Chemistry 11 and Chemistry 12

Guide

NOVA SCOTIA
NOUVELLE-ÉCOSSE

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Chemistry 11 and Chemistry 12

Prepared by the Department of Education and Early Childhood Development

This is the most recent version of the current curriculum materials as used by teachers in Nova Scotia.

Atlantic Canada Science Curriculum:
Chemistry 11 and Chemistry 12

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Foreword

The pan-Canadian *Common Framework of Science Learning Outcomes K to 12*, released in October 1997, will assist in standardizing science education across the country. New science curriculum for the Atlantic Provinces is described in *Foundation for the Atlantic Canada Science Curriculum* (1998). The Council of Atlantic Ministers of Education and Training (CAMET), formerly the Atlantic Provinces Education Foundation (APEF), developed new science curriculum guidelines for grades 1–10. One of the implications for implementation of the new curriculum is that the Science 10 course is significantly different from the previous Integrated Science 10 course. This change also necessitates an edit of the existing biology, chemistry, and physics guides to bring them into alignment with the new Science 10 course.

Chemistry 11 and Chemistry 12 include the following units: Stoichiometry; From Structures to Properties; Organic Chemistry; Thermochemistry; Solutions, Kinetics, and Equilibrium; Acids and Bases; and Electrochemistry.

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

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Introduction

Background

The curriculum described in *Foundation for the Atlantic Canada Science Curriculum* was planned and developed collaboratively by regional committees. The process for developing the common science curriculum for Atlantic Canada involved regional consultation with the teacher workgroups, student reviewers, education department science, and school boards in the education system in each Atlantic province. The Atlantic Canada science curriculum is consistent with the framework described in the pan-Canadian *Common Framework of Science Learning Outcomes K to 12*.

Aim

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.

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 from a wide repertoire of teaching strategies

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 they engage in, the discourse in which they participate, and the settings in which these activities occur. Students' disposition towards 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.

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 better record, organize, and understand information from a variety of sources. The process of creating webs, maps, charts, tables, graphs, drawings and diagrams to represent data and results helps students learn and 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. It is through opportunities to talk and write about the concepts they need to learn that students come to better understand both the concepts and related vocabulary.

Learners will need explicit instruction in, and demonstration of, the strategies they need 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 need to develop and apply in selecting, constructing, and using various forms of communicating in science.

The Three Processes of Scientific Literacy

An individual can be considered scientifically literate when 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 that will permit students to address their various learning styles.

As well, teachers must not only remain aware of and avoid gender and cultural biasses in their teaching, they must 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 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 provide 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 here.

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.

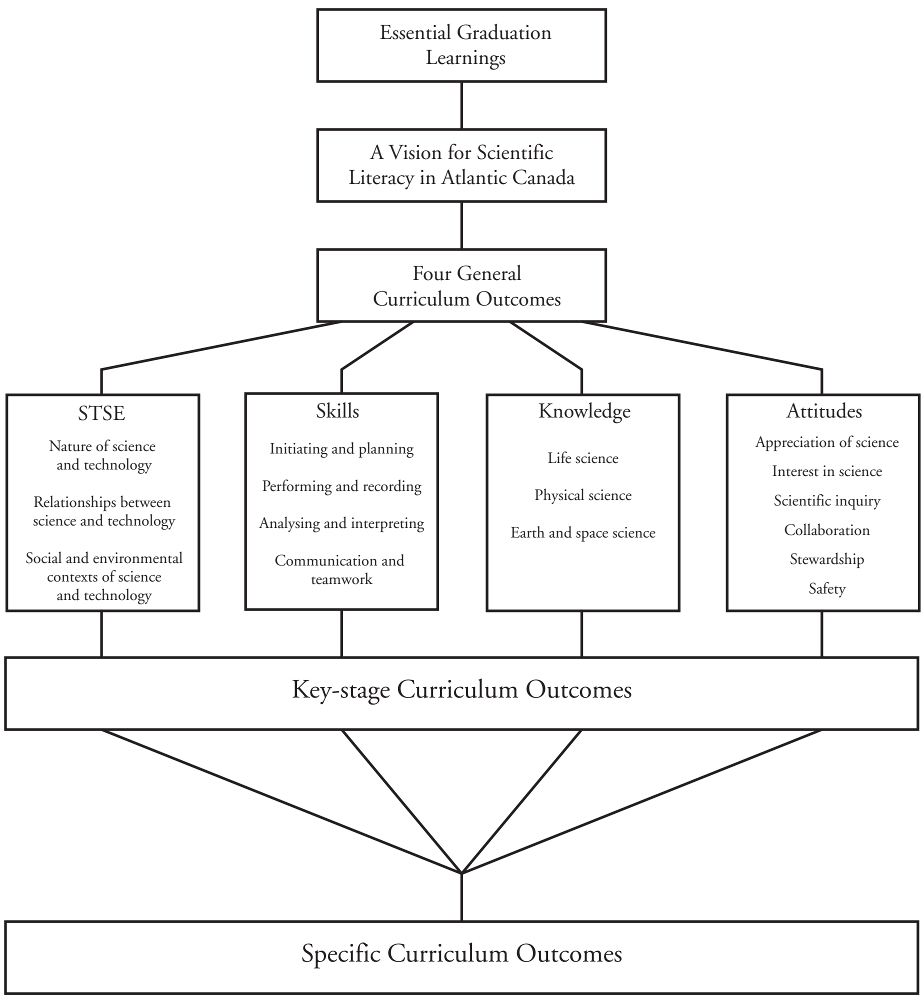
The Atlantic Canada science curriculum reflects the three major processes of science learning: inquiry, problem solving, and decision making. When a teacher assesses student progress, it is helpful to know some activities, skills, and actions that are associated with each process of science learning.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

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*.

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 to 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

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 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 *Foundation for the Atlantic Canada Science Curriculum*.

