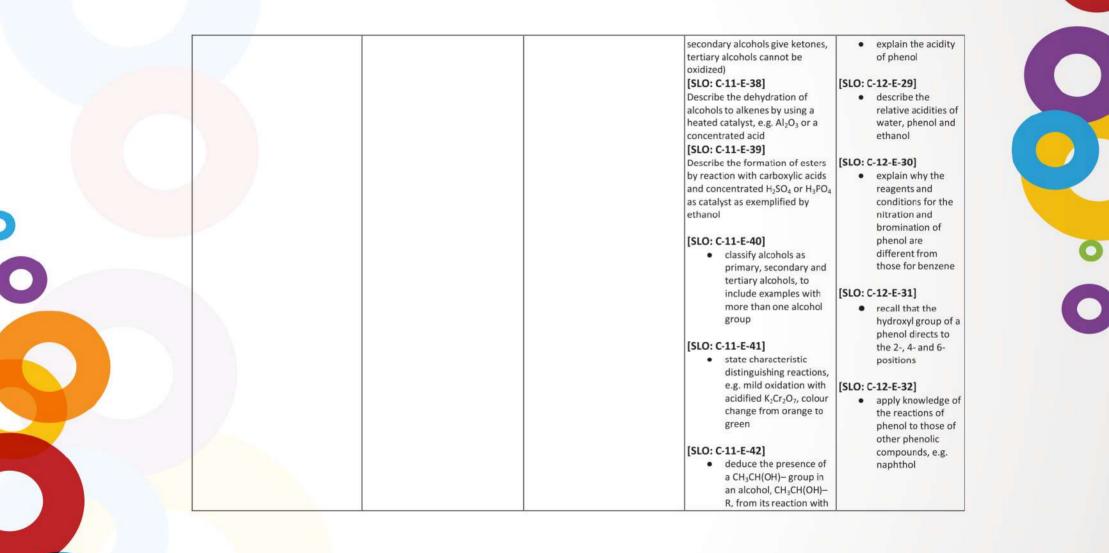
# [SLO: C-11-E-37]

Describe the oxidation with acidified K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> or acidified KMnO<sub>4</sub> 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<sub>2</sub>O to give phenol 0

### [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<sub>2</sub>(g) in NaOH(aq) with diazonium salts, to give azo compounds
- nitration of the aromatic ring with dilute HNO<sub>3</sub>(aq) at room temperature to give a mixture of 2-nitrophenol and 4-nitrophenol
- bromination of the aromatic ring with Br<sub>2</sub>(aq) to form 2,4,6tribromophenol

[SLO: C-12-E-28]



alkaline  $I_2(aq)$  to form a yellow precipitate of triiodomethane and an ion,  $RCO_2^{-}$  0

[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.

	tify and explain the properties and reactions of d esters, including their preparation, structure, and daily life.	Benchmark 1: Explain the reaction acids are produced and the nature 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-11-E-44] [9 • state the reactions (reagents and conditions) by which aldehydes and ketones can be produced: a. the oxidation of	<ul> <li>state the reaction by which benzoic acid can be produced: reaction of an alkylbenzene with</li> </ul>
	[SLO: C-10-E-21] Describe the formation of ethanoic acid by the oxidation of ethanol: with acidified aqueous potassium manganate(VII) & by bacterial	primary alcohols using acidified K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> or acidified KMnO <sub>4</sub> and distillation to produce aldehydes	hot alkaline KMnO₄ 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 K2Cr2O7 or acidified KMnO4 and distillation to produce ketones

### [SLO: C-11-E-45]

- describe: a. the reduction of aldehydes and ketones, using NaBH<sub>4</sub> or LiAlH<sub>4</sub> 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 2,4dinitrophenylhydrazine (2,4-DNPH reagent) to

### of [SLO: C-12-E-34]

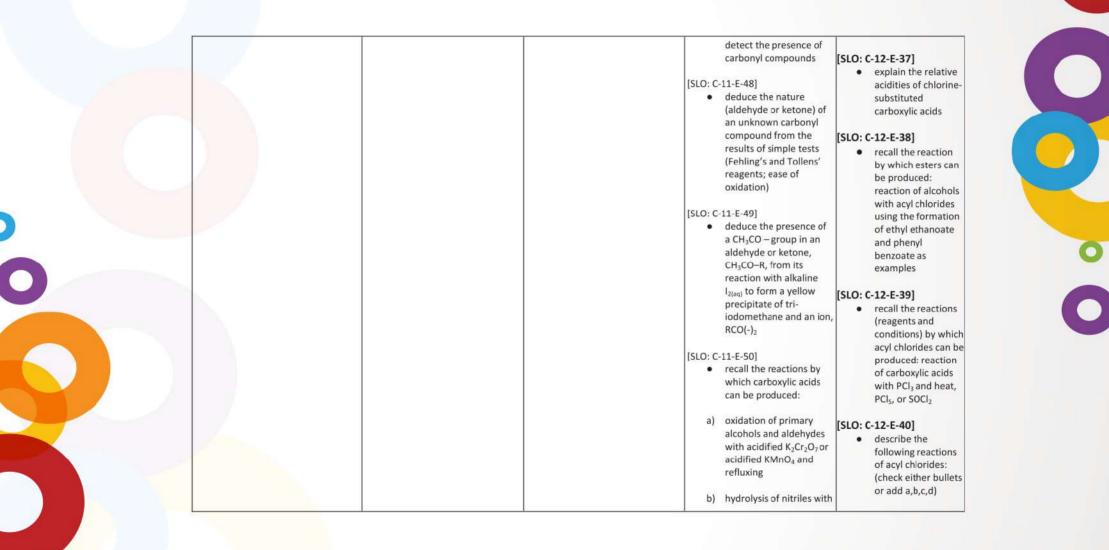
 describe the reaction of carboxylic acids with PCl<sub>3</sub> and heat, PCl<sub>5</sub>, or SOCl<sub>2</sub> to form acyl chlorides 0

