Advanced Chemistry 11 and Advanced Chemistry 12

Guide

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Advanced Chemistry 11 and Advanced Chemistry 12

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Advanced Chemistry 11 and Advanced Chemistry 12

Acknowledgments

The Nova Scotia Department of Education expresses its indebtedness to chemistry teachers, university professors, community college instructors, and our educational colleagues for their professional expertise and insights in developing this regional Advanced Chemistry 11 and Advanced Chemistry 12 curriculum guide. In addition, pilot teachers and others who contributed comments and suggestions are to be commended for their commitment to developing exemplary science programs.

Foreword

The pan-Canadian *Common Framework of Science Learning Outcomes K to 12* (1997) provides a framework for standardizing science education across the country. Science curriculum for the Atlantic provinces is described in *Foundation for the Atlantic Canada Science Curriculum* (1998).

This guide is intended to provide teachers with the overview of the outcomes framework for the advanced courses. It also includes some suggestions to assist teachers in designing learning experiences and assessment tasks.

Contents

Introduction

The aim of science education in the Atlantic provinces is to develop scientific literacy.

Scientific literacy is an evolving combination of the science-related attitudes, skills, and knowledge students need to develop inquiry, problem-solving, and decision-making abilities; to become lifelong learners; and to maintain a sense of wonder about the world around them. To develop scientific literacy, students require diverse learning experiences that provide opportunities to explore, analyse, evaluate, synthesize, appreciate, and understand the interrelationships among science, technology, society, and the environment that will affect their personal lives, their careers, and their futures.

Advanced science courses offer expanded and extended learning outcomes in both the theoretical and applied aspects of science. The Department of Education has worked with chemistry teachers, university professors, and other interested parties to establish a set of principles to guide the development of advanced chemistry courses.

Although advanced chemistry courses would be best offered in discrete classes, the advanced chemistry courses themselves are built on curriculum prescribed for academic chemistry courses. Therefore, where discrete courses are not possible, advanced chemistry classes can be combined with the academic-level courses. The advanced courses are distinguished by three means of increased depth in certain parts of the curriculum. These are numerical problem solving, a literature search and report, and an independent study/experiment.

Numerical problem solving is enhanced by the inclusion of more situations presented in variable terms only (no numbers), as well as a selection of more-challenging application problems.

Advanced chemistry courses require students to do an independent study/experiment and to present the results visually, orally, and in written report form. *A Closer Look: Doing Project-Based Science* is a useful resource for this component of the courses. It is important that students be encouraged to investigate the science involved in a topic of personal interest such as vehicle safety, music and musical instruments, energy for the future, or sports. Project-based learning provides students with an opportunity to demonstrate their initiative and perseverance. These qualities are essential for success in continued study and eventual employment.

This guide is organized as a supplement to *Atlantic Canada Science Curriculum: Chemistry 11 and Chemistry 12* (2010).

Advanced Chemistry 11 and Advanced Chemistry 12, like other Public School Programs advanced courses, may be available for in-class and on-line delivery to give more students the opportunity to take advanced courses.

Program Design and Components

Learning and Teaching Science

What students learn is fundamentally connected to how they learn it. The aim of scientific literacy for all has created a need for new forms of classroom organization, communication, and instructional strategies. The teacher is a facilitator of learning whose major tasks include

- creating a classroom environment to support the learning and teaching of science
- designing effective learning experiences that help students achieve designated outcomes
- stimulating and managing classroom discourse in support of student learning
- learning about and then using students' motivations, interests, abilities, and learning styles to improve learning and teaching
- assessing student learning, the scientific tasks and activities involved, and the learning environment to make ongoing instructional decisions
- selecting teaching strategies from a wide repertoire

Effective science learning and teaching take place in a variety of situations. Instructional settings and strategies should create an environment that reflects a constructive, active view of the learning process. Learning occurs through actively constructing one's own meaning and assimilating new information to develop a new understanding.

The development of scientific literacy in students is a function of the kinds of tasks in which they engage, the discourse in which they participate, and the settings in which these activities occur. Students' disposition toward science is also shaped by these factors. Consequently, the aim of developing scientific literacy requires careful attention to all of these facets of curriculum.

Learning experiences in science education should vary and should include opportunities for group and individual work, discussion among students as well as between teacher and students, and hands-on, minds-on activities that allow students to construct and evaluate explanations for the phenomena under investigation. Such investigations and the evaluation of the evidence accumulated provide opportunities for students to develop their understanding of the nature of science and the nature and status of scientific knowledge.

Students in Advanced Chemistry 11 and Advanced Chemistry 12 are expected to meet all of the outcomes in Chemistry 11 and Chemistry 12. The depth of treatment is the major distinction. Advanced chemistry requires an in-depth treatment of chemistry concepts, a major literature search and report, and a hands-on investigation of a major chemical concept.

Generally, advanced chemistry should attract students who have a high level of science interest and are strong, independent learners. Students will be identified by science teachers or in consultation with administration and counsellors. These students may wish to pursue further study at a post-secondary level or careers in science, engineering, or technology.

Advanced Chemistry 11 is built on three content areas: Stoichiometry, From Structures to Properties, and Organic Chemistry. The following table lists the minimum time allocations.

Comparison: Chemistry 11 and Advanced Chemistry 11

Topics	Chemistry 11 (hours)	Advanced Chemistry 11 (hours)	Enhancement
The Mole and Molar Mass	10	6	These hours may be used to begin an independent study/experiment.
Calculations and Chemical Equations	10	6	
Stoichiometric Experimentation	8	6	
Applications of Stoichiometry	2	7	
Properties of Ionic and Molecular Compounds and Metallic Substances	3	3	
Classifying Compounds	4	3	
Bonding	5	8	
Structural Models of Bonding	3	3	continue work on study/experiment
Bond Energies	3	5	
Polar and Pure Covalent Bonding	3	8	
So Many Compounds	1	4	extend to other functional groups
Influences of Organic Compounds in Society	1	3	
Classfying Organic Compounds	6	2	
Naming and Writing Organic Compounds	6	6	extend to other functional groups
Applications of Organic Chemistry	3	3	
Isomers in Organic Chemistry	2	3	
Writing and Balancing Chemical Equations	3	6	extend to more complex reaction types
Polymerization	1	2	
Risks and Benefits of Organic Compounds: STSE Perspectives	2	3	
Total minimum time allocation of the maximum 110 hours	76	87	

Advanced Chemistry 12 is built on Thermochemistry; Solutions, Kinetics, and Equilibrium; Acids and Bases; and Electrochemistry. The following table lists the maximum time allocations.

Comparison: Chemistry 12 and Advanced Chemistry 12

Segment	**Chemistry 12 (hours)**	**Advanced Chemistry 12 (hours)**	**Enhancement**
Thermochemistry STSE	3	3	
Experiments with Energy Changes	7	3	begin work on independent study/ experiment
Thermochemistry and Potential Energy	2	2	
Bonding and Hess's Law	6	7	extend to entropy and spontaneity
Science Decisions Involving Thermochemistry	3	3	
Concentration, Properties, and Solubility	6	6	extend to K_{sp}, X, and m
Solubility and Precipitates	6	6	
Kinetics and Rate of Reaction	3	2	
Collision Theory, Reaction Mechanism, and Catalysts	2	5	extend to rate law expressions and calculations
Equilibrium	2	1	
Le Châtelier's Principle and Equilibrium Constant	10	7	note 3-hour difference
Equilibrium Applications	3	4	extend to position of equilibrium
Properties and Definitions of Acids and Bases	3	3	extend to Lewis definitions
Acid-Base Reactions	3	3	
Using the Equilibrium Concept with Acids and Bases	11	8	continue work on independent study/ experiment
Indicators and Acids and Bases	2	2	
Acid-Base Titrations	5	3	continue work on independent study/ experiment
H^+, OH^-, and Le Châtelier	4	5	extend to buffers
Oxidation and Reduction	2	2	
Redox and Half Reactions	8	8	
Electrochemical and Electrolytic Cells	6	6	
Redox Reactions with Standard Reduction Potentials	5	5	
Energy Efficiency of Cells	3	3	
Total minimum time allocation of the maximum 110 hours	**101**	**97**	

Writing in Science

Learning experiences should provide opportunities for students to use writing and other forms of representation as ways of learning. Students at all grade levels should be encouraged to use writing to speculate, theorize, summarize, discover connections, describe processes, express understandings, raise questions, and make sense of new information using their own language as a step to the language of science. Science logs are useful for such expressive and reflective writing. Purposeful note making is an intrinsic part of learning in science, helping students to better record, organize, and understand information from a variety of sources. The process of creating word webs, maps, charts, tables, graphs, drawings, and diagrams to represent data and results helps students learn and also provides them with useful study tools.

Learning experiences in science should also provide abundant opportunities for students to communicate their findings and understandings to others, both formally and informally, using a variety of forms for a range of purposes and audiences. Such experiences should encourage students to use effective ways of recording and conveying information and ideas and to use the vocabulary of science in expressing their understandings. Through opportunities to talk and write about the concepts they need to learn, students come to better understand both the concepts and related vocabulary.

Learners will need explicit instruction in, and demonstration of, the strategies they have to develop and apply in reading, viewing, interpreting, and using a range of science texts for various purposes. It will be equally important for students to have demonstrations of the strategies they have to develop and apply in selecting, constructing, and using various forms for communicating in science.

The Three Processes of Scientific Literacy

An individual can be considered scientifically literate when he or she is familiar with, and able to engage in, three processes: inquiry, problem solving, and decision making.

Inquiry

Scientific inquiry involves posing questions and developing explanations for phenomena. While there is general agreement that there is no such thing as the scientific method, students require certain skills to participate in the activities of science. Skills such as questioning, observing, inferring, predicting, measuring, hypothesizing, classifying, designing experiments, collecting data, analysing data, and interpreting data are fundamental to engaging in science. These activities provide students with opportunities to understand and practise the process of theory development in science and the nature of science.

Problem Solving

The process of problem solving involves seeking solutions to human problems. It consists of proposing, creating, and testing prototypes, products, and techniques to determine the best solution to a given problem.

Decision Making

The process of decision making involves determining what we, as citizens, should do in a particular context or in response to a given situation. Decision-making situations are important in their own right, and they also provide a relevant context for engaging in scientific inquiry and problem solving.

Meeting the Needs of All Learners

Foundation for the Atlantic Canada Science Curriculum stresses the need to design and implement a science curriculum that provides equitable opportunities for all students according to their abilities, needs, and interests. Teachers must be aware of, and make adaptations to accommodate, the diverse range of learners in their classes. To adapt instructional strategies, assessment practices, and learning resources to the needs of all learners, teachers must create opportunities to address their students' various learning styles.

As well, teachers must not only remain aware of and avoid gender and cultural bias in their teaching, but also actively address cultural and gender stereotyping (e.g., about who is interested in and who can succeed in science and mathematics). Research supports the position that when science curriculum is made personally meaningful and socially and culturally relevant, it is more engaging for groups traditionally under-represented in science and, indeed, for all students.

While this curriculum guide presents specific outcomes for each unit, it must be acknowledged that students will progress at different rates.

Teachers should provide materials and strategies that accommodate student diversity and should validate students when they achieve the outcomes to the best of their abilities.

It is important that teachers articulate high expectations for all students and ensure that all students have equitable opportunities to experience success as they work toward achieving designated outcomes. Teachers should adapt classroom organization, teaching strategies, assessment practices, time, and learning resources to address students' needs and build on their strengths. The variety of learning experiences described in this guide provides access for a wide range of learners. Similarly, the suggestions for a variety of assessment practices provide multiple ways for learners to demonstrate their achievements.

Assessment and Evaluation

The terms **assessment** and **evaluation** are often used interchangeably, but they refer to quite different processes. Science curriculum documents developed in the Atlantic region use these terms for the processes described below.

Assessment is the systematic process of gathering information on student learning.

Evaluation is the process of analysing, reflecting upon, and summarizing assessment information and making judgments or decisions based upon the information gathered.

The assessment process provides the data, and the evaluation process brings meaning to the data. Together, these processes improve teaching and learning. If we are to encourage enjoyment in learning for students now and throughout their lives, we must develop strategies to involve students in assessment and evaluation at all levels. When students are aware of the outcomes for which they are responsible and of the criteria by which their work will be assessed or evaluated, they can make informed decisions about the most effective ways to demonstrate their learning.