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. Specific curriculum outcomes represent a framework for helping students achieve the key-stage curriculum outcomes, the general curriculum outcomes, and ultimately the essential graduation learnings.

Specific curriculum outcomes are organized in three units for Chemistry 11 and four units for Chemistry 12. Each unit is organized by topic. Chemistry 11 units and topics follow.

Chemistry 11

Stoichiometry

- The Mole and Molar Mass (10 hours)
- Calculations and Chemical Equations (10 hours)
- Stoichiometric Experimentation (8 hours)
- Applications of Stoichiometry (2 hours)

From Structures to Properties

- Properties of Ionic and Molecular Compounds and Metallic Substances (3 hours)
- Classifying Compounds (4 hours)
- Bonding (5 hours)
- Stuctural Models of Bonding (3 hours)
- Bond Energies (3 hours)
- Polar and Pure Covalent Bonding (3 hours)

Organic Chemistry

- So Many Compounds (1 hour)
- Influences of Organic Compounds on Society (1 hour)
- Classifying Organic Compounds (6 hours)
- Naming and Writing Organic Compounds (6 hours)
- Applications of Organic Chemistry (3 hours)
- Isomers in Organic Chemistry (2 hours)
- Writing and Balancing Chemical Equations (3 hours)
- Polymerization (1 hour)
- Risks and Benefits of Organic Compounds: STSE Perspectives (2 hours)

The following pages outline Chemistry 11 specific curriculum outcomes grouped by units and topics.

Stoichiometry

Students will be expected to

The Mole and Molar Mass

- define molar mass and perform mole-mass inter-conversions for pure substances (323-1)
- explain how a major scientific milestone, the mole, changed chemistry (115-3)

Calculations and Chemical Equations

- identify mole ratios of reactants and products from balanced chemical equations (323-10)
- identify practical problems that involve technology where equations were used (214-13)
- state a prediction and a hypothesis based on available evidence and background information (212-4)
- perform stoichiometric calculations related to chemical equations (323-11)

Stoichiometric Experimentation

- design stoichiometric experiments identifying and controlling major variables (212-3)
- use instruments effectively and accurately for collecting data (213-3)
- identify and explain sources of error and uncertainty in measurement using precision and accuracy (214-10)
- communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others (215-1)
- identify various constraints that result in trade-offs during the development and improvement of technologies (114-4)

Applications of Stoichiometry

- identify various stoichiometric applications (323-12)
- predict how the yield of a particular chemical process can be maximized (323-13)
- explain how data support or refute the hypotheses or prediction of chemical reactions (214-12)
- compare processes used in science with those used in technology (114-7)
- analyse society's influence on science and technology (117-2)

From Structures to Properties

Students will be expected to

Properties of Ionic and Molecular Compounds and Metallic Substances

- select and integrate information from various print and electronic sources or from several parts of the same source (213-7)
- identify and describe the properties of ionic and molecular compounds and metallic substances (321-7)

Classifying Compounds

- classify ionic, molecular, and metallic substances according to their properties (321-9)
- identify consumer products and investigate the claims made by companies about the products (212-5)

Bonding

- illustrate and explain the formation of ionic, covalent, and metallic bonds (321-4)

Structural Models of Bonding

- explain the structural model of a substance in terms of the various bonds that define it (321-11)
- explain how knowledge of bonding evolves as new evidence and theories are tested and subsequently revised or replaced (115-7)
- analyse examples of Canadian contributions to bonding (117-11)
- analyse and describe examples where technologies were developed based on bonding (116-4)
- analyse, from a variety of perspectives, the risks and benefits to society and the environment of applying bonding knowledge or introducing a particular technology (118-2)

Bond Energies

- identify limitations of categorizing bond types based on differences in electronegativity between the elements and compounds (214-2)
- explain the evidence from a bonding experiment and from collected data in the development of bond energies (114-2)
- describe how the different types of bonds account for the properties of ionic and molecular compounds and metallic substances (321-8)

Polar and Pure Covalent Bonding

- illustrate and explain hydrogen bonds and van der Waals' forces (321-5)
- use library and electronic research tools to collect bonding information (213-6)
- select and integrate information from various print and electronic sources or from several parts of the same source (213-7)
- compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, and graphs (214-3)

Organic Chemistry

Students will be expected to

So Many Compounds

- explain the large number and diversity of organic compounds with reference to the unique nature of the carbon atom (319-4)

Influences of Organic Compounds on Society

- explain how synthesizing organic molecules revolutionized thinking in the scientific community (115-3)
- explain how organic chemistry has evolved as new evidence has come to light (115-6)
- identify various constraints that result in trade-offs during the development and improvement of technologies (114-4)
- provide organic chemistry examples of how science and technology are an integral part of their lives and their community (117-5)
- analyse natural and technological systems to interpret and explain the influence of organic compounds on society (116-7)

Classifying Organic Compounds

- classify various organic compounds by determining to which families they belong, based on their names or structures (319-7)

Naming and Writing Organic Compounds

- write the formula and provide the IUPAC name for a variety of organic compounds (319-5)

Applications of Organic Chemistry

- identify limitations of the IUPAC classification system and identify alternative ways of classifying to accommodate anomalies (214-2)
- distinguish between scientific questions and technological problems (115-1)
- select and use apparatus and material safely (213-8)
- provide a statement that describes the relationship between bonding and organic chemistry investigated in light of the link between data and the conclusion (214-11)
- evaluate the design of a technology and the way it functions, on the basis of a variety of criteria that they have identified themselves (118-4)
- identify and apply criteria, including the presence of bias, for evaluating evidence and sources of information on an organic topic (214-9)

Isomers in Organic Chemistry

- define isomers and illustrate the structural formulas for a variety of organic isomers (319-6)

Writing and Balancing Chemical Equations

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

Polymerization

- define problems to facilitate investigation of polymers (212-2)
- design an experiment identifying and controlling major variables (212-3)
- describe processes of polymerization and identify some important natural and synthetic polymers (319-9)

Risks and Benefits of Organic Compounds: STSE Perspectives

- communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others (215-1)
- describe and evaluate the design of technological solutions and the way they function using scientific principles (116-6)
- analyse from a variety of perspectives the risks and benefits to society and the environment of applying organic chemistry knowledge or introducing a particular technology (118-2)
- develop, present, and defend a position or course of action on organic chemistry based on findings (215-5)
- select, integrate, and synthesize information from multiple sources including various print and electronic sources, and make inferences on this information (213-7, 215-3)
- debate the merits of funding specific scientific or technological endeavours and not others (117-4)

Chemistry 12

The following are specific curriculum outcomes organized by topic for Chemistry 12.