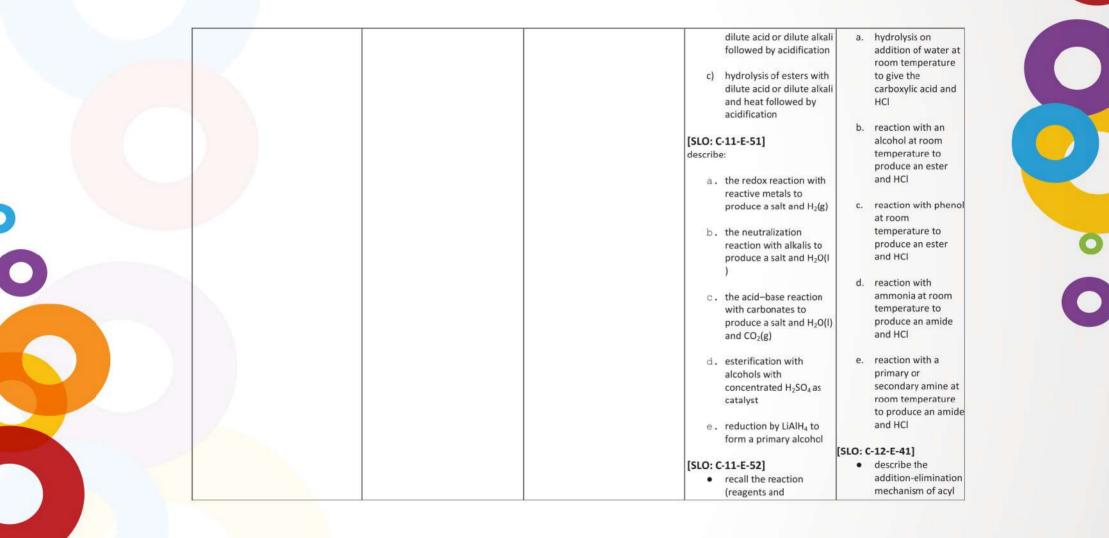
#### [SLO: C-12-E-35]

- 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<sub>4</sub> or acidified K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> to carbon dioxide and water
- B. the oxidation of ethanedioic acid, HOOCCOOH, with warm acidified KMnO<sub>4</sub> to carbon dioxide

#### [SLO: C-12-E-36]

 explain the relative acidities of carboxylic acids, phenols and alcohols





	conditions) by which esters can be produced:	chlorides in reactions
	the condensation reaction between an	[SLO: C-12-E-42]
	alcohol and a carboxylic acid with concentrated	explain the relative     ease of hydrolysis of
	$H_2SO_4$ as catalyst	acyl chlorides, alkyl chlorides and
	[SLO: C-11-E-53]	halogenoarenes
	<ul> <li>describe the hydrolysis of esters by dilute acid and by dilute alkali and</li> </ul>	(aryl chlorides)
	heat	

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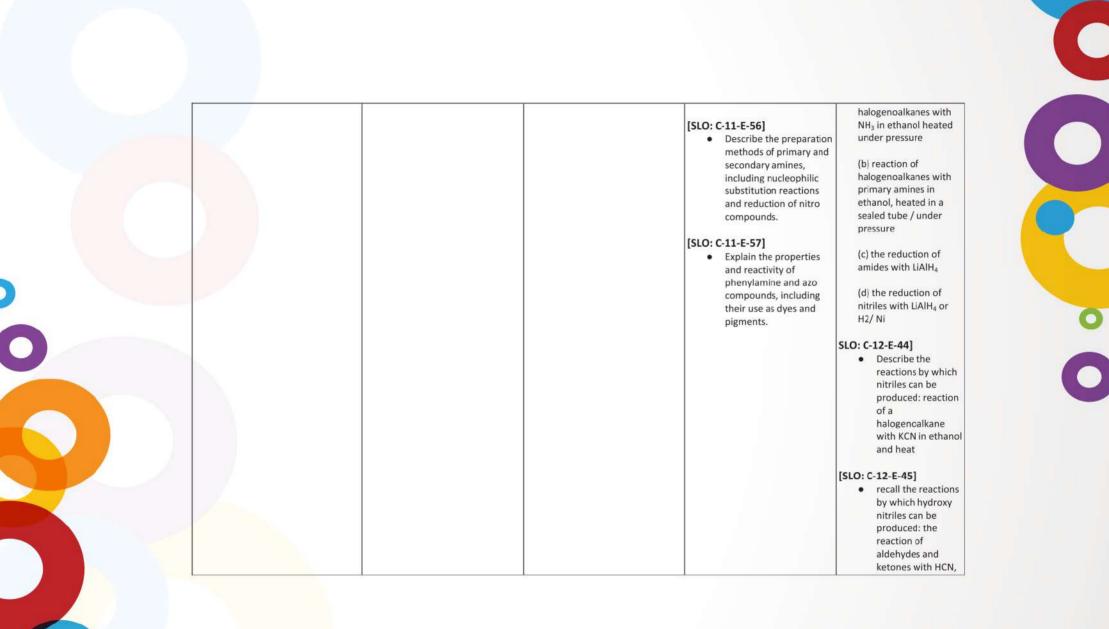
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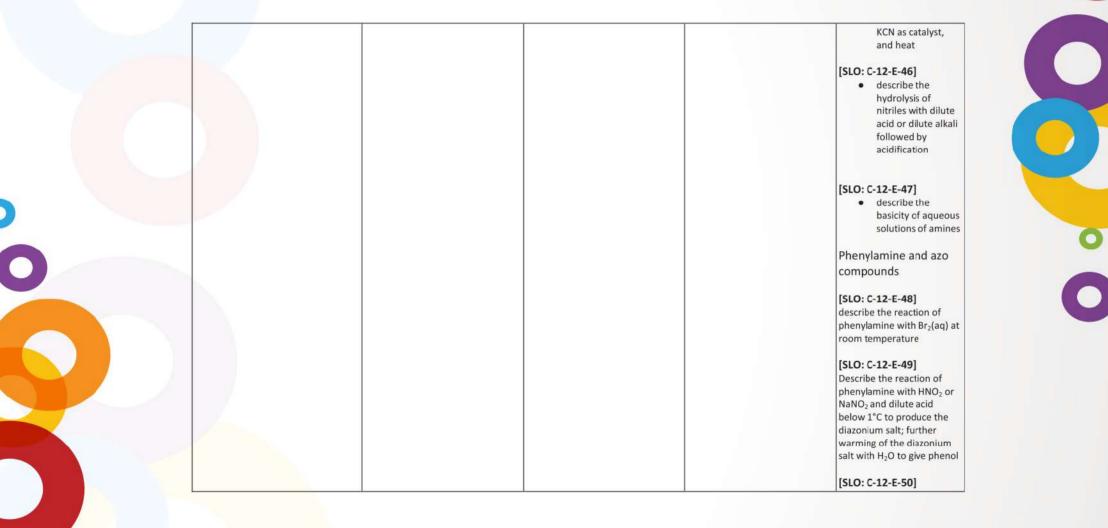
Standard: (Nitrogen Compounds) Students should be able to: Describe the structure and properties of nitrogen compounds, including their characteristic functional groups.