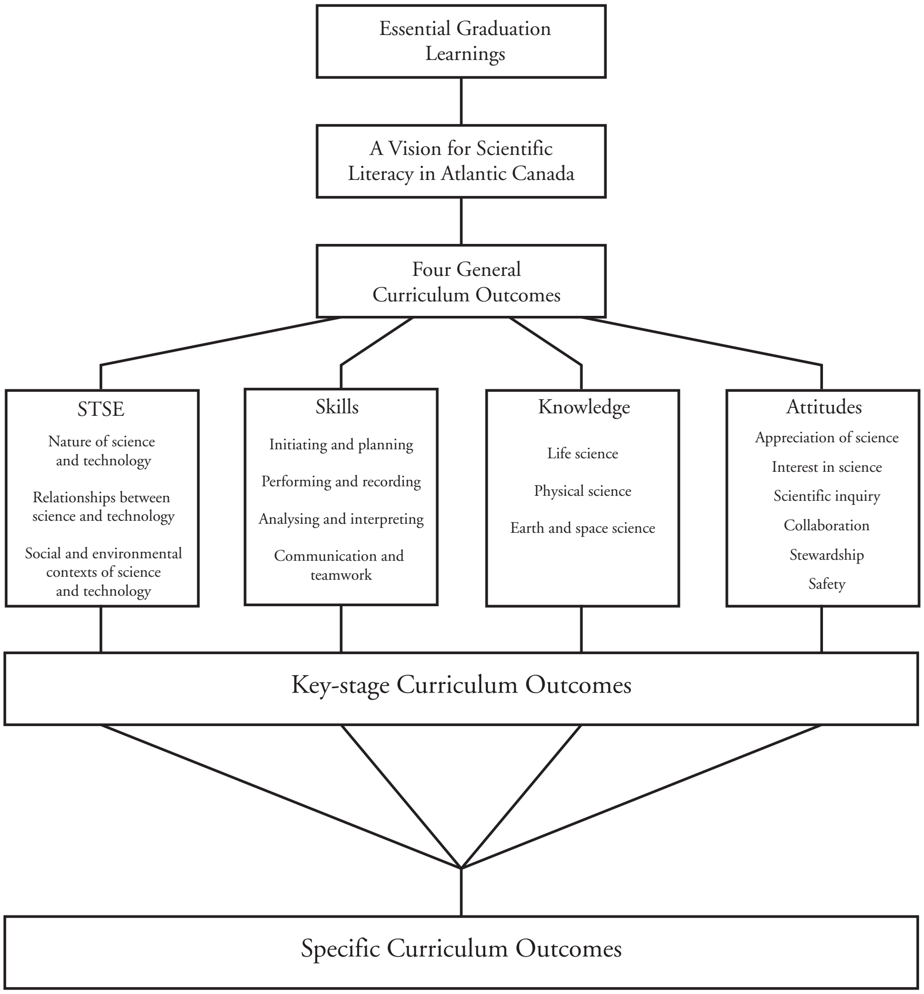
The Atlantic Canada science curriculum reflects the three major processes of science learning: inquiry, problem solving, and decision making. When assessing student progress, it is helpful to know some activities/skills/actions that are associated with each process of science learning. Student learning may be described in terms of ability to perform these tasks.

Curriculum Outcomes Framework

Overview

The science curriculum is based on an outcomes framework that includes statements of essential graduation learnings, general curriculum outcomes, key-stage curriculum outcomes, and specific curriculum outcomes. The general, key-stage, and specific curriculum outcomes reflect the pan-Canadian C*ommon Framework of Science Learning Outcomes K to 12*. The diagram below illustrates the outcomes framework.

Outcomes Framework



Essential Graduation Learnings

Essential graduation learnings are statements describing the knowledge, skills, and attitudes expected of all students who graduate from high school. Achievement of the essential graduation learnings will prepare students to continue to learn throughout their lives. These learnings describe expectations not in terms of individual school subjects but in terms of knowledge, skills, and attitudes developed throughout the curriculum. They confirm that students need to make connections and develop abilities across subject boundaries and be ready to meet the shifting and ongoing opportunities, responsibilities, and demands of life after graduation. Provinces may add additional essential graduation learnings as appropriate. The essential graduation learnings are described below.

Aesthetic Expression

Graduates will be able to respond with critical awareness to various forms of the arts and be able to express themselves through the arts.

Citizenship

Graduates will be able to assess social, cultural, economic, and environmental interdependence in a local and global context.

Communication

Graduates will be able to use the listening, viewing, speaking, reading, and writing modes of language(s) as well as mathematical and scientific concepts and symbols to think, learn, and communicate effectively.

Personal Development

Graduates will be able to continue to learn and to pursue an active, healthy lifestyle.

Problem Solving

Graduates will be able to use the strategies and processes needed to solve a wide variety of problems, including those requiring language, mathematical, and scientific concepts.

Technological Competence

Graduates will be able to use a variety of technologies, demonstrate an understanding of technological applications, and apply appropriate technologies for solving problems.

General Curriculum Outcomes

The general curriculum outcomes form the basis of the outcomes framework. They also identify the key components of scientific literacy. Four general curriculum outcomes have been identified to delineate the four critical aspects of students' scientific literacy. They reflect the wholeness and interconnectedness of learning and should be considered interrelated and mutually supportive.

Science, Technology, Society, and the Environment (STSE)

Students will develop an understanding of the nature of science and technology, of the relationships between science and technology, and of the social and environmental contexts of science and technology.

Skills

Students will develop the skills required for scientific and technological inquiry, for solving problems, for communicating scientific ideas and results, for working collaboratively, and for making informed decisions.

Knowledge

Students will construct knowledge and understandings of concepts in life science, physical science, and Earth and space science and will apply these understandings to interpret, integrate, and extend their knowledge.

Attitudes

Students will be encouraged to develop attitudes that support the responsible acquisition and application of scientific and technological knowledge to the mutual benefit of self, society, and the environment.

Key-Stage Curriculum Outcomes

Key-stage curriculum outcomes are statements that identify what students are expected to know, be able to do, and value by the end of grades 3, 6, 9, and 12 as a result of their cumulative learning experiences in science. The key-stage curriculum outcomes are from the *Common Framework of Science Learning Outcomes K to 12.*

Specific Curriculum Outcomes

This curriculum guide outlines specific curriculum outcomes for Chemistry 11 and Chemistry 12 and provides suggestions for learning, teaching, assessment, and resources to support students' achievement of these outcomes. Teachers should consult *Foundation for the Atlantic Canada Science Curriculum* for descriptions of the essential graduation learnings, vision for scientific literacy, general curriculum outcomes, and key-stage curriculum outcomes.

Specific curriculum outcome statements describe what students are expected to know and be able to do at each grade level. They are intended to help teachers design learning experiences and assessment tasks.

Each unit is organized by topic. Advanced Chemistry 11 and Advanced Chemistry 12 units and topics follow.

Advanced Chemistry 11

The following outcomes are to be extended in their depth as indicated in the Learning and Teaching Advanced Chemistry section.

Stoichiometry

Students will be expected to

- perform stoichiometric calculations related to chemical equations (323-11)
- predict how the yield of a particular chemical process can be maximized (323-13)
- design stoichiometric experiments identifying and controlling major variables (212-3)
- use instruments effectively and accurately for collecting data (213-3)

From Structures to Properties

Students will be expected to

- illustrate and explain the formation of ionic, covalent, and metallic bonds (321-4)
- explain the structural model of a substance in terms of the various bonds that define it (321-11)
- identify limitations of categorizing bond types based on differences in electronegativity between the elements and compounds (214-2)

Organic Chemistry

Students will be expected to

- analyse natural and technological systems to interpret and explain the influence of organic compounds on society (116-7)
- develop, present, and defend a position or course of action on organic chemistry based on findings (215-5)
- define isomers and illustrate the structural formulas for a variety of organic isomers (319-6)
- write and balance chemical equations to predict the reactions of selected organic compounds (319-8)
- describe processes of polymerization and identify some important natural and synthetic polymers (319-9)

Advanced Chemistry 12

The following outcomes are to be extended in their depth as indicated in the Learning and Teaching Advanced Chemistry section.

Thermochemistry

Students will be expected to

- calculate and compare the energy involved in changes in state in chemical reactions (324-3)
- analyse the knowledge and skills acquired in their study of thermochemistry to identify areas of further study related to science and technology (117-9)
- calculate the changes in energy of various chemical reactions using bond energy, heats of formation, and Hess's Law (324-4)

Solutions, Kinetics, and Equilibrium

Students will be expected to

- determine the molar solubility of a pure substance in water (323-6)
- describe a reaction mechanism and catalyst's role in a chemical reaction (ACC-3)

Acids and Bases

Students will be expected to

- describe and apply classification systems and nomenclature used in acids and bases (214-1)
- describe various acid-base definitions up to the Brønsted-Lowry definition (320-1)
- calculate the pH of an acid or a base given its concentration, and vice versa (320-4)

Electrochemistry

Students will be expected to

- predict whether oxidation-reduction reactions are spontaneous based on their reduction potentials (322-5)
- explain the process of electrolysis and electroplating (322-8)

Literature Search and Report

Advanced Chemistry 11

Students will be expected to

- develop the nature of bonding through a time line (AC-01)
- outline the past/present scientific discoveries and match these with the previously developed time line (AC-02)

Advanced Chemistry 12

Students will be expected to

- collect, organize, edit, and present a summary of current information related to a specific topic (AC-03)
- write a report as a formal research paper (AC-04)

Investigation of a Physical Concept

Advanced Chemistry 11

Students will be expected to

- gain information through modelling and guidance on the processes involved in scientific research and development (AC-05)
- conduct a hands-on, minds-on, self-directed experience and generate a report for public presentation (AC-06)

Advanced Chemistry 12

Students will be expected to

- collaborate on and investigate an independent research project (AC-07)
- maintain a research log, including personal reflection and data collection (AC-08)
- use technology and apply skills effectively to communicate results publically (AC-09)

Attitudes Outcomes

It is expected that the Atlantic Canada science program will foster certain attitudes in students throughout their school years. The STSE, skills, and knowledge outcomes contribute to the development of attitudes, and opportunities for fostering these attitudes are highlighted in the Elaborations—Strategies for Learning and Teaching section of each unit.

Attitudes refer to generalized aspects of behaviour that teachers model for students by example and by selective approval. Attitudes are not acquired in the same way as skills and knowledge. The development of positive attitudes plays an important role in students' growth by interacting with their intellectual development and by creating readiness for responsible application of what students learn.

Since attitudes are not acquired in the same way as skills and knowledge, outcome statements for attitudes are written as key-stage curriculum outcomes for the end of grades 3, 6, 9, and 12. These outcome statements are meant to guide teachers in creating a learning environment that fosters positive attitudes.

The following pages present the attitude outcomes from the pan-Canadian *Common Framework of Science Learning Outcomes K to 12* for the end of grade 12.