Thermochemistry

- Thermochemistry STSE (3 hours)
- Experiments with Energy Changes (7 hours)
- Thermochemistry and Potential Energy (2 hours)
- Bonding and Hess's Law (6 hours)
- Science Decisions Involving Thermochemistry (3 hours)

Solutions, Kinetics, and Equilibrium

- Concentration, Properties, and Solubility (6 hours)
- Solubility and Precipitates (6 hours)
- Kinetics and Rate of Reaction (3 hours)
- Collision Theory, Reaction Mechanisms, and Catalysts (2 hours)
- Equilibrium (2 hours)
- Le Châtelier's Principle and Equilibrium Constant (10 hours)
- Equilibrium Applications (3 hours)

Acids and Bases

- Properties and Definitions of Acids and Bases (3 hours)
- Acid/Base Reactions (3 hours)
- Using the Equilibrium Concept with Acids and Bases (11 hours)
- Indicators and Acids and Bases (2 hours)
- Acid/Base Titrations (5 hours)
- H^+, OH^-, and Le Châtelier (4 hours)

Electrochemistry

- Oxidation and Reduction (2 hours)
- Redox and Half-Reactions (8 hours)
- Electrochemical and Electrolytic Cells (6 hours)
- Redox Reactions with Standard Reduction Potentials (5 hours)
- Energy Efficiency of Cells (3 hours)

The following pages outline Chemistry 12 specific curriculum outcomes grouped by units and topics.

Thermochemistry

Students will be expected to

Thermochemistry STSE

- analyse why scientific and technological activities take place in a variety of individual and group settings (117-6)
- analyse from a variety of perspectives the risks and benefits to society and the environment by applying thermochemistry (118-2)
- distinguish between questions that can be answered using thermochemistry and those that cannot, and between problems that can be solved by technology and those that cannot (118-8)
- compare the molar enthalpies of several combustion reactions involving organic compounds (324-7)
- write and balance chemical equations for combustion reactions of alkanes, including energy amounts (324-1)
- propose courses of action on social issues related to science and technology, taking into account an array of perspectives, including that of sustainability (118-10)

Experiments with Energy Changes

- define endothermic reaction, exothermic reaction, specific heat, enthalpy, bond energy, heat of reaction, and molar enthalpy (324-2)
- calculate and compare the energy involved in changes of state in chemical reactions (324-3)
- design a thermochemistry experiment identifying and controlling major variables (212-3)
- work co-operatively with team members to develop and carry out thermochemistry experiments (215-6)
- evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making (212-8)

- determine experimentally the changes in energy of various chemical reactions (324-6)
- analyse the knowledge and skills acquired in their study of thermochemistry to identify areas of further study related to science and technology (117-9)
- propose alternative solutions to solving energy problems and identify the potential strengths and weaknesses of each (214-15)

Thermochemistry and Potential Energy

- illustrate changes in energy of various chemical reactions, using potential energy diagrams (324-5)
- compile and display evidence and information on heats of formation in a variety of formats, including diagrams, flow charts, tables, and graphs (214-3)

Bonding and Hess's Law

- calculate the changes in energy of various chemical reactions using bond energy, heats of formation, and Hess's Law (324-4)
- apply one of the methods of predicting heats of reactions to your experimentally determined values (214-6)
- analyse and describe examples where technologies were developed based on understanding thermochemistry (116-4)

Science Decisions Involving Thermochemistry

- describe the importance of peer review in the development of their knowledge about thermochemistry (114-5)
- use library and electronic research tools to collect information on a given topic (213-6)
- select and integrate information from various print and electronic sources or from several parts of the same source (213-7)
- identify multiple perspectives that influence a science-related decision or issue involving their thermochemistry project (215-4)

Solutions, Kinetics, and Equilibrium

Students will be expected to

Concentration, Properties, and Solubility

- compile and organize solution data, using appropriate formats and data treatments to facilitate interpretation of solubility (213-5)
- determine the molar solubility of a pure substance in water (323-6)

Solubility and Precipitates

- explain the variations in the solubility of various pure substances, given the same solvent (323-7)
- use the solubility generalizations to predict the formation of precipitates (323-8)
- identify and explain sources of error and uncertainty (214-10)
- identify and describe science- and technology-based careers related to solutions and equilibrium (117-7)

Kinetics and Rate of Reaction

- identify, through experiments and graphing, factors that affect the rate of the reaction (ACC-1)
- implement appropriate sampling procedures (213-1)

Collision Theory, Reaction Mechanisms, and Catalysts

- describe collision theory and its connection to factors involved in altering reaction rates (ACC-2)
- describe a reaction mechanism and catalyst's role in a chemical reaction (ACC-3)

Equilibrium

- compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data (213-5)
- define the concept of equilibrium as it pertains to solutions (323-3)

Le Châtelier's Principle and Equilibrium Constant

- explain how different factors affect solubility, using the concept of equilibrium (323-5)
- develop appropriate sampling procedures for equilibrium expressions (212-9)
- explain solubility, using the concept of equilibrium (323-4)

Equilibrium Applications

- analyse and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology (116-2)
- analyse and describe examples where technologies were developed based on scientific understanding (116-4)