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 reactio aliphatic and aromatic amines including their conv to amides, forming amino acids.	
N/A	<ul> <li>Define primary and secondary amines, and</li> </ul>	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-12-E-56] describe the formation of amide (peptide) bonds between amino acids to give di- and tripeptides C

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#### [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	<ul> <li>[SLO: C-10-E-25]</li> <li>Define polymers as large molecules built up from many smaller molecules called monomers</li> <li>[SLO: C-10-E-26]</li> <li>Identify the repeating units and/or linkages in addition polymers and in</li> </ul>	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	describe the condensation reaction of ammonia or an
[SLO: C-10-E-27]	amine with an acyl chloride
Deduce the structure or	at room temperature to give
repeat unit of an addition	an amide
polymer from a given	
alkene and vice versa	[SLO: C-12-E-60]
	Discuss the
[SLO: C-10-E-28]	importance of
Deduce the structure or	chemical industries
repeating unit of a	in the economy of
condensation polymer	Pakistan, and
from given monomers and	describe the raw
vice versa, limited to:	materials that are
	available in the
a. polyamides from a	country for various
dicarboxylic acid	chemical industries
and a diamine	
	[SLO: C-12-E-61]
b. polyesters from a	Describe the
dicarboxylic acid	chemical processes
and a diol	of addition and
	condensation
[SLO: C-10-E-29]	polymerization and
Describe the differences	the differences
between addition and	between them.
condensation	Examples include
polymerisation	
	a. addition polymers
[SLO: C-10-E-30]	such as
<ul> <li>State that plastics are</li> </ul>	poly(ethene) and
made from polymers	poly(chloroethene)
	PVC,
[SLO: C-10-E-31]	
Describe how the	b. polyesters (from
properties of plastics have	reactions of diol

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# 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

 State that PET can be converted back into monomers and repolymerised

### [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), 0

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.



polyamides are biodegradable by acidic and alkaline hydrolysis

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[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.

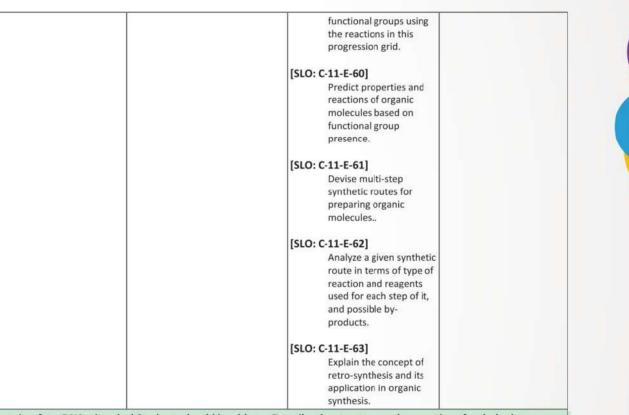
Demonstrate understanding of the basic mechanisms of common organic reactions of functional groups.

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 o organic synthesis and functional group interconversions. [SLO: C-11-E-59] Identify organic	



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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.