Key-Stage Curriculum Outcomes: Attitudes

By the end of grade 12, students will be expected to

Appreciation of Science	Interest in Science	Scientific Inquiry
436 value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not 437 appreciate that the applications of science and technology can raise ethical dilemmas 438 value the contributions to scientific and technological development made by women and men from many societies and cultural backgrounds *Evident when students, for example,* • consider the social and cultural contexts in which a theory developed • use a multi-perspective approach, considering scientific, technological, economic, cultural, political, and environmental factors when formulating conclusions, solving problems, or making decisions on STSE issues • recognize the usefulness of being skilled in mathematics and problem solving • recognize how scientific problem solving and the development of new technologies are related • recognize the contribution of science and technology to the progress of civilizations • carefully research and openly discuss ethical dilemmas associated with the applications of science and technology • show support for the development of information technologies and science as they relate to human needs • recognize that western approaches to science are not the only ways of viewing the universe • consider the research of both men and women	439 show a continuing and more informed curiosity and interest in science and science-related issues 440 acquire, with interest and confidence, additional science knowledge and skills, using a variety of resources and methods, including formal research 441 consider further studies and careers in science- and technology-related fields *Evident when students, for example,* • research the answers to their own questions • recognize that part-time jobs require science- and technology-related knowledge and skills • maintain interest in or pursue further studies in science • recognize the importance of making connections between various science disciplines • explore and use a variety of methods and resources to increase their own knowledge and skills • are interested in science and technology topics not directly related to their formal studies • explore where further science- and technology-related studies can be pursued • are critical and constructive when considering new theories and techniques • use scientific vocabulary and principles in everyday discussions • readily investigate STSE issues	442 confidently evaluate evidence and consider alternative perspectives, ideas, and explanations 443 use factual information and rational explanations when analysing and evaluating 444 value the processes for drawing conclusions *Evident when students, for example,* • insist on evidence before accepting a new idea or explanation • ask questions and do research to ensure they understand • criticize arguments based on the faulty, incomplete, or misleading use of numbers • recognize the importance of reviewing the basic assumptions from which a line of inquiry has arisen • expend the effort and time needed to make valid inferences • critically evaluate inferences and conclusions, cognizant of the many variables involved in experimentation • critically assess their opinion of the value of science and its applications • criticize arguments in which evidence, explanations, or positions do not reflect the diversity of perspectives that exist • insist that the critical assumptions behind any line of reasoning be made explicit so that the validity of the position taken can be judged • seek new models, explanations, and theories when confronted with discrepant events

Key-Stage Curriculum Outcomes: Attitudes

By the end of grade 12, students will be expected to

Collaboration	**Stewardship**	**Safety**
445 work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas *Evident when students, for example,* • willingly work with any classmate or group of individuals regardless of their age, gender, or physical and cultural characteristics • assume a variety of roles within a group, as required • accept responsibility for any task that helps the group complete an activity • provide the same attention and energy to the group's product as they would to a personal assignment • are attentive when others speak • are capable of suspending personal views when evaluating suggestions made by a group • seek the points of view of others, and consider a multitude of perspectives • accept constructive criticism when sharing their ideas or points of view • criticize the ideas of their peers without criticizing the persons • evaluate the ideas of others objectively • encourage the use of procedures that enable everyone, regardless of gender or cultural background, to participate in decision making • participate with others in peaceful conflict resolution • encourage the use of a variety of communication strategies during group work • share the responsibility for errors made or difficulties encountered by the group	**446** have a sense of personal and shared responsibility for maintaining a sustainable environment **447** project the personal, social, and environmental consequences of proposed action **448** want to take action for maintaining a sustainable environment *Evident when students, for example,* • willingly evaluate the impact of their own choices or the choices scientists make when they carry out an investigation • assume part of the collective responsibility for the impact of humans on the environment • participate in civic activities related to the preservation and judicious use of the environment and its resources • encourage their peers or members of their community to participate in a project related to sustainability • consider all perspectives when addressing issues, weighing scientific, technological, and ecological factors • participate in the social and political systems that influence environmental policy in their community • discuss both the positive and negative effects on human beings and society of environmental changes caused by nature and by humans • willingly promote actions that are not injurious to the environment • make personal decisions based on a feeling of responsibility toward less privileged parts of the global community and toward future generations • are critical-minded regarding the short- and long-term consequences of sustainability	**449** show concern for safety and accept the need for rules and regulations **450** be aware of the direct and indirect consequences of their actions *Evident when students, for example,* • read the label on materials before using them, interpret the WHMIS symbols, and consult a reference document if they don't understand safety symbols • criticize a procedure, a design, or materials that are not safe or that could have a negative impact on the environment • consider safety a positive limiting factor in scientific and technological endeavours • carefully manipulate materials, cognizant of the risks and potential consequences of their actions • write into a laboratory procedure safety and waste-disposal concerns • evaluate the long-term impact of safety and waste disposal on the environment and the quality of life of living organisms • use safety and waste disposal as criteria for evaluating an experiment • assume responsibility for the safety of all those who share a common working environment by cleaning up after an activity and disposing of materials in a safe place • seek assistance immediately for any first aid concerns such as cuts, burns, or unusual reactions • keep the work station uncluttered, with only appropriate lab materials present

Learning and Teaching Advanced Chemistry: In-depth Treatment

Advanced Chemistry 11

Stoichiometry

• perform stoichiometric calculations related to chemical equations (323-11)	An in-depth understanding of the mole and its significance in chemical reactions is essential in many aspects of science in our everyday lives. For example, environmental scientists can use stoichiometry in their study of bioaccumulation. Students in advanced chemistry should be given ample opportunities to work with a variety of problems involving moles. Students should also be involved in a problem-solving approach to stoichiometric reactions. They should study examples of the kind of complex reactions that arise in the real world.
• predict how the yield of a particular chemical process can be maximized (323-13)	Chemistry, like all science, should help students understand the interaction between science and the world. Percent yield extensions for Advanced Chemistry 11 would provide students with opportunities to study green chemistry in terms of maximizing yields and minimizing waste. An evaluative approach to such reactions would give students the opportunity for mathematical and theoretical discussions regarding real-world reactions.
• design stoichiometric experiments identifying and controlling major variables (212-3) • use instruments effectively and accurately for collecting data (213-3)	In advanced chemistry, students should be given the opportunity to design their own experiments from the research they read or learn about in class. Depending on their experimental design, students could be given the opportunity to carry out their experiments in the laboratory setting. If the experimental design does not allow them to carry out procedures in the chemistry lab, they should include a theoretical hypothesis and yield in the analysis of their reports. Designing experiments allows students to connect to science as they play the role of the scientist in the classroom.

From Structures to Properties

• illustrate and explain the formation of ionic, covalent, and metallic bonds (321-4)	Students in the academic program are introduced to energy-level diagrams of some of the elements in the periodic table. At the advanced level, students should be introduced to the connection between the emission spectrum of hydrogen and the energy levels of electrons. Students should be asked to draw transitions between energy levels and recognize or predict line spectrums from these transitions. As well, students should be able to list the characteristic properties of the d-block elements, discuss the importance of paramagnetism and diamagnetism as they relate to electronic configuration, and draw conclusions, based on research, about the catalytic behaviour of compounds containing d-block elements in reactions. As an extension to the writing of Lewis structures, students should be asked to determine the formal charges in order to determine the most likely structures.
• explain the structural model of a substance in terms of the various bonds that define it (321-11)	When students are doing valence shell electron pair repulsion (VSEPR) theory in Advanced Chemistry 11, all eight geometric shapes of the simple molecules delineated from the five main classes should be part of this course. Students should have the opportunity to discuss and work with arrangements of electron pairs, angles, and electrostatic repulsion of electron pairs. A discussion of dipole moments and the existence of such for each VSEPR shape should also be part of the Advanced Chemistry course. The calculation of the bond polarity (using $\mu = Q \times r$) and its effect on the percentage ionic character is part of the Advanced Chemistry 11 course (see **p. 62** of the *Chemistry 11 and Chemistry 12* curriculum guide). Microwave ovens provide an excellent example of dipole moments. Students should also have the opportunity to study bond hybridization in their exploration of VSEPR. Through this topic, students can gain a thorough understanding of the composition of double and triple bonding that is to be studied in further detail with organic compounds.
• identify limitations of categorizing bond types based on differences in electronegativity between the elements and compounds (214-2)	Ionization energy, atomic size, and electron affinity are periodic trends that may go deeper in the Advanced Chemistry 11 course. Discussion on periodic trends may focus on differences and limitations.

Organic Chemistry

- analyse natural and technological systems to interpret and explain the influence of organic compounds on society (116-7)

Once students have had the opportunity to study the structures of functional groups and reactions of organic compounds, they should be given the option to analyse the uses of organic reactions in society. In their analysis, students can explain the influence of different chemical reactions on our everyday lives. Students could analyse manufacturing products such as the development of different pharmaceuticals, the use of MBTE as a fuel additive, the different food additives and their role in food manufacturing, or sunscreen chemical additives.

- define isomers and illustrate the structural formulas for a variety of organic isomers (319-6)
- develop, present, and defend a position or course of action on organic chemistry based on findings (215-5)

Students will have experience with isomers as outlined in the Chemistry 11 and Chemistry 12 curriculum guide (**p. 94**). They should look at, compare, and find everyday examples of organic compounds such as organic halides, as well as larger organic compounds and other functional groups. Students should also have the opportunity to study optical isomers and chirality. From here, students should explore the role of chirality in systems such as biology. The stereochemistry of drug design and subsequent action is an interesting research topic in the study of medicines. Biological systems contain naturally chiral compounds; most drug companies produce products that also contain chiral compounds. Students can then examine the risks and benefits to this. One example is the development of the drug thalidomide. Students should have time in this course to research and analyse reactions and uses of organic compounds to develop a position on the potential risks and benefits.

- write and balance chemical equations to predict the reactions of selected organic compounds (319-8)

This is an opportunity to introduce students to some methods of identifying products using spectroscopy. Instruments such as NMR and mass spectrometers, and their identification abilities, can be shown to students as a means of identifying products. Students might be familiar with some of these terms from the media and could have an opportunity to identify compounds from spectra produced by these instruments.

Beyond the academic Chemistry 11 requirements, teachers may show and include reactions such as the Sn1 and Sn2 reactions, E1 and E2 reactions, reactions with amino acids, and more complex condensation reactions. This allows the possibility for students to study topics such as human biochemistry, environmental chemistry, and fossil fuel debates. Students may choose to connect their previous learning of molecular geometry to the reactions in organic chemistry through the learning of reactions such as the E2 mechanism for the Hofmann Elimination and studying Zaitsev's rule.

- describe processes of polymerization and identify some important natural and synthetic polymers (319-9)	An in-depth study of reactions involving polymerization will give students the skills necessary to study topics such as recycled and biodegradable plastics. Students should be given the opportunity to study the additional polymer reactions and relate these products to commercial goods in society. Some of these products include the sports equipment found in their schools, the trash containers, helmets and tires for motorcycles or bicycles, backpacks, and superglue (used in forensic science). From here they can assess the risks and benefits to society.

Advanced Chemistry 12

Thermochemistry

- calculate and compare the energy involved in changes in state in chemical reactions (324-3)	To address this outcome involving heat capacity to the advanced level, students should have the opportunity to work with problems involving constant volume calorimetry. Students should have some time to explore the value of using a constant volume calorimeter rather than the constant pressure calorimeter, as well as work with problems involving the formula $q_{cal} = C_{cal} \Delta t$. Bomb calorimeters are used to calculate the fuel values for foods because metabolism of food closely resembles combustion. Students should be able to explain the benefits of both types of calorimeters.
- analyse the knowledge and skills acquired in their study of thermochemistry to identify areas of further study related to science and technology (117-9)	The curriculum guide (**p. 113**) suggests that students in Chemistry 12 design an experiment for the preparation of an inexpensive hand warmer. At the advanced level, students should be asked to research, design, and set up an experiment that could, for example, allow for the calculation and comparison of the energy content in two nuts or candies.
- calculate the changes in energy of various chemical reactions using bond energy, heats of formation, and Hess's Law (324-4)	Going beyond the academic level, students should have an opportunity here to learn about the factors of disorder, entropy change (ΔS), predicting the sign of ΔS based in the factors of disorder, and also calculating the value of ΔS°. This outcome may address the Gibbs free energy equation ($\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$). It is here that students have their first look at spontaneity. Problem solving will greatly assist the students in understanding how to calculate ΔG°, to predict spontaneity, and to use the equation. Students should be able to calculate ΔG° either by using the values of $\Delta G^\circ{}_f$ or by using the Gibbs free energy equation.

Solutions, Kinetics, and Equilibrium

- determine the molar solubility of a pure substance in water (323-6)

Molar solubility is confined, by definition to the units of mol/L. However, for the Advanced Chemistry 12 student, some emphasis should be placed on problem solving involving molality(m = amount of solute ÷ mass of solvent) and mole fraction (X_a = moles of a ÷ sum of moles of all other components). Students would then, be exposed to the colligative properties of electrolyte and non-electrolytes where these other forms of concentration units are most useful. Real-world applications of colligative properties such as de-icing of airplanes, crenation in cell biology, desalination processes, and the use of time-release drugs in medicine are all examples of topics students could explore after studying colligative properties.

- describe a reaction mechanism and catalyst's role in a chemical reaction (ACC-3)

Advanced Chemistry 12 should go beyond the discussion of the details of reaction mechanisms to include the definition of the rate of reaction as the change in concentration of the reactant or product over time.

Thus, for the reaction $A + B \rightarrow C$

$$rate = -\frac{\Delta[A]}{\Delta t} \text{ or } rate = -\frac{\Delta[B]}{\Delta t} \text{ or } rate = -\frac{\Delta[C]}{\Delta t}$$

Students should also define terms such as reaction order and rate constant and determine the rate expression from tables. Thus, for the reaction above, $rate = k[A]^m[B]^n$, students can determine the overall order of a reaction ($m + n$) using tables of data collected for rate, [A], and [B].

If time permits, students may look at the Arrhenius equation that shows how rate constants are dependent on temperature (consistent with Maxwell).