Acids and Bases

Students will be expected to

Properties and Definitions of Acids and Bases

- 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)
- explain how acid-base theory evolves as new evidence and laws and theories are tested and revised, or replaced (115-7)
- explain the roles of evidence, theories, and paradigms in acid-base theories (114-2)

Acid/Base Reactions

- predict products of acid-base reactions (320-2)
- identify new questions or problems that arise from what was learned (214-17)
- explain the importance of communicating the results of acid-base reactions using appropriate language and conventions (114-9)

Using the Equilibrium Concept with Acids and Bases

- identify a line of best fit on a scatter plot and interpolate or extrapolate based on the line of best fit (214-4)
- select and use apparatus and materials safely (213-8)
- demonstrate a knowledge of WHMIS standards by selecting proper techniques for handling and disposing of materials (213-9)
- state a prediction and a hypothesis based on available evidence and background information (212-4)
- compare strong and weak acids and bases using the concept of equilibrium (320-3)
- calculate the pH of an acid or a base given its concentration, and vice versa (320-4)

Indicators and Acids and Bases

- explain how acid-base indicators function (320-7)
- analyse and describe examples where acid-base understanding was enhanced as a result of using titration curves (116-2)

Acid/Base Titrations

- determine the concentration of an acid or base solution using stoichiometry (320-6)
- use instruments effectively and accurately for collecting titration data (213-3)
- interpret patterns and trends in data, and infer or calculate relationships among variables from titration data (214-5)
- work co-operatively with team members to develop and carry out a plan for a titration experiment, and troubleshoot problems as they arise (215-6)
- evaluate and select appropriate instruments for collecting evidence and appropriate processes for titrations (212-8)
- select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, titrations, and results (215-2)

H^+, OH^-, and Le Châtelier

- describe the interactions between H^+ ions and OH^- ions using Le Châtelier's principle (320-5)
- analyse society's influence on acid and base scientific and technological endeavours (117-2)
- construct arguments to support a decision using examples and evidence and recognizing various perspectives (118-6)
- identify and describe science- and technology-based careers related to acids and bases (117-7)

Electrochemistry

Students will be expected to

Oxidation and Reduction

- identify questions to investigate that arise from practical problems and issues on redox (212-1)
- distinguish between scientific questions and technological problems (115-1)
- define oxidation and reduction experimentally and theoretically (322-1)

Redox and Half-Reactions

- compare oxidation-reduction reactions with other kinds of reactions (322-3)
- write and balance half-reactions and net reactions (322-2)

Electrochemical and Electrolytic Cells

- describe and evaluate the design of chemical cells and the way they function, including the technological and scientific principles (116-6)
- define problems regarding experimental designs for cells and evaluate the processes used in problem solving and decision making (215-7, 212-2)
- illustrate and label the parts of electrochemical and electrolytic cells and explain how they work (322-4)
- select and use apparatus and materials safely for electrochemistry experiments (213-8)
- evaluate a personally designed and constructed cell on the basis of criteria they have developed themselves (214-16)
- design an experiment identifying and controlling major variables (212-3)
- formulate operational definitions of major variables (212-7)

Redox Reactions with Standard Reduction Potentials

- predict whether oxidation-reduction reactions are spontaneous based on their reduction potentials (322-5)
- predict the voltage of various electrochemical cells (322-6)
- compare theoretical and experimental reduction potential values and account for discrepancies (214-7)
- evaluate the reliability of data and data collection methods involving reduction potentials (214-8)

Energy Efficiency of Cells

- compare electrochemical and electrolytic cells in terms of energy efficiency, electron flow/transfer, and chemical change (322-7)
- explain the processes of electrolysis and electroplating (322-8)
- evaluate the design of a technology and the way it functions on the basis of a variety of criteria that they have identified themselves (118-4)

- explain how electrical energy is produced in a hydrogen fuel cell (322-9)
- analyse natural and technological systems to interpret and explain their structure and dynamics (116-7)
- identify and evaluate potential applications of findings (214-18)

Attitude 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 sections 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 a 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,* • conduct research to answer 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 among 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 conduct research to confirm and extend their understanding • 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 opinions 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 or evidence

Key-Stage Curriculum Outcomes: Attitudes *(continued)*

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

Collaboration	Stewardship	Safety in Science
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 • give 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 diverse 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 • contribute to 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 social and political systems that influence environmental policy in their community • recognize and examine 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

Curriculum Guide Organization

Specific curriculum outcomes are organized in units for each grade level. Each unit is organized by topic. Suggestions for learning, teaching, assessment, and resources are provided to support student achievement of the outcomes.

The order in which the units of a grade appear in the guide is meant to suggest a sequence. In some cases, the rationale for the recommended sequence is related to the conceptual flow across the year. That is, one unit might introduce a concept that is then extended in a subsequent unit. Likewise, one unit might focus on a skill or context that will be built upon later in the year.

Some units or certain aspects of units may also be combined or integrated. This is one way of assisting students as they attempt to make connections across topics in science or between science and the real world. In some cases, a unit might require an extended time frame to collect data on weather patterns, plant growth, etc. These cases could warrant starting the activity early and overlapping it with the existing unit. In all cases, the intent is to provide opportunities for students to deal with science concepts and scientific issues in personally meaningful and socially and culturally relevant contexts.

Unit Organization

Each unit begins with a two- or three-page synopsis. On the first page, introductory paragraphs provide a unit overview. These are followed by a section that specifies the focus (inquiry, problem solving, decision making) and possible contexts for the unit. Finally, a paragraph or two of curriculum links specify how this unit relates to science concepts and skills addressed in other grades so teachers will understand how the unit fits with the students' progress through the complete science program.