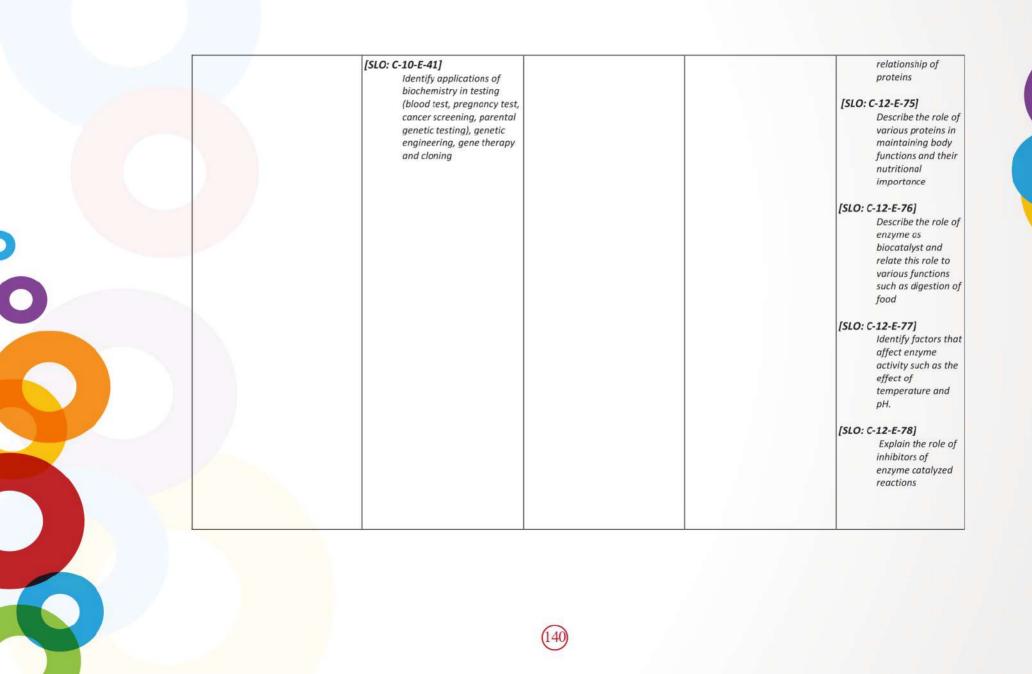
Describe the structure and function of DNA and RNA, including the role of DNA in genetics and the mechanism of transcription and translation.

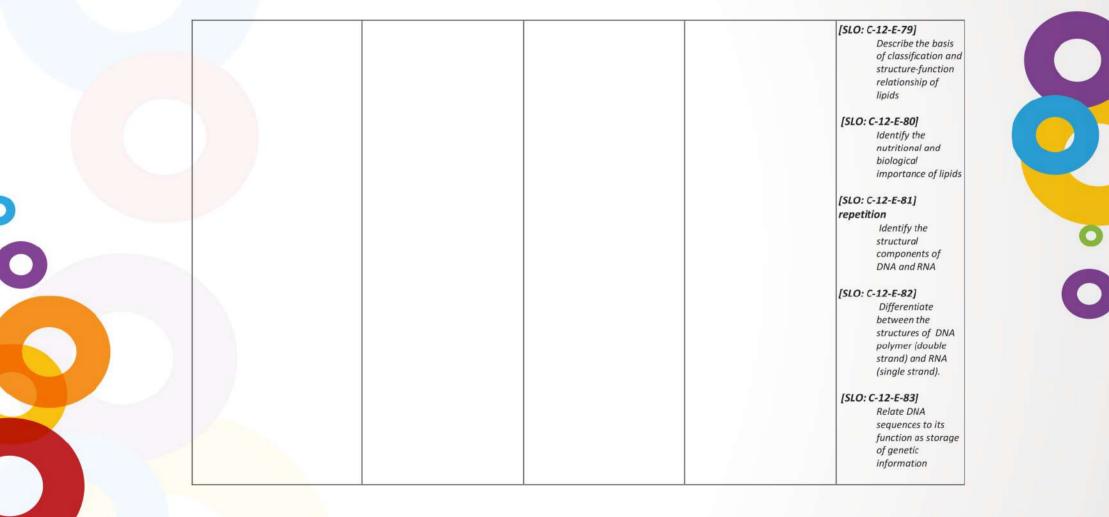
Discuss the importance of vitamins and minerals in human nutrition, including their role in metabolic processes and the consequences of deficiencies.

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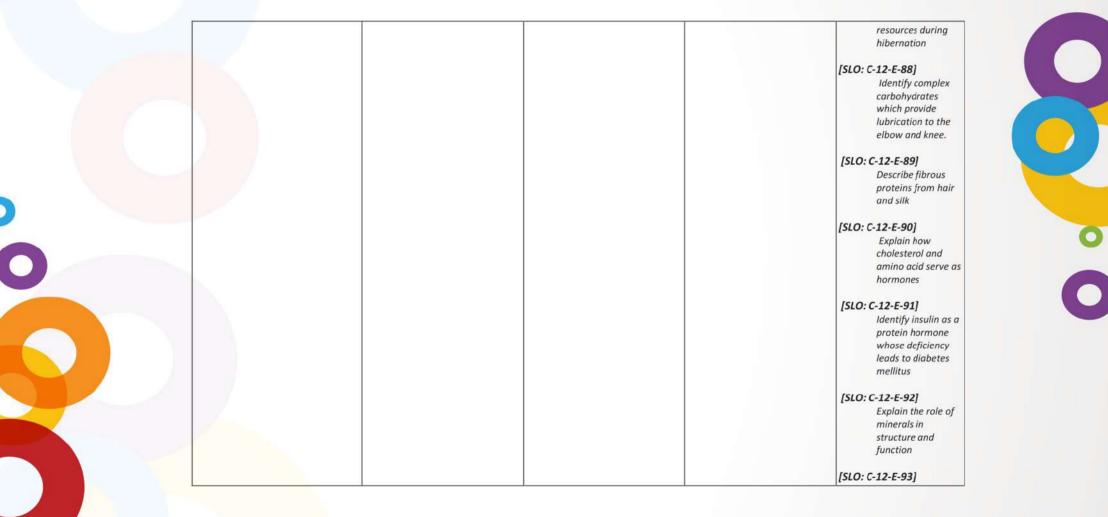
Benchmark 1:Identify the impo fats, DNA and vitamins in biolo	rtance of carbohydrates, proteins, gical systems.	Benchmark 1: Explain the structures of different biochemical compounds, their reactions and role inside living organisms.	
[SLO: C-09-E-15] Explain the importance and ba of nutrition and healthy eating [SLO: C-09-E-16]	natural polyamides and that they are formed from amino acid monomers with the general structure	[SLO: C-12-E-71] Explain the basis of classification and structure-function relationship of carbohydrates	
Recognize the main biomolecu carbohydrates, proteins, lipids and nucleic acids. their sources along with the required daily intake for young adults	es; [SLO: C-10-E-37] draw the general structure of proteins	[SLO: C-12-E-72] Explain the role of various carbohydrates in	
[SLO: C-09-E-17] Identify carbohydrates as a source of energy	[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	health and diseases [SLO: C-12-E-73] Identify the nutritional importance of carbohydrates and	
	nucleic acids [SLO: C-10-E-40] explain vitamins, their sources and their importance to health	their role as energy storage [SLO: C-12-E-74] Explain the basis of classification and structure-function	