Teachers may connect spectroscopy to Brad Moore's (UC Berkeley) research and the discovery of the first transition state series of molecules. Using photofragment spectroscopy, this team was able to identify the first transition state of a reaction sequence after 50 years of trials.

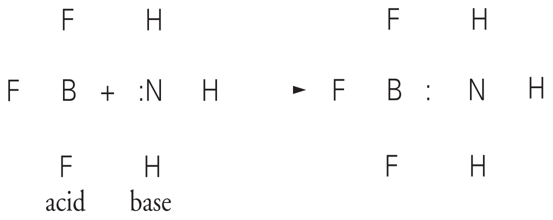
Acids and Bases

- describe and apply classification systems and nomenclature used in acids and bases (214-1)

After learning the operational definitions of acids and bases, students should have the opportunity to study salt solution in order to derive which salts would produce acidic, basic, or neutral solutions. Students could design an experiment and carry out their investigation in order to derive a sample chart to begin their classification organizer of acidic, basic, and neutral salts. They could determine which cations and anions are acidic, basic, or neutral, and relate them to the strong or weak acids and bases.

- describe various acid-base definitions up to the Brønsted-Lowry definition (320-1)

The extension here for outcome (320-1) should include the Lewis definition of acids and bases. Students have studied Lewis theory in grade 11, so this will be a good connection to their previous knowledge. Lewis acids are ones that accept electron pairs, Lewis bases donate electron pairs.



One of the biggest advantages to the Lewis theory was that the power of the reaction did not lie with the hydrogens, but with the electrons.

- calculate the pH of an acid or a base given its concentration, and vice versa (320-4)

After completing the analysis of K*a* and K*b* calculations and applications, students should then proceed to the analysis of buffer solutions. Here students should study the common ion effect, preparation of buffer solutions, and the Henderson-Hasselbalch equation:

$$pH=pK_a = \log\frac{[\text{conjugate base}]}{[\text{acid}]}$$

Buffer solutions have many applications in the realworld from maintaining blood pH to the chemistry of antacids, from soil chemistry to pharmaceutical drugs.

Electrochemistry

- predict whether oxidation-reduction reactions are spontaneous based on their reduction potentials (322-5)

One enhancement for this outcome is to include the calculation of Gibbs free energy using Faraday's constant.

$$\Delta G^\circ = -nFE^\circ_{\text{cell}}$$

If the value of ΔG° is negative, the redox reaction is spontaneous; if large, it favours the reactants. If the value of ΔG° is positive, it is non-spontaneous; if small, it favours the products. The use of this equation also gives students a connection to the Gibbs free energy calculation completed in the Thermochemistry unit done previously, connecting to prior knowledge.

If time permits, students may want to continue the mathematical connection of the formula of Gibbs free energy to the equilibrium constant ($\Delta G^\circ = -RT \ln K$) to the one above ($\Delta G^\circ = -nFE^\circ_{\text{cell}}$). From here, students can find that $-RT\ln K = -nFE^\circ_{\text{cell}}$ or

$$E^\circ_{\text{cell}} = \frac{RT}{nF} ln\, K$$

Following this, students can extend their formula analysis to the Nernst equation to show the relationship between E°_{cell} and the concentration of products and reactants in the solution:

$$E = E^\circ - \frac{RT}{nF}\ln Q$$

Now students have a variety of methods for predicting and calculating spontaneity of redox reactions.

- explain the process of electrolysis and electroplating (322-8)

Extending Faraday's constant to this outcome allows the student to study electrolysis from a quantitative viewpoint. Using the fact that

1 faraday = 6.022×10^{23} e^- = 96 490 coulombs, and 1 A = 1 C/s, students can calculate the mass of the product produced in electrolysis reactions. Being able to exactly calculate the quantity of voltage or product required to electroplate is essential in industry. This process is used for electroplating metals and for electrolytic refining.

Electrochemistry reactions are found in many facets of the real world. For example, they are responsible for the neurotoxin reactions from the venom of snakebites. Students may choose to explore this topic in addition to the examples of batteries and galvanic cells found in the text.

Investigations and Experiments

The Investigations and Experiments component is an important aspect of any scientific study. A student enrolled in advanced chemistry is expected to complete the required investigations. The investigations should include, but are not limited to, the following:

Advanced Chemistry 11

Required Investigations and Experiments

- Determination of a chemical formula
- Determination of a mole ratio in a chemical reaction
- Percentage composition
- Molecular geometry and polarity
- Chemical periodicity
- Isomers
- Synthesis of an organic compound
- Separation and/or analysis of cations and anions
- Green chemistry

Extensions

Potential topics for students to design their own investigations may include the following:

- Determination of percent water in a chemical formula
- Gravimetric determination
- Renewable energy sources
- Hybridization
- Esterification
- Spectrophotometric methods
- Chromatography
- Microchemistry

All students must successfully design their own investigations.

Advanced Chemistry 12

Required Investigations and Experiments

- Specific heat capacity of a metal
- Heat of fusion of ice
- Hess's law and the enthalpy of combustion of magnesium
- Degree of saturation of a solution
- Solution preparation and dilutions
- Solubility curve of NH_4Cl
- Forming precipitates
- Factors affecting reaction rates
- Study of chemical equilibrium
- Le Châtelier dynamic
- Properties of acids and bases
- Acid-base titration/indicators
- Concentration of acetic acid in vinegar
- Designing an orange-juice clock

Extensions

Potential topics for students to design their own investigations may include the following:

- Enthalpy, entropy, and free energy
- Global warming
- Solutions and molecular polarity
- Freezing point depression (colligative properties)
- Graphical analysis of rate laws and reaction orders
- Belousov-Zhabotinsky reactions and the butterfly effect
- The Arrhenius equation
- K_a and/or K_b experiment
- Colours of manganese ions
- Titrations (acid-base, redox)

All students must successfully design their own investigations.

Literature Search and Report

A literature search and report is a required part of advanced chemistry. This search can take on many forms and can be reported in a variety of ways. Students, like scientists, must be able to effectively communicate their knowledge and findings to a variety of audiences in order to compare results, ask for funding, or write proposals and articles.

Advanced Chemistry 11

Outcomes

Students will be expected to

- develop the nature of bonding through a time line (AC-01)
- outline the past/present scientific discoveries and match these with the previously developed time line (AC-02)

Tasks for Instruction and/or Assessment

Journal and Presentation

- Outline the impact of green chemistry innovations on society over the past ten years. Describe the implication of green-chemistry initiatives as opposed to environmental-chemistry initiatives. Design a graphic organizer that would best display a summary of each of these two pieces. (AC-01, AC-02)
- Design a slideshow presentation or brochure to outline the development of the bonding theory and VSEPR structures. (AC-01, AC-02)
- Albert Einstein once said, "The more success the quantum theory has, the sillier it looks." Based on your knowledge of quantum theory, what do you think he meant by this? (AC-01, AC-02)

Paper and Pencil

- Prepare a written report that profiles your research. (AC-01, AC-02)

Resources

Books

- *Chemical Bonding and Molecular Geometry: From Lewis to Electron Densities*, Ronald J. Gillespie
- *Chemical Structure and Bonding*, Roger L. DeKock and Harry B. Gray
- *Cross-Curricular Reading Tools* (available through CAMET)
- *The Evolution of Physics*, Albert Einstein and Leopold Infeld

Websites

- United States Environmental Protection Agency Green Chemistry (epa.gov/greenchemistry/)
- Chemical Institute of Canada (cheminst.ca/)
- American Chemical Society (portal.acs.org/portal/acs/corg/content)

Advanced Chemistry 12

Outcomes

Students will be expected to

- collect, organize, edit, and present a summary of current information related to a specific topic (AC-03)
- write a report as a formal research paper (AC-04)

Elaborations—Strategies for Learning and Teaching

Students are expected to explore the historical development of chemistry concepts and ideas related to current studies. Historical development helps students contextualize theory development.

Students are expected to examine the role of chemistry in the world around them. This exploration should include Internet research, periodical research, and library research. Possible topics include

- Forensic science
- Green chemistry
- Environmental chemistry
- Pharmacology
- Nanotechnology
- Identification techniques for unknown compounds
- Biodegradable versus bio-compostable product design

Tasks for Instruction and/or Assessment

Students are required to complete an independent research paper. Numerous examples of rubrics for assessment of the research paper can be found on the Internet. Students should be made aware of assessment criteria well in advance of completing the research paper. (AC-03, AC-04)

Possible topics for the research include

- Nanocrystals
- Stereochemistry of drugs
- Biodiesel production and use
- Transition-state theory
- Solar and renewable energy
- Microbial redox reactions
- Consumer chemistry

Resources

Books

- *Chemistry in the Marketplace*, Ben Selinger
- *The Genie in the Bottle: 68 All New Commentaries on the Fascinating Chemistry of Everyday Life*, Dr. Joe Schwarcz

Investigation: An Independent Study/ Experiment

Outcomes

Advanced Chemistry 11

Students will be expected to

- gain information through modelling and guidance on the processes involved in scientific research and development (AC-05)
- conduct a hands-on, self-directed experience and generate a report for public presentation (AC-06)

Advanced Chemistry 12

Students will be expected to

- collaborate on and investigate an independent research project (AC-07)
- maintain a research log, including personal reflection and data collection (AC-08)
- use technology and other skills effectively to communicate results publically (AC-09)

Introduction

A key aspect of the advanced chemistry program is the opportunity for students to complete a long-term project, one that includes an extensive chemical analysis. The project creates an opportunity for students to explore chemistry from their own perspective. It can also provide them with an opportunity to delve deeper into a topic of interest that might have been sparked in conversations they had in class or read in the newspaper or seen on the Internet. Through project-based science, teachers free the students to explore chemistry in ways that can incorporate in their research their backgrounds, skill sets, and interests. It allows students to become real scientists and truly learn about chemistry in the world around them.

Chemistry and Problem/Project-Based Science

Problem/project-based science, often referred to as “real science,” is a science instruction method that has students and teachers completing projects in a fashion similar to the research methods of scientists. Through individual and collaborative research, students have the opportunity to construct science knowledge through hands-on, minds-on, self-directed experiences.

The problem/project-based method encourages teachers and students to explore and examine a variety of different activities and situations that address different learning styles and cognitive strengths. Through this process a number of science curriculum outcomes are easily addressed, as well as outcomes from other curriculum programs.

A problem/project-based science activity can be designed to fit any science classroom. It can be a small activity that covers a few class periods to a full-course investigation that results in a project to be celebrated in a variety of ways. Whatever the end result, problem/project-based science activities all include a number of common components:

- *A focus question or hypothesis:* Students should create a focus question for their investigation. A question that they develop will help them attend to the project from the beginning. A clear focus question allows organization of the method that will be used to direct the research. The question is key here and is one of the most difficult parts of the process. The focus question also provides a reference point for reflection throughout the study. The question may be revised throughout the course of study as directed by the research.
- *Investigation:* In project-based science the focus question leads directly to authentic problem solving through textual and online research, experimental design and operation, data collection and analysis, estimation, discussion and debate, group interaction, summarizing and drawing conclusions, and the refining and examination of the original question.
- *Artifacts:* Throughout the duration of a project, artifacts—such as a number of reports, devices, and displays that show a true understanding of the focus question—will be produced.
- *Collaboration:* Whether working alone or in groups, students will collaborate throughout a project-based exercise. Working in class, sharing new discoveries, questioning others' conclusions, and participating in classroom presentations allow students and teachers to explore avenues in their research that they might not follow on their own and to further expand the study of the focus question.
- *Technology and Telecommunications:* Modern technology allows exploration science in a wide variety of ways. Communication with professional scientists, discussions with other students from around the region or the world, and the accessibility of vast amounts of information allow students and teachers to completely explore the answers to their questions and share the information that they have collected.

How to use Project-Based Science:

Project-based science can be used to cover virtually any topic in the science classroom. It allows the teacher to cover a variety of skills and social outcomes that are not always reached by traditional methods of science instruction. Project-based science should be used to bring the process of science (inquiry, problem solving, and decision making) to students. A project should include a discussion to establish focus questions, a specific time line for research and time for investigation. Creating a time line and a bank of resources will make projects run smoothly. A well-planned project that is presented with enthusiasm will be sure to cover a number of science outcomes.

Finding a Focus Question:

The focus question is the most important part of a student and teacher project. Spending time on instruction of focus question development will pay off with better project results for students. When creating a focus question, students should consider the following:

- Is the question interesting?
- Can the focus question be answered with the resources available for research?
- Does the focus question fit within the parameters set out for the project?
- Is the focus question clearly posed?
- Does the focus question clearly direct research?
- Can the focus question be completely investigated within the time line of the research?