The second and subsequent pages of the overview provide a table of the outcomes from the *Common Framework of Science Learning Outcomes K to 12* that the unit will address. The numbering system used is the one in the pan-Canadian document as follows:

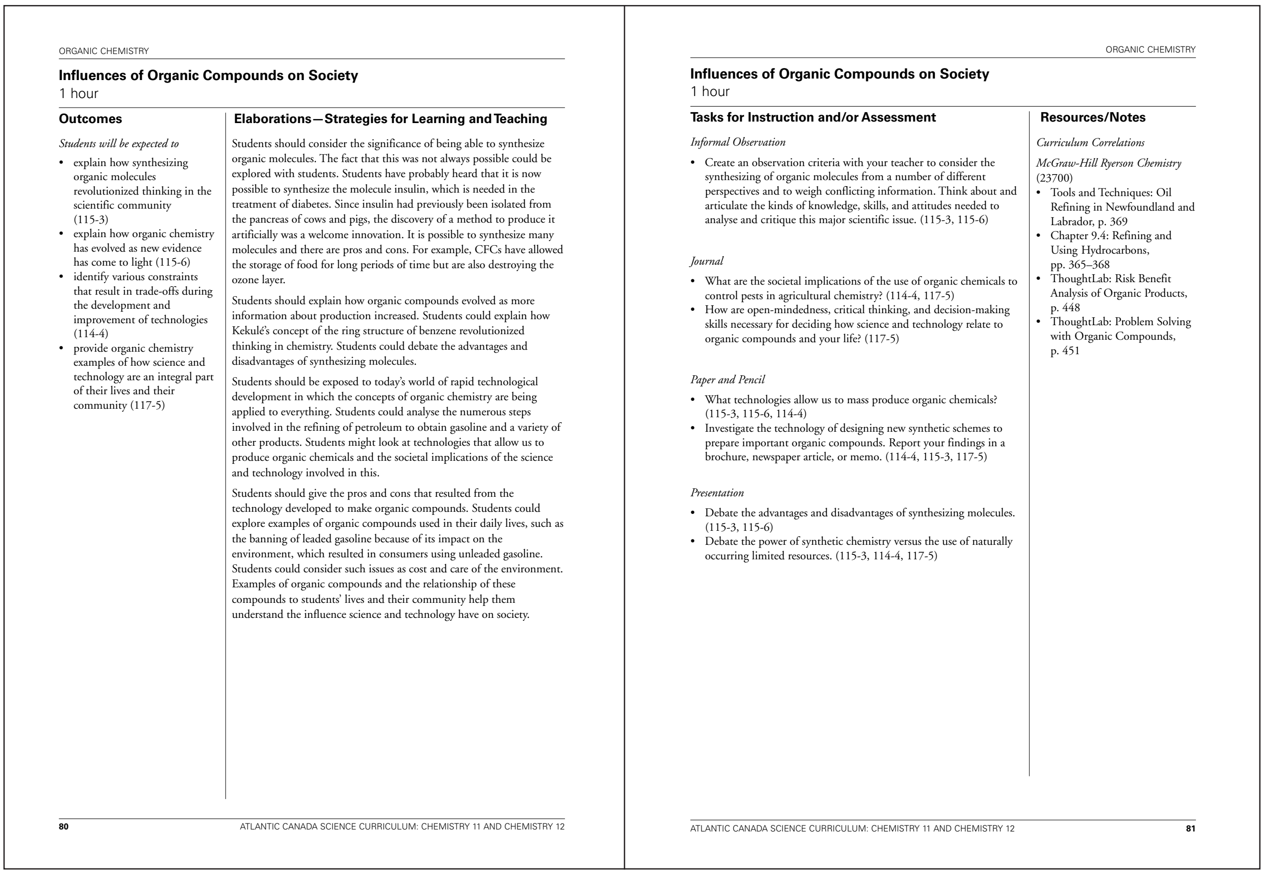
- 100s—Science, Technology, Society, and the Environment (STSE) outcomes
- 200s—Skills outcomes
- 300s—Knowledge outcomes
- 400s—Attitude outcomes (see pages 23–25)
- ACCs—Atlantic Canada Chemistry outcomes

These code numbers appear in parentheses after each specific curriculum outcome (SCO).

The Four-Column Spread

Each unit has a two-page layout of four columns as illustrated below. In some cases, the four-column spread continues to the next two-page layout. Outcomes are grouped by the topic indicated at the top of the left page.

Two-Page, Four-Column Spread



ORGANIC CHEMISTRY

Influences of Organic Compounds on Society
1 hour

Outcomes

Students will be expected to

- explain how synthesizing organic molecules revolutionized thinking in the scientific community (115-3)
- explain how organic chemistry has evolved as new evidence has come to light (115-6)
- identify various constraints that result in trade-offs during the development and improvement of technologies (114-4)
- provide organic chemistry examples of how science and technology are an integral part of their lives and their community (117-5)

Elaborations—Strategies for Learning and Teaching

Students should consider the significance of being able to synthesize organic molecules. The fact that this was not always possible could be explored with students. Students have probably heard that it is now possible to synthesize the molecule insulin, which is needed in the treatment of diabetes. Since insulin had previously been isolated from the pancreas of cows and pigs, the discovery of a method to produce it artificially was a welcome innovation. It is possible to synthesize many molecules and there are pros and cons. For example, CFCs have allowed the storage of food for long periods of time but are also destroying the ozone layer.

Students should explain how organic compounds evolved as more information about production increased. Students could explain how Kekulé's concept of the ring structure of benzene revolutionized thinking in chemistry. Students could debate the advantages and disadvantages of synthesizing molecules.

Students should be exposed to today's world of rapid technological development in which the concepts of organic chemistry are being applied to everything. Students could analyse the numerous steps involved in the refining of petroleum to obtain gasoline and a variety of other products. Students might look at technologies that allow us to produce organic chemicals and the societal implications of the science and technology involved in this.

Students should give the pros and cons that resulted from the technology developed to make organic compounds. Students could explore examples of organic compounds used in their daily lives, such as the banning of leaded gasoline because of its impact on the environment, which resulted in consumers using unleaded gasoline. Students could consider such issues as cost and care of the environment. Examples of organic compounds and the relationship of these compounds to students' lives and their community help them understand the influence science and technology have on society.