Apply the concepts of biochemistry to understand the molecular basis of biological processes, diseases, and treatments.









Identify calcium as a requirement for coagulation 0

## [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<sup>3</sup>, 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  $1 \leq A < 10$ 

#### [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.) 0

#### [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



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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	N/A	
xperimental design	N/A	N/A	N/A	
<b>SLO: C-09-F-11]</b> Define important terms associated with creating chemical solutions. (Some examples include:				
a) solvent as a substance that dissolves a solute				
<li>b) solute as a substance that is dissolved in a solvent</li>				
<ul> <li>c) solution as a mixture of one or more solutes dissolved in a solvent</li> </ul>				
<ul> <li>d) saturated solution as a solution containing the maximum concentration of solute dissolved in the</li> </ul>	a			
Ivent at a specified temperature				
e) residue as a substance that remains after evaporation, distillation, filtration or any				

similar process		
f) filtrate as a liquid or solution		
that has passed through a		
filter)		
[SLO: C-09-F-12]		
Explain methods of separation		
and purification		
(some 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		

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		
impo	ribe tests to identify ortant gasses camples include: ammonia, NH <sub>3</sub> , using damp red litmus paper carbon dioxide, CO <sub>2</sub> , using limewater chlorine, Cl <sub>2</sub> , using damp litmus paper	N/A	N/A	N/A
e. f.	lighted splint			

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 <sup>+</sup> b) sodium, Na <sup>+</sup> c) potassium, K <sup>+</sup> d) calcium, Ca <sup>2+</sup> e) copper(II), Cu <sup>2+</sup> f) barium, Ba <sup>2+</sup> )			
		N/A	
	a.	• N/A	N/A
N/A		help analyse different at	nd how mass spectrometers can toms including isotopes based o entify molecules based on their 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 spectromete is not required)

(151)



 deduce the presence of bromine and chlorine atoms in a compound using the Mpeak

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## Standard: (Spectroscopy)

The students will be able to:

Describe the principles of spectroscopy and relate it to the interaction of electromagnetic radiation with matter.

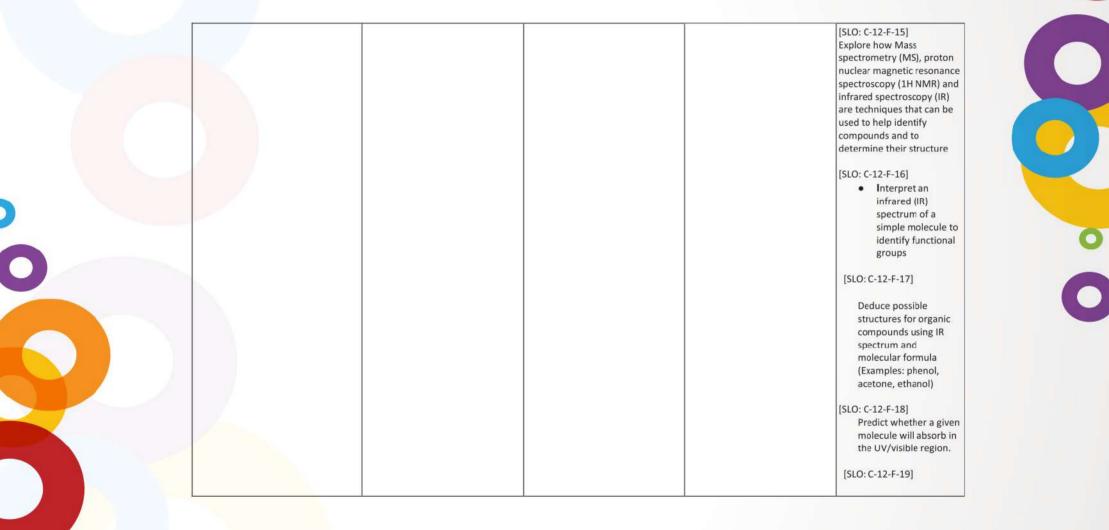
Analyze spectra to determine the presence and concentration of chemical species.

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		can be used to id structures of com	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 iden organic compound		



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Predict the color of a transition metal complex from its UV/visible spectrum. 0

[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 the compounds present and help ascertain its st in addition to deducing the relative number of d 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





of O–H and N–H protons by proton exchange using D<sub>2</sub>O

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## 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<sub>f</sub> 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, Rf 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	unknown materials.
[SLO: C-09-F-19] Interpret simple chromatograms (For context, students should identify: a) unknown substances by comparison with known substances b) pure and impure substances)	[SLO: C-12-F-33] interpret R <sub>f</sub> values and retention times in chromatograms to determine the composition of a mixture.
[SLO: C-09-F-20] State and use the equation for R <sub>f</sub>	[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. C

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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		materials, tl	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-40] Explain the use of X-ray crystallography in analyzing structures.