A student or teacher should be able to answer yes to all of the questions above. The focus question will be the driving force of research, so should be considered carefully.

The benefit to students of a clear focus question is the fact that it directs research along one specific pathway. Many students find long-term projects difficult because they find the amount of information available to be immense. If a clear focus question is developed before the start of in-depth research, the student will have less difficulty with the massive amounts of information available on any topic. The focus question allows students to quickly sort through useful and non-useful information.

Sample Teacher Project

The teacher project gives a teacher a unique opportunity to guide student efforts without controlling the direction or methodology of student research. The teacher is always one step ahead of the student and uses the project to highlight where a student should be with their research as time passes. The teacher project also enables teachers to look into specific aspects of the curriculum they might not otherwise explore.

Possible Topic List

- Alcohols-carboxylic acids
- Acids-esters
- Aldehydes-ketones-ethers
- Amines-carboxylic acids-amides
- Aromatics hydrocarbons
- DDT-CFCs-PAHs
- Petroleum refining
- Fossil fuels and global warming
- DNA-RNA
- Alkyl halides-alcohols-ethers
- Sugars
- Plastics and recycling

Benefits of Project-Based Learning

Project-based science provides unique learning opportunities not found in traditional lecture and laboratory science classrooms. Treating students like real scientists turns the table on science learning and makes the student the constructor of knowledge. The many benefits of a project-based approach to science instruction include

- the achievement of a number of STSE and science skills outcomes
- the achievement of a number of language arts outcomes with respect to writing
- the achievement of a number of mathematics outcomes
- the development of authentic learning and assessment practices
- the transfer of knowledge development from teacher to student
- the opportunity for teachers to become students and develop project skills along with students
- the correlation of knowledge from physics, biology, chemistry, and other branches of science
- the development of problem-solving and questioning skills in students
- the opportunity for students to enhance research skills and develop critical- thinking and evaluation skills
- the opportunity for students to collect and share knowledge in a number of formats addressing a variety of intelligences
- the introduction of students to real science practices
- the opportunity for teachers in different curriculum areas to work collaboratively on a project
- the ability to modify and adapt student projects in order to accommodate their strengths and avoid weaknesses
- the chance to showcase student work to the school, to parents, and to the general public

Appendices

Appendix A: Problems for Advanced Chemistry 11

Following are four sets of sample problems that illustrate enrichment strategies.

Stoichiometry

1. Green chemists use an additional measure regarding reactants and products: the atom economy. Usually measured for organic synthesis, the atom economy calculation can be applied to any reaction.

   $$\textit{atom economy} = \frac{\textit{mass of desired product}}{\textit{mass of all reactants}} \times 100\%$$

   Calculate the theoretical atom economy of carbon dioxide in the complete combustion of octane.
2. Histamine is a chemical that is released by the cells in response to infections, bee and wasp stings, and other allergy-type reactions. It causes your blood vessels to dilate and swell because excess liquid builds up in the tissues surrounding the vessels. This is the reason people take antihistamines—to relieve the symptoms of the histamine response. A 125 mg sample of histamine contains 67.5 mg of carbon and 10.1 mg of hydrogen, the rest being nitrogen. If the molecular mass of hydrogen is 111 g/mol, what is the molecular formula of histamine?
3. Your teacher gives you two substances to analyse in the laboratory. They are both found to have the same empirical formula, CH_2O, even though they are easily distinguishable due to their different physical properties (i.e., colour, physical state, smell). How is this possible? One compound is a colourless liquid with a foul odour. The other is a white crystalline solid. What further tests would you do to identify the samples?
4. Zinc oxide is a compound you would normally find around the home. Many cosmetics and medical supplies such as Band-Aids and analgesic creams contain this compound, as do some toothpastes and vitamins. Zinc(II) oxide can be prepared by reacting iron(III) oxide with zinc metal. If one vitamin capsule contains 15 mg of zinc(II) oxide, what mass of zinc was originally required for preparation. If 50 mg of each reactant were used, how many capsules could be produced?
5. In reading about a new chemical-free sun block, Laura searches the Internet for the product. On the list of ingredients is magnesium sulfate. Laura, being the keen chemistry student, realizes that magnesium sulfate is indeed a chemical. However, for sunscreen, it is considered an inactive ingredient and therefore the product is considered chemical-free.

   a. Is this a true advertisement for the consumer? Explain.
   b. For a 110 g bottle of this sunscreen, 0.5% is magnesium sulfate. How much magnesium metal was used to prepare this amount of sulfate according to the equation below?

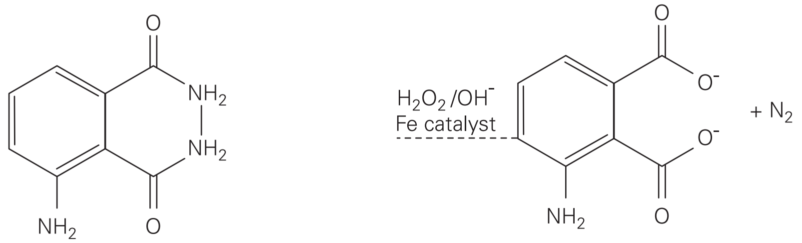
   $Mg(s) + FeSO_4(aq) \rightarrow MgSO_4(aq) + Fe(s)$
6. Betulin and its oxidation product betulinic acid are chemicals found in the outer bark of the common European white birch tree. Betulinic acid is known for its anticancer properties. Here in the Maritimes, the Mi'kmaq used the bark of the native Canadian yellow birch tree for its medicinal properties. For example, they would steep the bark in water, then rub the liquid on the body to relieve rheumatic pains. The inner bark was used to make a tea that would help relieve indigestion. Chewing the bark itself was said to give extra energy.

Betulinic acid forms from the reaction, called selective oxidation, of betulin.

$$C_{30}H_{50}O_2 + H_2O \xrightarrow{\substack{\text{NaOCl} \\ \text{NaOCL}_2 \\ 50\ ^\circ\text{C}}} C_{30}H_{48}O_3 + 4H^+$$

a. The white birch tree has a maximum of 25% betulin in its bark. Assuming that a 245 g sample of bark was obtained, what is the maximum quantity of betulinic acid extracted?
b. If the actual yield in an experiment is 71%, what percentage of betulin was in a 50 g sample of bark?

7. On most forensic science shows, you see the scientists use clear liquid spray to check for the presence of blood at a crime scene. This clear liquid is often luminol (5-amino-2,3-dihydro-1,4-phthalazinedione). Discovered in 1902 in Germany, luminol was named in 1928 and first used at a crime scene in 1937. It gives off a blue green light when it reacts with blood. Hemoglobin contains iron that acts as a catalyst for the reaction. The reaction for the detection of blood by luminol is shown below. Remember that light must be emitted from the 3-aminophthalate in order for the reaction to reveal any traces of blood.



luminol 3-aminophthalate

a. Luminol's reaction depends on the catalyst of iron in the blood. What other catalysts can interfere with the reaction?
b. Where else is luminol found in society or in nature?
c. If 25.0 mL of luminol is sprayed on an area in a crime scene suspected of being 75% covered in blood, how much 3-aminophthalate would you expect to form?

8. The Oswald process is a common process for the industrial production of nitric acid. Here is the reaction sequence:

$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(l)$

$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$

$3NO_2(g) + H_2O(l) \rightarrow 2HNO_3(l) + NO(g)$

a. If a customer orders 1.5×10^4 kg of nitric acid, what amount of ammonia would the company use in the initial reaction?
b. If the company started with 2.0×10^3 kg of $NH_3(\ )$ and the actual yield of product was 3.25×10^3 kg, what would be the percent yield?

9. Tristearin ($C_{57}H_{110}O_6$) is the fat stored in the humps of camels. This fat is a source of energy and water for the camel. You can see the production of water from the fat by writing the combustion reaction of the fat. The fat is burned when the camel is moving along in the desert.
    a. Write the combustion reaction for the complete combustion of tristarin.
    b. What mass of oxygen would be required to completely react 750 g of the fat?
    c. If excess oxygen were available, how much water would be produced?
    d. What mass of tristarin would be required to produce 1 L of water?

From Structures to Properties

10. Write the electronic configuration for each of the following. Indicate whether each is paramagnetic or diamagnetic. Why is this important? What properties does it contribute to the element or ion?
    a. Mn^{3+} c. Ca e. Co
    b. Fe^{2+} d. V

11. Graph the trends of atomic radii, first ionization energy, electron affinity, and electronegativity on four separate graphs. For each graph use atomic number (up to 40) as the -axis.
    a. Determine the general trend for each graph as it relates to the periodic table design by Mendeleev.
    b. How would these graphs change if we had used the data from the Newlands periodic table created four years prior to Mendeleev's?
    c. Understanding the terminology associated with periodicity, do any of the periodic trends compare to each other? Explain?

12. Create a flowchart that combines your knowledge of ionic compounds, covalent molecules, and network solids, and the types of bonding that occur in each. Using examples, illustrate how this flowchart can be used to make predictions about melting points and boiling points.

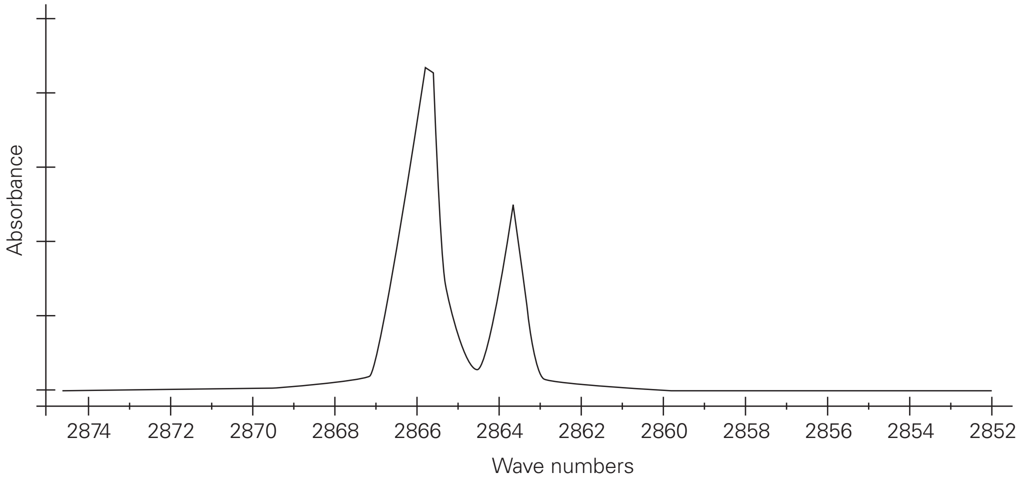
13. Draw Lewis structures for each compound below. Indicate the VSEPR shapes for each as well as the formal charges.
    a. SCN^-
    b. CH_3CN
    c. H_3O^+
    d. SO_4^{2-}

14. Explain what is meant by the term **crystal field stabilization energy** (CFSE). Research the calculation for the CFSE for octahedral and tetrahedral complexes as well as how to tell if compounds will have high or low spins. CFSE is particularly useful in its ability to relate to the colour of complexes. How?

15. Show, using examples, how a hybridized orbital differs from a pure atomic orbital. Buckminsterfullerene (buckyball) is a newly discovered **allotrope of carbon**. Discovered in 1985, it is a beautiful example of a molecule utilizing the hybridized orbital. Describe the structure of the buckyball and some potential uses of this new discovery.