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ORGANIC CHEMISTRY

Influences of Organic Compounds on Society
1 hour

Tasks for Instruction and/or Assessment

Informal Observation

- Create an observation criteria with your teacher to consider the synthesizing of organic molecules from a number of different perspectives and to weigh conflicting information. Think about and articulate the kinds of knowledge, skills, and attitudes needed to analyse and critique this major scientific issue. (115-3, 115-6)

Journal

- What are the societal implications of the use of organic chemicals to control pests in agricultural chemistry? (114-4, 117-5)
- How are open-mindedness, critical thinking, and decision-making skills necessary for deciding how science and technology relate to organic compounds and your life? (117-5)

Paper and Pencil

- What technologies allow us to mass produce organic chemicals? (115-3, 115-6, 114-4)
- Investigate the technology of designing new synthetic schemes to prepare important organic compounds. Report your findings in a brochure, newspaper article, or memo. (114-4, 115-3, 117-5)

Presentation

- Debate the advantages and disadvantages of synthesizing molecules. (115-3, 115-6)
- Debate the power of synthetic chemistry versus the use of naturally occurring limited resources. (115-3, 114-4, 117-5)

Resources/Notes

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Tools and Techniques: Oil Refining in Newfoundland and Labrador, p. 369
- Chapter 9.4: Refining and Using Hydrocarbons, pp. 365–368
- ThoughtLab: Risk Benefit Analysis of Organic Products, p. 448
- ThoughtLab: Problem Solving with Organic Compounds, p. 451

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Column One: Outcomes

The first column provides the specific curriculum outcomes. These are based on the pan-Canadian *Common Framework of Science Learning Outcomes K to 12*. The statements involve the Science, Technology, Society, and the Environment (STSE), skills, and knowledge outcomes indicated by the outcome number(s) that appears in parentheses after the outcome. Some STSE and skills outcomes have been written in a context that shows how these outcomes should be addressed.

Specific curriculum outcomes have been grouped by topic. Other groupings of outcomes are possible and in some cases may be necessary to take advantage of local situations. The grouping of outcomes provides a suggested teaching sequence. Teachers may prefer to plan their own teaching sequence to meet the learning needs of their students.

Columns one and two define what students are expected to learn and be able to do.

Column Two: Elaborations—Strategies for Learning and Teaching

The second column might include elaborations of outcomes listed in column one, and it describes learning environments and experiences that will support students' learning.

The strategies in this column are intended to provide a holistic approach to instruction. In some cases, they address a single outcome; in other cases, they address a group of outcomes.

Column Three: Tasks for Instruction and/or Assessment

The third column provides suggestions for ways that students' achievement of the outcomes could be assessed. These suggestions reflect a variety of assessment techniques and materials that include, but are not limited to, informal/formal observation, performance, journal, interview, paper and pencil, presentation, and portfolio. Some assessment tasks may be used to assess student learning in relation to a single outcome, others to assess student learning in relation to several outcomes. The assessment item identifies the outcome(s) addressed by the outcome number in parentheses after the item.

Column Four: Resources/Notes

This column provides an opportunity for teachers to make note of useful resources.

Chemistry 11 Outcomes

Stoichiometry

Introduction

Chemistry is a qualitative and quantitative science. Students have generally been studying chemistry in a qualitative sense. In this introduction to the quantitative aspect of chemistry, students will examine stoichiometry. Stoichiometry is the mole-to-mole relationship in a balanced chemical equation.

When studying reactions, students need opportunities to investigate the usefulness of the reactions. This unit provides the opportunity to apply chemical principles to everyday life and industry. The corresponding calculations provide the tools to investigate and support the students' responses.

Experiments are compulsaory in Chemistry 11 and students should have foty percent of their time in hands-on, minds-on exploration. Specific curriculum outcomes state which experiments should be done.

Focus and Context

This unit focusses on problem solving and decision making. One way to introduce this unit is to begin with a contextualized problem requiring students to learn the chemistry to solve the problem and make decisions. The unit begins with an introduction to the concept of moles, Avogadro's number, and molar mass.

Stoichiometry introduces the problem-solving aspect of this course, providing students with the opportunity to develop skills in single problem solving (finding molar mass) and multi-level problem solving (percent yield).

This unit should focus on both the laboratory exercises and mathematical calculations as well as research on commercial production of compounds used by society. Chemicals in commercial or industrial environments are a context used through stoichiometry.

Science Curriculum Links

In grade 10, students began naming and writing formulas for ionic and molecular compounds and balancing equations and types of reactions. In grade 12, stoichiometry is used in solutions, acids and bases, and redox chemistry.

The stoichiometry unit provides the quantitative foundations for the remainder of high school chemistry.

Curriculum Outcomes

STSE	Skills	Knowledge
Students will be expected to	*Students will be expected to*	*Students will be expected to*
114-4 identify various constraints that result in trade-offs during the development and improvement of technologies	**212-3** design stoichiometric experiments identifying and controlling major variables	**323-1** define molar mass and perform mole-mass inter-conversions for pure substances
114-7 compare processes used in science with those used in technology	**212-4** state a prediction and a hypothesis based on available evidence and background information	**323-10** identify mole ratios of reactants and products from balanced chemical equations
115-3 explain how a major scientific milestone, the mole, changed chemistry	**213-3** use instruments effectively and accurately for collecting data	**323-11** perform stoichiometric calculations related to chemical equations
117-2 analyse society's influence on science and technology	**214-10** identify and explain sources of error and uncertainty in measurement using precision and accuracy	**323-12** identify various stoichiometric applications
	214-12 explain how data support or refute the hypotheses or prediction of chemical reactions	**323-13** predict how the yield of a particular chemical process can be maximized
	214-13 identify practical problems that involve technology where equations were used	
	215-1 communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others	

The Mole and Molar Mass

10 hours

Outcomes

Students will be expected to

- define molar mass and perform mole-mass inter-conversions for pure substances (323-1)

Elaborations—Strategies for Learning and Teaching

Students should explain the relative nature of atomic mass. Students should identify the unit for counting atoms, ions, or molecules as the mole. The mole should be defined as the number of atoms in exactly 12 g of carbon-12. Throughout this stoichiometry unit, teachers might wish to look at chemicals and chemical reactions that are used in commercial or industrial environments.