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### Standard: (Energy)

The students will be able to:

Compare and contrast the different energy sources based on their availability, efficiency, and environmental impact.

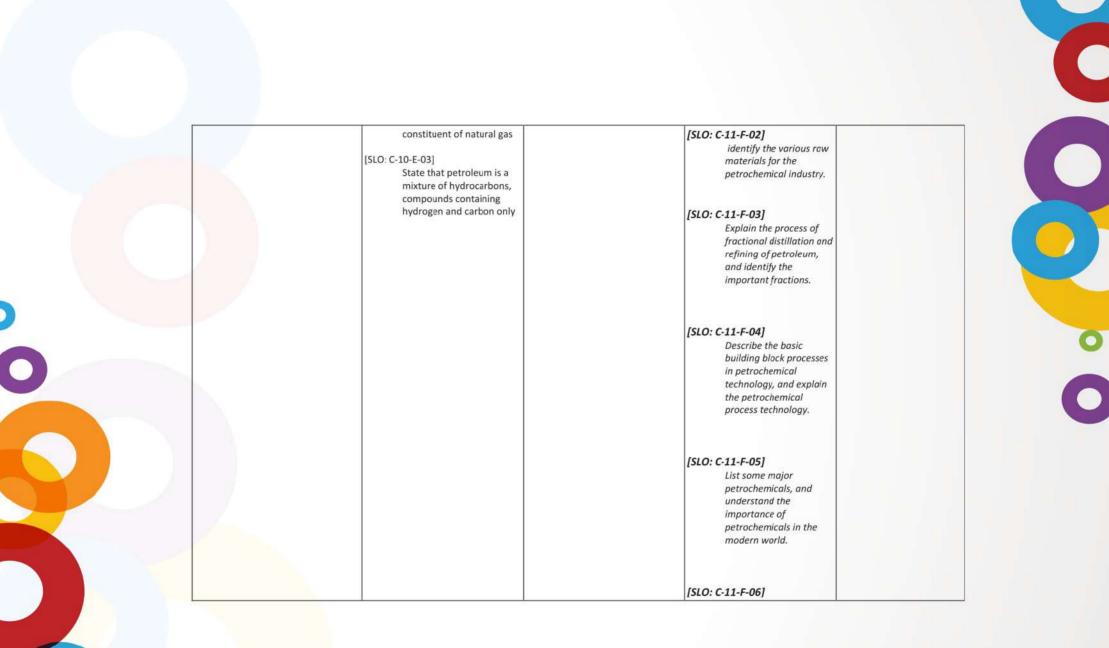
Analyze the extraction, processing, and utilization of fossil fuels, including their effects on the environment and human health.

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.

energy fuels, such as co	the composition and properties of various pal, oil, natural gas, and biofuels and explain involved in the combustion of energy fuels.	Benchmark 2: Understand the use energy, their properties and reus effect of these sources on the atm	ability and explain the
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





Distinguish between energy density and specific energy of different energy sources, and explain the efficiency of energy transfer. 6

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## [SLO: C-11-F-07]

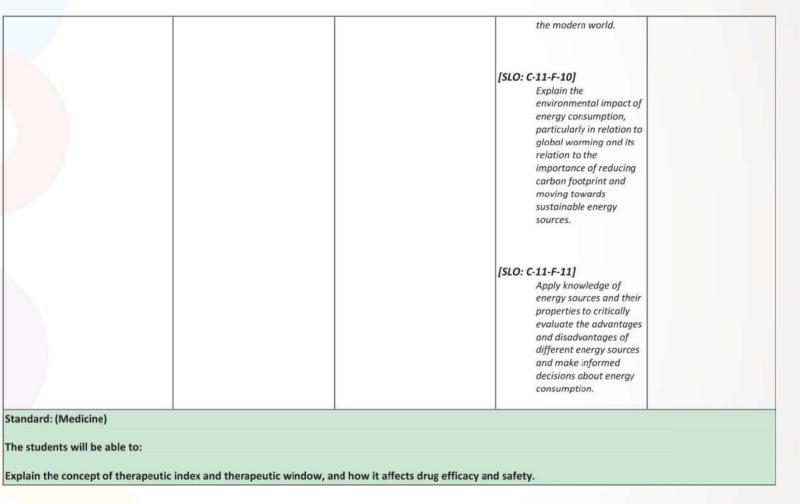
Explain the formation, properties, and uses of fossil fuels, and the importance of fossil fuels in the modern world.

### [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



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]

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Describe the

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Standard: (Agriculture)

The students will be able to:

Describe the chemistry of fertilizers and its impact on plant growth and soil health.

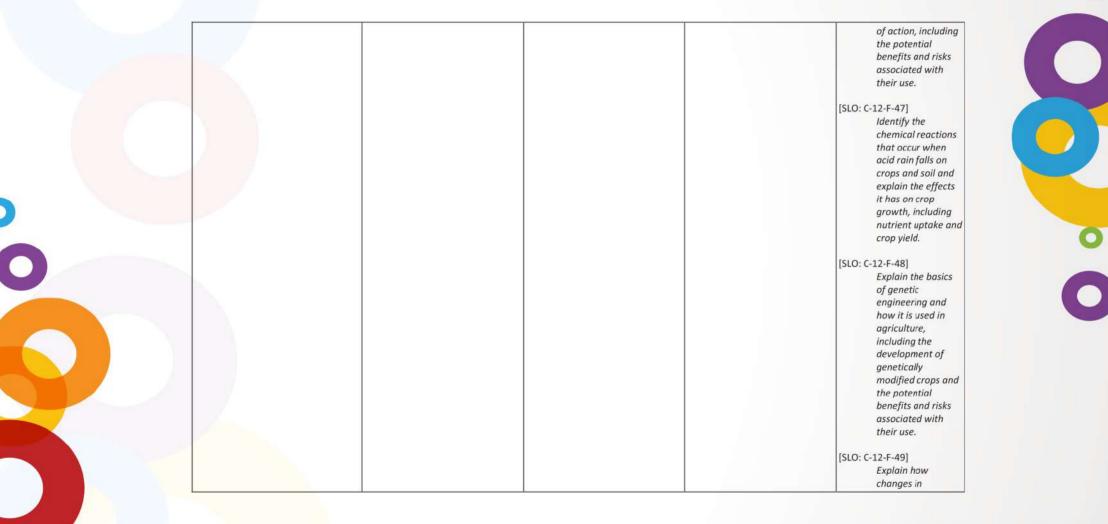
Evaluate the benefits and risks of using pesticides in agriculture, including their effects on the environment and human health.