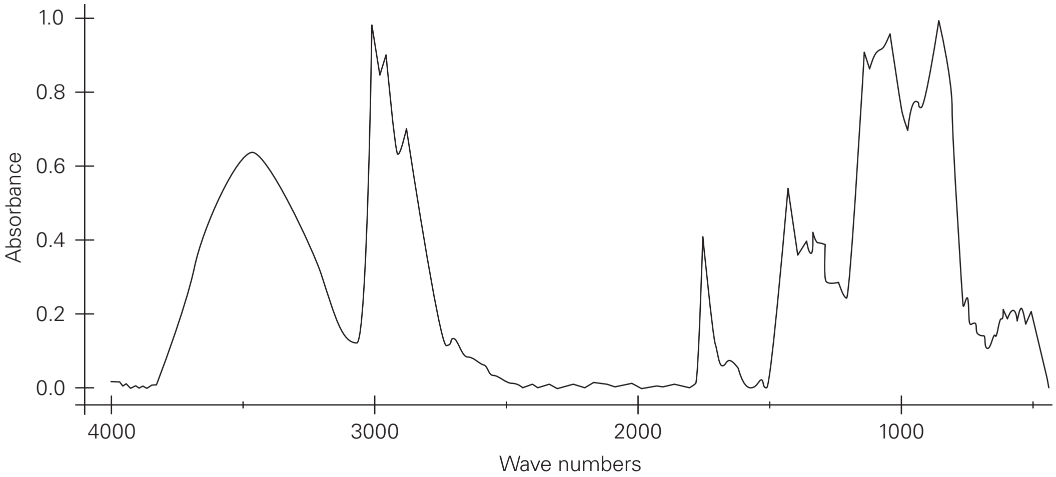
Organic Chemistry

16. Thomas, a three-year-old boy, describes chemistry as something where "you put two yucky things together and you come out with one yummy thing." To Thomas, chemistry is cooking. But he is not too far off if you look at the process of the preparation of esters. Look, for example, at the production of amyl butyrate. Amyl butyrate forms from pentyl alcohol and butyric acid, two compounds that smell- wise would not be particularly pleasing. Amyl butyrate, on the other hand, smells a lot like Juicy Fruit gum.
    a. Write the reaction for the esterification of amyl butyrate.
    b. Another such compound that smells like pineapple is derived from two not-so-great smelling compounds. Research the ester responsible for the odour of pineapple and write the esterification reaction.
17. In determining whether a nucleophilic displacement will undergo SN1 or SN2, what characteristics of the alkyl halide must be considered? Use examples where applicable. Why do you think these characteristics are important, based on your knowledge of organic reactions? To determine experimentally whether a reaction was SN1 or SN2, what tests would you do? What would you predict?
18. NMR, IR, and mass spectrometry are based on the structural properties of the compounds being analysed. What characteristics is each of these identification techniques using when scientists choose them to identify compounds in experiments?

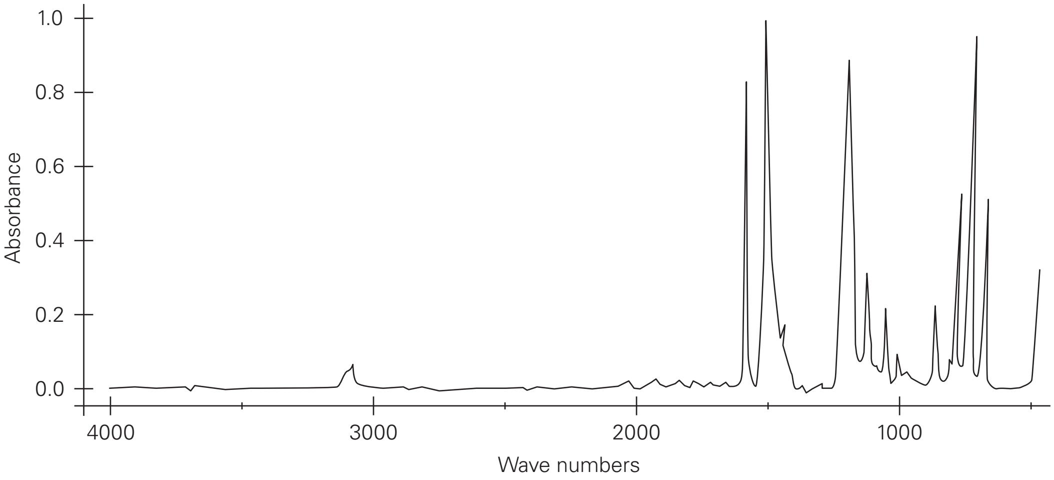


    a. Identify the compound in this IR spectrum. What do the peaks represent?

b. Identify the compound in this IR spectrum. What do the peaks represent?



c. Identify the compound in this IR spectrum. What do the peaks represent?



d. Draw a mass spectrometer printout of the compounds found in (a), (b), and (c).

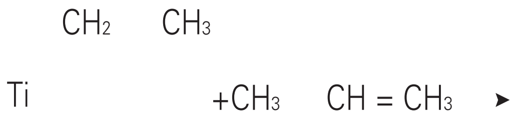
19. Boeing announced the premier flight of the 787 Dreamliner in early August 2007. This new plane is said to represent a new era in fuel efficiency with lower emissions. Research the increase or decrease in air travel over the past 10 years. Using an Internet search, research the improvements to the design of the new Boeing Dreamliner and how these improvements will help in the endeavour for more environmental consciousness in the air as well as on the ground.

20. In 2001, three scientists won the Nobel Prize in Chemistry for their work in chirality. Together, these three men have helped to make huge inroads in the pharmaceutical industry as well as the possibility of protecting the public from future harmful drug side effects. Research the work of William S. Knowles, Ryoji Noyori, and K. Barry Sharpless, and prepare a summary or Main Ideas Map of their work. Provide examples of drugs the pharmaceutical industry has already developed that use the (R) – /(S) – enantiomer chirality.

21. What is so exciting about the German origin Ziegler-Natta catalyst for vinyl polymerization is that it involves a transition metal catalyst ($TiCl_3$) as well as $Al(C_2H_5)_3Cl$ so that there is a catalyst/co-catalyst pair occurring in the reactions.

    a. Complete the first two steps of the Ziegler-Natta catalyst reaction started below.

    Step 1:

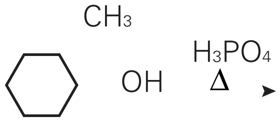
    

    $Ti \quad \overset{CH_2}{} \quad \overset{CH_3}{} \quad +CH_3 \quad CH = CH_3 \rightarrow$

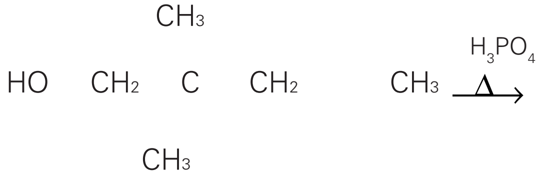
    b. What is the significance of high density (HDPE) versus low-density (LDPE) polymer manufacturing?

22. Define Zaitsev's rule. For what situations does Zaitsev's rule apply? When Zaitsev's rule is followed for elimination reactions, the reaction is said to be regioselective. For each of the following reactions, determine the products and indicate the product present in the greatest amount.

    a.

    b.

    $HO \quad CH_2 \quad \overset{CH_3}{\underset{CH_3}{C}} \quad CH_2 \quad CH_3 \xrightarrow[\Delta]{H_3PO_4}$

23. Michelle Francl once wrote, "Chemistry, even physical chemistry, is not a world unto itself. Chemistry is woven firmly into the fabric of the rest of the world, and various fields, from literature to archaeology, thread their way through the chemist's turf." Based on your knowledge of chemistry so far, how might you defend or oppose this statement.

24. Draw the structure for Vitamin E ($C_{29}H_{50}O_2$), knowing that it has one benzene ring. How many chiral carbon atoms does it have? Vitamins can be found in the stores as natural or synthetic. Determine what the difference is between these two types of compounds by using the Internet, interviewing the local druggist, or calling/e-mailing the nearest university organic chemistry professor.

Appendix B: Problems for Advanced Chemistry 12

Following are four set of sample problems that illustrate enrichment strategies.

Thermochemistry

1. Into a constant pressure calorimeter holding 45.1 g of water at 24.3 °C, you pour 55.6 g of water at 97.5 °C. The final temperature of the combined water samples reaches 62.8 °C. What is the specific heat capacity for the calorimeter? Using this same calorimeter, a 72.6 g sample of an unknown metal is heated to 103 °C and dropped into 150 g of water at 25 °C. After the reaction is complete, the final temperature is 28.7 °C. Calculate the heat capacity of the metal. Is it possible to identify the unknown? What was the purpose of the first calculation?
2. A sugar cube has 71.1 kJ of energy. An active person, one who regularly participates in some form of physical exercise, burns 10 041 kJ per day. Therefore, this sugar cube would give the person enough energy for about 10 minutes. A 5.4 g sample of sugar ($C_{12}H_{22}O_{11}$) was burned in a bomb calorimeter having a heat capacity of 3 998 J/°C. The temperature in the calorimeter rose by 3.81 °C.
   a. Write the reaction for the combustion of sucrose, and calculate the molar enthalpy for the reaction.
   b. How long would you estimate that this sample of sugar would keep the active person going? Explain your reasoning.
3. You may not have heard the chemical name elaidic acid before, but you have heard a lot about it. In recent years, fast foods, snack food vendors, and advertisers have been inundating the public with the idea that they are reducing the trans fats in their products. Elaidic acid ($C_{18}H_{34}O_2$) is an unsaturated fatty acid and is the trans isomer of oleic acid. It is the trans fat. Elaidic acid is often found in partially hydrogenated vegetable oils, whereas oleic acid is found in substances such as olive oil.
   a. Write the combustion reaction for the reaction of elaidic acid.
   b. Calculate the heat of reaction for the combustion of elaidic acid.
   c. Calculate $\Delta G°$ at standard conditions to determine if the reaction is spontaneous.
4. $CaO(s) + CO_2(g) \rightarrow CaCO_3(s)$
   a. Calculate $\Delta G°$ at 117 °C.
   b. Calculate the temperature when the above reaction is at equilibrium ($\Delta G° = 0$)
   c. At what temperature, if any, will this reaction be spontaneous?
5. One of the major pollutants (man-made, that is) present in the atmosphere is nitrogen oxide. NO is a product of combustion occurring in combustion engines, industrial plants, etc. NO is produced according to the following equation.

   $N_2 + O_2 \rightleftharpoons 2\ NO$

   In this problem you will study the temperature dependence of this reaction to learn how the emission of NO can be reduced. Answer the following questions (assume that $\Delta H°$ and ΔS are constant at each temperature):

a. What is ΔH°, ΔS, and ΔG° for each of the following temperatures?
  i. 25 °C
  ii. 100 °C
  iii. 1000 °C
  iv. 2500 °C

b. Display your data from (a) in a graphic organizer. Discuss the data in terms of spontaneity and the effect of the amount of product released.

c. Would lowering the combustion temperature from 2500 °C to 1000 °C, or even to 100 °C, have any effect on the NO emission?

Solutions, Kinetics, and Equilibrium

6. What is the freezing point of a solution that contains 43.5 g of sucrose ($C_{12}H_{22}O_{11}$) dissolved in 1.250×10^2 g of water? Boiling point?

7. Which aqueous solution has the higher boiling point: 0.25 M Na_3PO_4 or 0.25 M $CaCl_2$? Explain.

8. One step in the reaction mechanism is found to be $NO + Br_2 \rightleftharpoons NOBr_2$. The rate law expression was determined to be rate = k $[NOBr_2]$ [NO]. Write the complete reaction mechanism labelling the catalyst(s) and intermediate(s), if any, the rate determining step, the overall reaction, and the reaction order.

9. Salt trucks sprinkle a mixture of NaCl and $CaCl_2$ onto the streets in the winter. Cars will use ethylene glycol ($C_2H_6O_2$) to keep their radiator water from freezing in the winter months. As a point of fact, airplanes are sprayed with ethylene glycol when they are being de-iced. Assume one salt truckload (10 tonnes) is emptied in your neighbourhood. The mixture is known to be 60% NaCl and 40% $CaCl_2$. By how much will this effort change the temperature of the substance on the road surface? What happens to this surface substance?

10. An unknown powder has an odour similar to pine cleaner. Undergoing experimentation on a 0.005 g sample of the powder dissolved in 5.50 mL of water at 15 °C, the osmotic pressure is 13.3 kPa. Using combustion analysis, it is found that 77.86% is carbon, 11.76% is hydrogen, and the rest is oxygen. What is the unknown? A 75.9 g sample of a compound is found to have a molar mass of approximately 182 g/mol.

11. Here is one of the reactions in the production of photochemical smog.

$$C_2H_4(g) + O_3(g) \rightleftharpoons C_2H_4O(g) + O_2(g)$$

Calculate the reaction rate law, the rate constant, and the overall order, given the table shown below. Work out the calculations. Does the reaction represents a single step or part of a mechanism. Explain

Data Table: Initial rates for reaction of $C_2H_4(g)$ and $O_3(g)$

Trial	**$[C_2H_4]$ (mol/L)**	**$[O_3]$ (mol/L)**	**Initial rate of $C_2H_4O(g)$**
1	0.100	0.100	4.0×10^{-4}
2	0.100	0.200	4.0×10^{-4}
3	0.300	0.100	2.8×10^{-3}

12. Research the work of Brad Moore at UC Berkeley. Use the Internet to learn a little of his discovery of the transition state series of molecules, photofragment spectroscopy, and the fact that he and his team were able to identify the first transition state of a reaction sequence after 50 years of trials. Develop a fishbone graphic organizer to display the connection of these ideas.