Teachers might begin this unit by having students write individual lists of the things they know about how atoms are counted and how their masses are measured. A useful question is "If you know the mass of a dozen identical items, how could you find the mass of one of the items without measuring it directly?" After discussion, students might consider the question "How can chemists count atoms by using a balance?" An activity to visualize the relationships among counting units, such as dozens; counting individual items within a unit; and finding the mass of both would help students consolidate their experiences with their new knowledge. An experiment counting identical items such as beans, peas, or rice, can be performed. Teachers should explain to students that models do not necessarily perfectly illustrate any given system. Some students see all the peas or grains of rice as each being different and therefore do not get the concept of the atom that the exercise is meant to portray.

One mole of sample elements and compounds that are visible in sealed containers could be displayed so that students see the volume associated with molar mass of elements and compounds.

From the following table, students should see that 6.02×10^{23} is common in each case and is a quantity that represents the number of particles in a sample of a given substance. The new unit created is called the mole (mol), which is defined as the number of atoms in exactly 12 g of carbon-12. Elemental carbon comprises several isotopes, causing its average atomic mass to slightly exceed the exactly 12 g of carbon-12.

Avogadro's Number, 6.02×10^{23}

	Element	**Ionic Compound**	**Molecular Compound**
name	carbon, C	sodium chloride, NaCl	water, H_2O
mass	12.01 g	58.44 g	18.02 g
number	6.02×10^{23} atoms	6.02×10^{23} formula units of NaCl 6.02×10^{23} Na^+ ions 6.02×10^{23} Cl^- ions	6.02×10^{23} molecules of H_2O 6.02×10^{23} O atoms $2(6.02 \times 10^{23})$ H atoms

The Mole and Molar Mass

10 hours

Tasks for Instruction and/or Assessment

Informal Observation

- Look at your partner's solutions to your problems to see if the following are included: proper use of symbols, inclusion of all units in each step, logical sequence of steps, and completed answer. (323-1)

Performance

- Conduct an experiment/activity to count bean particles and find the mass of one. Other particles that might be used are peas or rice.(323-1)

Paper and Pencil

- Prepare a KWL chart on atoms. Fill in the chart with your information about atoms and their mass. (323-1)

KWL Chart

What I know:

____

____

What I want to know:

____

____

What I learned:

____

____

Resources/Notes

Experiments

Chemistry 11 and Chemistry 12: A Teaching Resource

- Activity 1: Atomic Mass—Beans, Peas, and Rice
- Activity 2: Analysis of a Hydrate
- Activity 13: Determining Atomic Mass, Molecular Mass, Formula Mass, and Molar Mass

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Chapter 2.1: Isotopes and Average Atomic Mass, pp. 43–46
- Chapter 2.2: The Avagadro Constant and the Mole, pp. 47–54
- ThoughtLab: The Magnitude of 6.02×10^{23}, p. 50

The Mole and Molar Mass *(continued)*

Outcomes

Students will be expected to

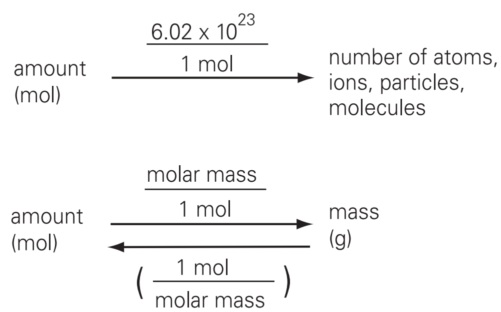
- define molar mass and perform mole-mass inter-conversions for pure substances (323-1)

Elaborations—Strategies for Learning and Teaching

For enrichment, teachers might address the statement “List the reasons that explain why relative atomic masses are not exact whole numbers.” Teachers might use the particles of atoms and their relative masses and the mass of a mixture of isotopes to illustrate atomic mass units (amu) and their relationships to grams. Students could calculate the average atomic mass of an element from data for each of its isotopes. Teachers might ask the class how they would calculate the average mass of students in the classroom.

Students should define molar mass of an element and compound. Students should solve a variety of problems by performing calculations relating the number of particles, moles, and mass of various substances.

Teachers might use learning-centre activities for students to learn or review information on naming and writing chemical formulas. Students could associate the formula with its molar mass. Students could use various problem-solving techniques that involve mole-mass conversions. The conversion factor or the factor-label method are examples of techniques that might be used.



Teachers might look at students’ work involving calculations for the correct use of units and the organization and planning of responses. Significant figures are addressed in grade 10 mathematics. Time should be spent on understanding problem solving as opposed to time on significant figure rules.

Students could convert a substance from moles to mass and then trade their answers with other students who will convert from mass to moles. This co-operative learning will help students communicate the process of conversions using moles and masses of elements and compounds. Teachers might use interesting compounds— such as glucose, vinegar, ascorbic acid, propane, and vitamins—for mole–mass conversions,

The Mole and Molar Mass *(continued)*

Tasks for Instruction and/or Assessment

Journal

- What do all the following have in common: dozen, gross, seconds, and mole? What amount does each of these represent? (323-1)
- Design a problem to convert a mass of a substance to moles or to atoms and trade with a friend to solve. Discuss the problem-solving strategy you used to solve your friend's problem in your journal. (323-1)