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		used compounds in agricu fertilizers and pesticides,	their positive and negative reactivity based on external
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



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.

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## 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.

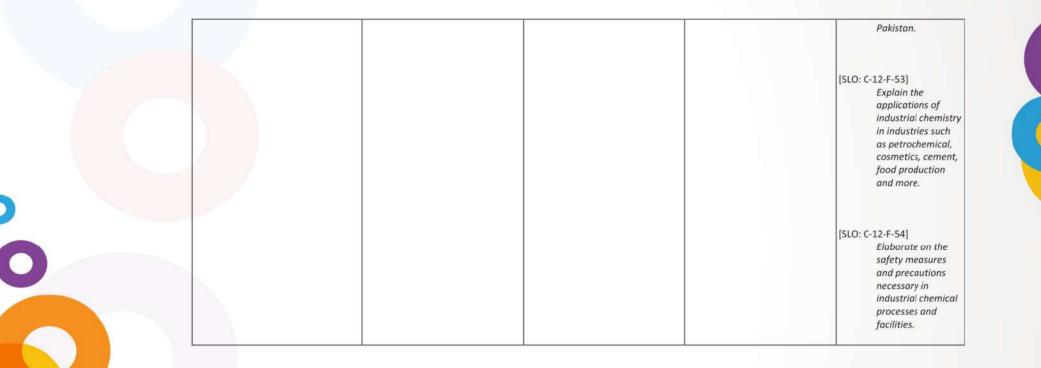
Describe the role of chemistry in key industrial sectors such as petrochemical, pharmaceutical and materials manufacturing.

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 inc compounds for manufactu reactions of various indust	ring, and elaborate on the
N/A	N/A	N/A	[SLO: C-12-F-50] Justify the importance and





# **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 Skil This domain is about the skills necessary to u should be applied not only in the science labo	inderstand how to plan and practically perfo	
Standard: Students should be able to demons	strate knowledge of how to select and safely	/ use techniques, apparatus and materials
Students should be able to follow provided	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.
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	<ul> <li>[SLO: C-11-G-01]</li> <li>Identify the chemical hazards in the lab in context of the experiment being conducted.</li> <li>[SLO: C-11-G-02]</li> <li>Test that the equipment is working properly without any potential risk of injury before conducting an experiment.</li> <li>[SLO: C-11-G-03]</li> <li>Ensure that work space for conducting the experiment is not crowded with apparatus as to be hazardous</li> <li>[SLO: C-11-G-04]</li> <li>Ensure that safe distance is kept at all times from other investigators who may be handling lab apparatus</li> </ul>	<ul> <li>[SLO: C-12-G-01]</li> <li>Analyse risks associated with experiments in the lab and suggest strategies to minimize hazards</li> <li>[SLO: C-12-G-02]</li> <li>Develop guidelines for lab experiments that incorporate appropriate safety measures.</li> <li>[SLO: C-12-G-03]</li> <li>Communicate laboratory safety protocols to their peers and colleagues.</li> <li>[SLO: C-12-G-04]</li> <li>Analyse chemical hazards in terms of impact on the environment.</li> </ul>

102/00 0000	[SLO: C-11-		
locate the nearest fire extingu		hat potential bodily harm could	
emergency shower.		m physical, chemical, biological and	
	safety ha	zards in the context of the	
[SLO: C-09-10-G-05]	experime	nt being conducted	
show awareness of emergence			
the event of an emergency in			
	Recognis	e that it is always better to ask for	
[SLO: C-09-10-G-06]		the lab instructor when unsure of	
dentify apparatus from diagra	ims or how to us	se new apparatus	
descriptions			
	[SLO: C-11-	G-07]	
[SLO: C-09-10-G-07]		ne proper waste disposal system for	
draw, complete or label diagra	ams of apparatus chemicals	s being used.	
[SLO: C-09-10-G-08]			
Explain the use of, common te	echniques,		
apparatus and materials	ASTACTICS, SALA CASSACTORY		
[SLO: C-09-10-G-09]			
select the most appropriate ap	oparatus or		
method for the task and justify			
SLO: C-09-10-G-10]			
describe tests (qualitative, gas	s tests, other		
tests)			
SLO: C-09-10-G-11]			
describe and explain techniqu	ies used to ensure		
	and data		

(175)

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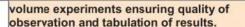
Benchmark I:Students should be able to apply scientific knowledge to conduct simple experiments using appropriate apparatus.	supervision while ensuring quality of	Benchmark: Accurately carry out titration experiments ensuring quality of observation and tabulation of results.
[SLO: C-09-10-G-12] Carry 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	<ul> <li>[SLO: C-11-G-08]</li> <li>set up apparatus following instructions given in written or diagrammatic form.</li> <li>[SLO: C-11-G-09] use apparatus to collect an appropriate quantity of data</li> <li>[SLO: C-11-G-10] make observations, including subtle differences in colour, solubility or quantity of materials</li> <li>[SLO: C-11-G-11] make measurements using pipettes, burettes,</li> </ul>	[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
<ul> <li>(This may include:</li> <li>filtration</li> <li>crystallisation</li> <li>simple distillation</li> <li>fractional distillation</li> <li>chromatography</li> <li>electrolysis)</li> </ul>	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]	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.
[SLO: C-09-10-G-14] suggest the most appropriate apparatus or technique and justify the choice made	[SLO: C-11-G-14]	Benchmark: Accurately carry out rate experiments ensuring quality of observation and appropriate presentation of results.
[SLO: C-09-10-G-15]	necessary, including where an anomaly is suspected	[SLO: C-12-G-10] Carry out rate investigation by mixing reagents and recording the time for an observation to occur.