Acids and Bases

13. One common problem in the Florida flatlands is the amount of calcium carbonate found in the soil. Calcareous soil, as it is known, is the name of the soil that is rich in calcium carbonate (lime). The $CaCO_3$ is having a very harmful effect of the citrus trees in the south. This type of soil usually has a pH between 7.6 and 8.4. What is the difference in $[H^+]$ for this pH range? What would this alkaline soil do to the citrus trees?
14. For each of the following reactions, indicate if they are Brønsted/Lowry acid-base reactions, Lewis acid-base reactions, or both. Label the acid and base, the conjugate acid-base pair.
    a. $2HCl(aq) + Ca(OH)_2(aq) \rightarrow CaCl_2(aq) + 2H_2O(l)$
    b. $Ag^+(aq) + 2NH_3(aq) \quad Ag(NH_3)^{2+}(aq)$
    c. $AgCl(s) + 2NH_3(aq) \rightarrow (NH_3)_2Ag^+(aq) + Cl^-(aq)$
    d. $HCCl_3CO_2(aq) + H_2O(l) \quad CCl_3CO^{2-}(aq) + H_3O^+(aq)$
15. Propanoic acid (CH_3CH_2COOH) has many uses in the food and drug industry as a preservative. The a for propanoic acid is 1.3×10^{-5}. What is the pH of a solution containing 0.15 mol/L of the acid? If 0.02 mol of NaOH were added to the solution, what is the new pH?
16. If you look around your home, or outside it for that matter, you can identify a variety of acid-base indicators. Beets change colour from red to purplish in basic solution. Essentially, any fruit or plant that is blue, purple, or red will act as an indicator because of a chemical compound known as an anthocyanin. In solution, blueberries are blue at around a pH = 2.8 and red at pH = 3.2.

    In a titration of 100 mL of 1.00 mol/L OCl^- with 1.00 mol/L HCl, are blueberries going to be a good indicator to use for this titration? Explain. $_b$ for OCl^- is 3.6×10^{-7}.

Electrochemistry

17. A piece of jewellery is to be coated with gold. A current of 10.0 A runs for one hour. What mass of gold is formed on the piece of jewellery?
18. Balance the following in basic solution using the half-reaction method. Determine if the reaction is spontaneous or non-spontaneous.

    $S(s) + NO_3^-(aq) \rightarrow SO_2(g) + NO(g)$
19. For the cell given by the notation $Zn \mid Zn^{2+} \parallel Cu^{2+} \mid Cu$, calculate $\Delta G°$ using the formula

    $\Delta G° = - \quad °$ cell. What other methods are available for you to calculate $\Delta G°$, if any?
20. What is the equilibrium constant for the reaction between solid lead and cobalt(II) chloride?

21. Spontaneity has been a common thread for many topics throughout Advanced Chemistry 12. In your journal, compile all of the evidence for spontaneity of reactions into one flowchart or graphic organizer that can be used for problem solving. Create one problem and share your problem and graphic with a classmate to test the flow of the organizer.

Appendix C: Suggested Activities

Advanced chemistry is designed to encourage students to explore chemistry through multiple formats. The program provides opportunities for exploration through problem solving, readings, writing, critical reflection, and questioning, all with the purpose of enabling students to explore the world around them.

Teachers should consider incorporating one or more of the following activities, or any others of their own design. Students should be encouraged to collaborate with each other on the activities.

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Examples:

- Design and construct
  - microchemistry lab similar to one done in class
  - design of esterification lab
  - testing of consumer products
  - crystal growing
  - chemical spills
  - forensic science
  - green-chemistry experiments
  - tracing DDT in food chain while analysing chemical reactions
- Trip with chemistry analysis (virtual or otherwise)
- History of chemistry (e.g., periodic table)
- Metabolic cycles
- Chirality and pharmaceutical drugs
- Design a Sudoku game using the mole concept
- Atmospheric chemistry

Advanced Chemistry 12

Examples:

- Design and construct
  - nuclear energy
  - comparing the pH of different consumer products
  - investigating concentration changes on reaction rates
  - biological catalysts
  - electroplating
  - percentage of iron in lawn sand
  - forensic science
  - green-chemistry experiments
- Trip with chemistry analysis (virtual or otherwise)
- Water treatment facilities
- Compare the microscale, technological, and traditional forms of laboratory work
- Fuel cells
- Solar cars
- Design a game using the concepts learned

Appendix D: Periodic Table

Periodic Table of Elements

atomic number — 1 1.01 **H** hydrogen — average atomic mass*

Transitional Elements

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 1.01 **H** hydrogen																	2 4.00 **He** helium
2	3 6.94 **Li** lithium	4 9.01 **Be** berylium											5 10.81 **B** boron	6 12.01 **C** carbon	7 14.01 **N** nitrogen	8 16.00 **O** oxygen	9 19.00 **F** fluorine	10 20.18 **Ne** neon
3	11 22.99 **Na** sodium	12 24.31 **Mg** magnesium											13 26.98 **Al** aluminum	14 28.09 **Si** silicon	15 30.97 **P** phosphorus	16 32.07 **S** sulfur	17 35.45 **Cl** chlorine	18 39.95 **Ar** argon
4	19 39.10 **K** potassium	20 40.08 **Ca** calcium	21 44.96 **Sc** scandium	22 47.87 **Ti** titanium	23 50.94 **V** vanadium	24 52.00 **Cr** chromium	25 54.94 **Mn** maganese	26 55.85 **Fe** iron	27 58.93 **Co** cobalt	28 58.69 **Ni** nickel	29 63.55 **Cu** copper	30 65.39 **Zn** zinc	31 69.72 **Ga** gallium	32 72.61 **Ge** germanium	33 74.92 **As** arsenic	34 78.96 **Se** selenium	35 79.90 **Br** bromine	36 83.80 **Kr** krypton
5	37 85.47 **Rb** rubidium	38 87.62 **Sr** strontium	39 88.91 **Y** yttrium	40 91.22 **Zr** zirconium	41 92.91 **Nb** niobium	42 95.94 **Mo** molybdenum	43 (98) **Tc** technetium	44 101.07 **Ru** ruthenium	45 102.91 **Rh** rhodium	46 106.42 **Pd** palladium	47 107.87 **Ag** silver	48 112.41 **Cd** cadmium	49 114.82 **In** indium	50 118.71 **Sn** tin	51 121.76 **Sb** antimony	52 127.60 **Te** tellurium	53 126.90 **I** iodine	54 131.29 **Xe** xenon
6	55 132.91 **Cs** cesium	56 137.33 **Ba** barium	57 138.91 **La** lanthanum	72 178.49 **Hf** hafnium	73 180.95 **Ta** tantalum	74 183.21 **W** tungsten	75 186.21 **Re** rhenium	76 190.23 **Os** osmium	77 192.22 **Ir** iridium	78 195.08 **Pt** platinum	79 196.97 **Au** gold	80 200.59 **Hg** mercury	81 204.38 **Tl** thallium	82 207.20 **Pb** lead	83 208.98 **Bi** bismuth	84 (209) **Po** polonium	85 (210) **At** astatine	86 (222) **Rn** radon
7	87 (223) **Fr** francium	88 (226) **Ra** radium	89 (227) **Ac** actinium	104 (261) **Rf** rutherfordium	105 (262) **Db** dubnium	106 (266) **Sg** seaborgium	107 (264) **Bh** bohrium	108 (269) **Hs** hassium	109 (268) **Mt** meitnerium	110 (271) **Ds** darmstadtium	111 (272) **Rg** roentgenium	112 (277) **Uub** ununbium	113 (282) **Uub** ununtrium	114 (285) **Uuq** ununquadium	115 (288) **Uub** ununpentium	116 (289) **Uuh** ununhexium		

elements 112-116 have not been officially named yet

Inner Transitional Elements

8	Lanthanoids	58 140.12 **Ce** cerium	59 140.90 **Pr** praseodymium	60 144.24 **Nd** neodymium	61 (145) **Pm** promethium	62 150.36 **Sm** samarium	63 151.96 **Eu** europium	64 157.25 **Gd** gadolinium	65 158.93 **Tb** terbium	66 162.50 **Dy** dysprosium	67 164.93 **Ho** holmium	68 167.26 **Er** erbium	69 168.93 **Tm** thulium	70 173.04 **Yb** ytterbium	71 174.97 **Lu** lutetium
9	Actinoids	90 232.04 **Th** thorium	91 231.04 **Pa** protactinium	92 238.03 **U** uranium	93 237.05 **Np** neptunium	94 (244) **Pu** plutonium	95 (243) **Am** americium	96 (247) **Cm** curium	97 (247) **Bk** berkelium	98 (251) **Cf** californium	99 (252) **Es** einsteinium	100 (257) **Fm** fermium	101 (258) **Md** mendelevium	102 (259) **No** nobelium	103 (262) **Lr** lawrencium

*average atomic mass values in parenthesis is the mass of the most stable isotope

Appendix E: Chemistry Exam Preparation

The following pages outline some information that might help students prepare to write a chemistry exam.

How is the examination organized?

The chemistry courses are organized around a set of outcomes. Outcomes are statements of the knowledge and skills students are expected to be able to demonstrate upon completion of the courses. Each course in the advanced program consists of a series of topics. The following table outlines the percentage that each topic represents in the respective course.

Chemistry 11

Stoichiometry	28.7%
From Structures to Properties	34.5%
Organic Chemistry	36.8%

Chemistry 12

Thermochemistry	18.6%
Solutions, Kinetics, and Equilibrium	32.0%
Acids and Bases	24.7%
Electrochemistry	24.7%

How can you best prepare for an examination?

The first step is to start now. The most effective way to prepare for any examination is to begin preparations when the course begins. Make review notes on a daily basis. Review them weekly. Gain clarification from the teacher quickly. If you do not work with what you have learned, up to 80 percent will be lost within 24 hours. The more often you read and recognize your notes as the course progresses, the less you will have to do immediately prior to the exam.

You should also use your entire textbook. Read the introductory material for each chapter and the margin notes. Read the chapter review thoroughly. The textbook questions are grouped under five headings: Knowledge, Inquiry, Communication, Making Connections, and Problems for Understanding. Do not limit yourself to those assigned by your teacher. Use the CD provided with the text and the website.

You can also develop your skills by looking for situations where chemistry can be applied outside of class. Observe the world around you. Read newspaper and magazine articles. Identify the chemistry concepts that apply as you read. This will make you confident with exam questions that present novel chemistry situations, using the concepts you have learned.

What should be brought to the examination on exam day?

In general, a chemistry exam would require the same things you would normally use in class:

- calculator
- ruler
- pencils

You might also bring

- an eraser
- a spare calculator (or batteries)
- a highlighter
- tissues
- coughdrops

What do teachers normally look for in written responses?

Teachers look for a clearly written, direct response to the question. Be sure to understand what is required before you start to write. Be clear and straightforward in your writing. Although every effort will be made to understand what you have written, try not to bury your thoughts in extra words.

What is expected in solutions to problems?

Using a clear problem-solving pattern is the best strategy when working out the solutions to problems.

In general, follow these steps:

1. List the known and unknown variables.
2. Draw a diagram where appropriate.
3. State the formula (or series of formulas) you will use.
4. Reorganize the formula for the unknown variable.
5. Show the replacement with units.
6. Show the answer with units.
7. Write a complete sentence that clearly answers the question posed.

This format, although general, will benefit you. Organized work is easier to check and retrace if you have to make a correction. If you are organized and neat, it is easier for you to go back and check your work. Writing a complete sentence as a final step is a way for you to ensure that you have done the right thing. Go back to the wording of the problem to be sure.

Preparation Tips

1. **Review time, place, and rules**
    - Post your exam schedule in a conspicuous place.
2. **Create a review schedule**
    - Plan your time for the four weeks prior to the exam.
    - Allocate time to create specific review notes for each unit in the curriculum.
    - Divide review time into blocks according to the time allocated for each unit and the effort you feel you need for each unit.
    - Review tests and assignments.
    - Schedule time to meet with your teacher to discuss things with which you will need help.
3. **Make summaries and outlines**
    - Separate major concepts from factual details.
    - Review laboratory reports to make sure you know the major concepts connected to each experimental procedure.
    - Think about real-world application of each topic.
    - Review graph plotting and analysing procedures on your calculator that apply to the concepts learned.
    - Ask your teacher for any formula sheets that may be provided with the exam. Become familiar with the possible arrangements of the formulas, the situations when they are to be used, and necessary information for required learning that is not to be provided.
4. **Develop memory aids**
    - Read key words aloud and state their meaning.
    - For lists, number each item to help remember the sequence.
    - Use sticky notes as margin tabs or a concept map on poster board.
    - Use a highlighter for emphasis. Using more than one colour might make sections more visually distinct and easier to remember.

During the Exam

1. **Plan to be comfortable**

    Eat properly and get plenty of rest in the days before the examination. Wear comfortable, loose clothing. If you know what the temperature will be like in the room where you will be writing, dress appropriately. Take a bathroom break before you write. Avoid last-minute conversations about the examination.

2. **Be prepared**

    Collect the things you need to bring on the day before the examination. Clear the memory on your calculator (if required). Plan to arrive early.

3. **Plan your time**

   Scan the exam and budget your time by using the point allocations as a guide. In the constructed response (long-answer sections), do the questions you are most sure of first. The questions are not normally in an order of difficulty. Do not waste time pondering a difficult question if there are others you can do faster and better.

4. **Answer each question**

   There is no penalty for wrong answers on any part of the examination. Partial answers are usually given partial credit.

5. **Summarize your answer**

   For both written response questions and algebraic problems, be sure to conclude with a statement that clearly answers the question.

6. **Be logical**

   Identify key words. Multiple-choice questions often contain choices that can be easily eliminated. Look at the remaining alternatives carefully. Is there a further clue to the right answer? Is there a choice between opposites, such as negative or positive, spontaneous or non-spontaneous? Is there an exponent in the alternatives that you can compare with a power of ten estimate in the answer? When you scanned the exam, did you notice something in another part that might be helpful? Finally, if the solution to the multiple-choice question seems to require more than five minutes, there is probably a faster method. Mark this question and come back to it later.

Appendix F: Key Directing Words

Compare	Point out only the similarities between two things being compared.
Contrast/Distinguish	Point out only the differences between two things being compared.
Conclude	Bring to a logical finish. Often, you will be required to draw a conclusion. A conclusion is drawn based on information provided or previously learned.
Define	Present clearly the meaning of a word or the essential qualities of a concept.
Describe	Provide a word summary of the characteristics of a specified item.
Design	Present a sequence of actions or steps that will achieve a desired goal (e.g., How would you do an experiment to measure the molecular formula of a hydrate?)
Evaluate	Indicate the good and bad (or the positive and negative) characteristics of some object, action, or event. Pay careful attention to any specific criteria against which your evaluation must be done.
Explain	Make clear using chemical principles.
Illustrate	Make clear by using an example.
Predict	Tell in advance based on trends in observed data.
Prove/Show	Support the truth of a fact or statement using evidence or logic.
Summarize	Give a brief account of the main points.
Trace	Give a step-by-step account of the development of a theory or technology.

Appendix G: Resources

The following resources are suggestions for teachers. All print resources are readily available. For details, see the list of resources on page 73.Web resources are current as of the date of publication.

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Books

- *Chemical Bonding and Molecular Geometry: From Lewis to Electron Densities*, Ronald J. Gillespie
- *Chemical Structure and Bonding*, Roger DeKock and Harry Gray
- *Cross-Curricular Reading Tools* (available through CAMET through camet-camef@cap-cpma.ca)
- *The Evolution of Physics*, Albert Einstein and Leopold Infeld
- *Micmac Medicines: Remedies and Recollections*, Laurie Lacey
- *The ACS Style Guide: Effective Communication of Scientific Information*, 3rd edition, Ann M. Coghill and Lorrin R. Garson (25149)
- *The Merck Index: An Encyclopedia of Chemicals, Drugs, and Biologicals with CD-ROM*, 14th edition
- *CRC Handbook of Chemistry and Physics,* 89th edition, David R. Lide

Websites

- US Environmental Protection Agency: Green Chemistry: epa.gov/greenchemistry
- Chemical Institute of Canada: cheminst.ca
- American Chemical Society: portal.acs.org/portal/acs/corg/content
- International Union of Pure and Applied Chemistry (IUPAC): iupac.org

Advanced Chemistry 12

Books

- *Chemistry in the Marketplace*, Ben Selinger
- *The Genie in the Bottle: 68 All New Commentaries on the Fascinating Chemistry of Everyday Life*, Dr. Joe Schwarcz
- *Cross-Curricular Reading Tools* (available through CAMET through camet-camef@cap-cpma.ca)
- *The ACS Style Guide: Effective Communication of Scientific Information*, Anne M. Coghill and Lorrin R. Garson (25149)
- *The Merck Index: An Encyclopedia of Chemicals, Drugs, and Biologicals with CD-ROM*, 14th edition
- *CRC Handbook of Chemistry and Physics,* 89th edition, David R. Lide

Websites

- *Chempire: A Kingdom of Chemistry Resources*: library.thinkquest.org/28330/
- International Union of Pure and Applied Chemistry (IUPAC): iupac.org
- Chemical Institute of Canada: cheminst.ca

Appendix H: Assessment and Evaluation

The assessment of a project-based science activity provides teachers with a unique opportunity to evaluate student learning in science. A variety of STSE, scientific skill, and knowledge outcomes may be covered through a project. Providing students with the opportunity to assist in the creation of evaluation tools for projects gives them an opportunity to examine how to design a project that fits the project they are working on.

Assessment of Learning

Assessment of learning is the method of evaluation most familiar to teachers. This type of assessment involves looking back at what students have covered and determining how well they have internalized the information. Completed projects should represent the learning of students at all stages of project development. A good rubric or set of rubrics makes the assessment of a student project quick and effective. Rubrics are useful tools in the final assessment of a chemistry project. Rubrics should include the assessment of all aspects of a student project, including focus question quality, research effectiveness, effort, and the overall quality of all artifacts produced through research.

Assessment for Learning

Assessment for learning involves the use of effective assessment tools to help develop knowledge through the act of assessment. A project-based investigation that includes clearly focussed assessment guidelines that involve students in all aspects of the assessment creates unique learning opportunities for both students and teachers. Students should be involved in the creation of rubrics, the creations of questions based on their research, and the evaluation of their work from start to finish. The chance to be part of the assessment of a project from start to finish empowers students and creates conditions that allow them to capitalize on every learning opportunity provided by a project.

Rubrics

A complete scoring rubric that addresses all aspects of a project is one of the most effective and efficient ways to evaluate a project. A rubric should be developed with students, and should be completed by both students

Evaluation Examples

Example 1: Project Evaluation Checklist

Teacher Name: ________________________ Student Name: ________________________

Reviewer Name: ______________________________ Date: __________________

Project: Sample Checklist

Example 2: Scoring Rubric (For student and Teacher)

Teacher Name: ________________________ Student Name: ________________________

Appendix I: Incorporating Project-Based Science in the Classroom

Project-based science is a rewarding method of learning and teaching that allows students and teachers to interact in ways that are not common in traditional science classrooms. The intent is that teachers do their own projects. Not only do they do and present their own projects, but they also model the behaviour to their students. Teachers are always ahead of the students in the process of their project. This ensures control over time lines, the opportunity to lead by example, and the chance to assess and examine students exploring science. This is a wonderful experience for all participants.

The role of the teacher in a project-based science activity changes from providing the knowledge to facilitating research. The teacher models the processes expected of the students, makes suggestions on the direction of student research, and encourages students to follow their successes and explain their questions. This offers teachers an opportunity to examine the content of their courses in a different light, and helps students to be independent learners.

Teachers must fully adopt the project-based science concept when carrying out active research with their students. They now facilitate the answering of questions. It is important for teachers to be aware of their students' progress throughout the entire investigation. Jjust by being aware of the current status of each project, teachers can guide the students' research without controlling the topics, methods, or focus questions.

Planning

The initial organization of a project-based science classroom has traditionally been thought of as time consuming and labour intensive; however, once the initial guidelines are established, the process uses time effectively. When properly organized, a project-based activity will run smoothly and achieve its goals for all students, and it will provide a number of opportunities for student assessment. Here are some suggested steps for beginning project-based science in the classroom:

1. *Decide on the type of project.* Project-based learning can address goals for short-term activities such as exploring a specific topic in a unit or a complete unit. It may also be used as a culminating activity to summarize learning in a course. A public presentation is part of the process.
2. *Establish a time line for the project.* No matter what type of project is ongoing, a well-defined and modelled time line for the activity is key to its success. When students are aware of time expectations, they are less likely to fall behind. The teacher project and designated class time are important to help keep all students on task and to ensure that all are progressing in a timely fashion on their individual projects. A checklist can be created to track progress during the project. Some sample time lines can be found at the end of this section.
3. *Organization of the Teacher Project.* The teachers must decide on a project to do as a model for the students. By going step-by-step through a project with the class, a teacher will model the work habits expected of students as well as keep the class on time and on task. Teachers should always be a week, a day, or an hour ahead of students.

4. *Determine the methods of evaluation that will be used.* Project-based science provides many opportunities for the evaluation of student work. By clearly knowing the value of the project in the overall marking scheme, students may be motivated to accept the challenge of a project and work hard to succeed. A clearly designed rubric should be created for updates and activities completed during project assessment, as well as a rubric for the final culminating activity. Some sample rubrics can be found in Appendix I.
5. *Prepare a list of books or websites containing project ideas.* Once the format of a project has been determined, create a list of possible resources that will aid in the beginning stages of a project.
6. *Establish cross-curricular links with other teachers.* Project-based science requires a wide variety of skills. Students will not only be meeting science outcomes through the project process but will also cover English language arts, arts education, mathematics, and other course outcomes. Teacher collaboration in the planning stage of a project will allow for a broad-based assessment of student projects.
7. *Establish mentorship links.* Professional or academic mentorships are a useful tool in long-term research. Arranging for mentors before a project begins will help begin a project and will provide someone to contact if questions come up through the process.
8. *Organize project showcase.* A public celebration of the project is part of this process. Time and space should be allotted to showcase project work. This includes the students' and teachers' work. Booking a time and space well in advance will give a clear target date and give the projects a clear focus for the activity.

Sample Time Lines

The following pages contain some sample documents that you may use to set up project-based science in the classroom. The samples include rubrics, time lines, required math skills, and some available resources to teachers. Some of the examples are content specific and others are generic ones that may be used as guidelines to set up individual investigations.

Section or Topic Project

Section or topic projects are short-term activities designed to quickly investigate a particular subject in a science classroom. This type of project allows students to obtain some background information about a topic before the class completes a full investigation. These activities may be used to introduce a chapter or to summarize a recently completed topic area.

Time line

Four one-hour periods will be set aside to complete the following project.

Unit Project

This is an activity that may address all or part of a unit. The project may be used to cover topics that are more difficult to cover using traditional methods or to provide a variation from traditional science teaching methods.

Time line

Nine class hours will be set aside over the next six weeks to complete and present the following project.

Long-Term Project

A long-term project can address a multitude of science topics. A long-term project requires time and committment from both the teacher and the students and should be valued to reflect its importance. As with any project-based science activity, the teacher should participate by completing a project with the students. This helps the students keep on task and interested in the work and provides the teacher the opportunity to demonstrate skills—such as research methods, experimental design, and data collection—that are not always involved in traditional science teaching.

Time line

One period of each Friday will be set aside for the long-term project science fair project work. In the sixteenth week there will be a public celebration of the projects (Science Night, Open House) and an in-school science fair.

Time line for research

Appendix J: Statistical Analysis for Science Projects

Bibliography

The following resources to support teaching and learning in science are currently available through the Nova Scotia School Book Bureau. The NSSBB number is given in parentheses. For more details, visit the website (https://w3apps.EDnet.ns.ca/nssbb).

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Other Print Resources

The following are resources—currently not listed on the Authorized Learning Resource list—that teachers may wish to access to support their Chemistry 11 and Chemistry 12 curriculum. Where possible, an ISBN number is included to aid in locating a title. Many of the titles are trade books available through Canadian publishers and educational distributors and can more than likely be found in publishers' catalogues.

Council of Atlantic Ministers of Education and Training. *Cross-Curricular Reading Tools* (available through CAMET at camet-camef@cap-cpma.ca).

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Websites

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portal.acs.org/portal/acs/corg/content

Chemical Institute of Canada
cheminst.ca

Chempire: A Kingdom of Chemistry Resources
library.thinkquest.org/28330

International Union of Pure and Applied Chemistry (IUPAC)
iupac.org

United States Environmental Protection Agency: Green Chemistry
epa.gov/greenchemistry