(176)

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-	- describe experimental procedures	[SLO: C-11-G-15]	[SLO: C-12-G-11]
[	SLO: C-09-10-G-16]	<ul> <li>identify where confirmatory tests are appropriate and the nature of such tests</li> </ul>	Suggest experimental designs to measure the rate
	take readings from apparatus (analogue and		of a reaction.
	digital) or from diagrams of apparatus with appropriate precision,	<ul> <li>[SLO: C-11-G-16]</li> <li>select reagents to distinguish between given ions.</li> </ul>	of observation and appropriate
1.2	SLO: C-09-10-G-17]		presentation of results.
	- take sufficient observations or measurements, ncluding repeats where appropriate	[SLO: C-11-G-17] Carry out procedures using simple apparatus, in situations where the method may not be	[SLO: C-12-G-12] prepare a sample for gravimetric analysis
[	SLO: C-09-10-G-18]	familiar to the candidate	[SLO: C-12-G-13]
	- record qualitative observations from chemical ests and other tests	na gan gan na an gan gan gan gan gan gan	Perform a gravimetric analysis using appropriate techniques (may include precipitation and filtration)
[	SLO: C-09-10-G-19]		20
5	ecord observations and measurements systematically (in a suitable table, to an appropriate degree of precision and using appropriate units)		[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

(177)



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#### [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]

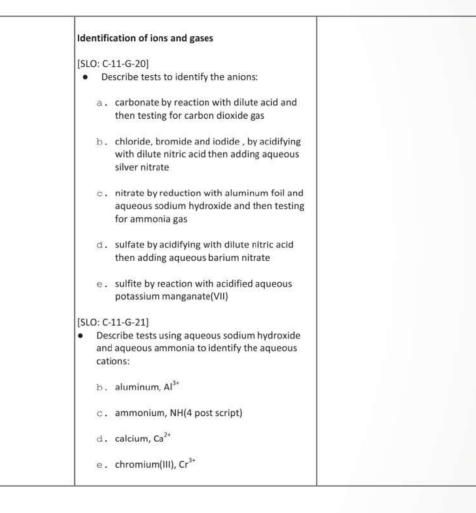
Understand the appropriate methods to be used when carrying out qualitative analysis tests: • to treat all unknown materials with caution • to use an appropriate quantity of the material under test • to add only the specified amount • to work safely, e.g. to use a test-tube holder

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 precipitat 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 <sub>3</sub> CO or CH <sub>3</sub> CH(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	



f. copper(II), Cu<sup>2+</sup> g. iron(II), Fe<sup>2+</sup>

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h. iron(III), Fe<sup>3+</sup> i. zinc, Zn<sup>2+</sup>

#### 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  $n = \frac{1.1 \times abundance \text{ of } M + ion}{1.1 \times abundance \text{ of } M + ion}$ 

Benchmark I: Students should be able to present data in a tabulated or graphical form.	Benchmark I: Students should be able to	Benchmark I: Students should be able to analyse the presented data and identify sources of error.
[SLO: C-09-10-G-20]	[SLO: C-11-G-22]	[SLO: C-12-G-21]
record the results of an experiment	present numerical data, values or observations in a single table of results with	Identify the best way to present collected and transformed data based on the experiment
[SLO: C-09-10-G-21]	headings and units that conform	being performed
process the results of an experiment to form a	to accepted scientific conventions	
conclusion or to evaluate a prediction	And South State St	[SLO: C-12-G-22]
	[SLO: C-11-G-22]	Interpret the collected data to draw
[SLO: C-09-10-G-22]	<ul> <li>record raw readings of a quantity to the</li> </ul>	conclusions based on the experiment being
Predict expected results	same degree of precision and observations to	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

[SLO: C-11-G-23] • show working in calculations and key steps in reasoning

the same level of detail

[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 

	<ul> <li>[SLO: C-11-G-31]</li> <li>determine the gradient of a straight-line graph and extrapolate the line of a graph.</li> <li>[SLO: C-11-G-32]</li> <li>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</li> <li>[SLO: C-11-G-33]</li> <li>draw conclusions from interpretations of observations, data and calculated values</li> <li>[SLO: C-11-G-34]</li> <li>make scientific explanations of data, observations and conclusions that they have described.</li> </ul>	
Standard: Students should be able to evaluate 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	N/A
	and safety.	
101 0 0 00 10 0 001		
[SLO: C-09-10-G-29] identify potential sources of error in an experimental design	[SLO: C-11-G-35] Analyse intrinsic errors in measuring device	
identify potential sources of error in an experimental design	Analyse intrinsic errors in measuring device [SLO: C-11-G-36]	
identify potential sources of error in an	Analyse intrinsic errors in measuring device [SLO: C-11-G-36] Describe systematic errors	
identify potential sources of error in an experimental design [SLO: C-09-10-G-30]	Analyse intrinsic errors in measuring device [SLO: C-11-G-36] Describe systematic errors	

(183)

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