Paper and Pencil

- Calculate the mass of two moles of hydrogen gas. (Hint: Diatomic molecules can be remembered by various mnemonics such as: 7Up, HOBrFINCl, HOFBrINCl, HON Hal) (323-1)
- Calculate how many moles are in 80.0 g of ammonium nitrate. (323-1)
- Calculate how many molecules are in 5.0 mol of water. (323-1)
- Calculate how many grams are in 1.2×10^{24} molecules of CH_3COOH. (323-1)
- Calculate the average atomic mass of oxygen. Oxygen has three naturally occurring isotopes: oxygen-16, with a mass of 15.99 amu; oxygen-17, with a mass of 17.00 amu; and oxygen-18, with a mass of 18.00 amu. The relative abundances are 99.76%, 0.038%, and 0.20%, respectively. (323-1)
- How is a mole defined? How is molar mass defined? (323-1)
- Laura has one mole of NaCl, one mole of $K_2Cr_2O_7$, and 6.02×10^{23} molecules, or one mole, of $C_6H_{12}O_6$. What aspect(s) of each sample is not equal? (323-1)

Resources/Notes

Learning Center Review Stations

- Significant Figures Rules (see Appendix B: Reference Information)

Curriculum Correlation

- *McGraw-Hill Ryerson Chemistry* (23700), Chapter 2.3: Molar Mass, pp. 55–65

Videos

- *Matter: Form and Substance in the Universe* (23380)
- *The Mole Concept* (23523)

The Mole and Molar Mass *(continued)*

Outcomes

Students will be expected to

- define molar mass and perform mole-mass inter-conversions for pure substances (323-1)
- explain how a major scientific milestone, the mole, changed chemistry (115-3)

Elaborations—Strategies for Learning and Teaching

Students should calculate the percent composition from a compound's formula. Students should calculate empirical and molecular formulas.

For percent composition, students could use everyday substances whose formulas they have looked up in the *CRC Handbook of Chemistry and Physics* or *The Merck Index*. Such examples as household chemicals, vitamins, drugs, nitrogen in fertilizers, and steroids might be interesting. One student could choose a formula and find the percent composition, which could be given to another student to find the empirical formula and thus arrive back at the original formula. Students could see that a compound cannot be identified by only its empirical formula. To determine the molecular formula, molar mass information is needed and questions could be solved involving this. Teachers might check students' work for appropriate choice of compounds, clear layout of the question, and correct molar masses and units.

Students should perform lab experiments to determine the empirical formula of a hydrate or an oxide. A standard procedure might be used here for empirical formulas. Another approach might have students calculate, based on their measurements and calculations, which hydrate they have from a choice of hydrates. Appropriate safety equipment should be worn at all times. See *Science Safety Guidelines* for more information. Students might need demonstrations and information on safety for these experiments.

Teachers might have students write a safety quiz, watch a safety video, or present safety simulations to demonstrate their knowledge of safety procedures that should be followed in the lab. Students' knowledge and attitudes about lab safety will be reflected in their behaviour during the activity.

Students should discuss the mole and its influence on chemistry with reference to commercial or industrial production. The impact of the mole, based on a standard, carbon-12, might be an interesting discussion for students because of its effect on production of chemicals for society. Chemistry has changed from hit and miss calculations for a product to exact amounts being calculated for an industrial product.

Avogadro's number, 6.02×10^{23}, might be celebrated on the 10^{th} month, 23^{rd} day, from 6:02 a.m. to 6:02 p.m. This celebration, Mole Day, has been around for years. Students could check the National Mole Day Foundation, Inc. website (www.moleday.org). Students might develop problems or activities based on the mole, molar mass, and mole–mass inter-conversions for pure substances. For students' interest, the number is named after Avogadro but it was Perrin's work on Brownian movement that connects the number and the mole.

The Mole and Molar Mass *(continued)*

Tasks for Instruction and/or Assessment

Paper and Pencil

- Celebrate Mole Day. Develop a Mole Day activity. Present your activity to the class in a variety of formats, such as a scavenger hunt, games, puzzles, songs, artwork, or poems. (323-1, 115-3)

Performance/Presentation

- Your teacher will give you a card with one of the following formulas on it:

Sample Hydrates

$NaCH_3COO \bullet 3H_2O$	$MgSO_4 \bullet 7H_2O$
$MgCl_2 \bullet 6H_2O$	$LiC_2H_3O_2 \bullet 2H_2O$

The question to answer is "What percentage of water is contained in your compound?" Determine the percentage of water by mass in the hydrated salt described by the formula. Explain the steps you would take to dry the salt completely. Do the experiment. (323-1)

Presentation

- Research, through print and electronic sources, some methods chemists initially used to arrive at Avogadro's number. Then compare these methods with modern methods. How have methods used in science changed or improved to help with information? (115-3)
- Research an element noting, its industrial uses, and present a time line of the information. Silicon and semiconductors might be a good example to show how scientific thinking has helped society. (115-3)
- Write a newspaper article about a famous chemist and his or her times. (115-3)
- Design a futures wheel or use Inspiration for one of the following (see Appendix C for futures wheel example and template):
  - What if carbon did not exist?
  - What if sodium chloride did not exist?
  - What if Teflon, or polytetrafluroethylene (PTFE), or Gortex did not exist? (323-1, 115-3)

Resources/Notes

Experiment

Chemistry 11 and Chemistry 12: A Teaching Resource

- Activity 14: Mole Conversions

Print Resources

- *CRC Handbook of Chemistry and Physics* (Hint: the older editions are best because these start with inorganic compounds)
- *The Merck Index*
- Chemistry Data Booklet (from Nova Scotia exams)
- *Science Safety Guidelines, Grades Primary–12* (2005)

Video

- *Lab Sense: Lab Safety for Science Students* (V1714, 21793)

Internet

- National Mole Day Foundation, Inc. website (www.moleday.org)

Curriculum Correlation

- *McGraw-Hill Ryerson Chemistry* (23700), Chapter 3: Chemical Proportions in Compounds, pp. 79–106

Calculations and Chemical Equations
10 hours

Outcomes

Students will be expected to

- identify mole ratios of reactants and products from balanced chemical equations (323-10)

Elaborations—Strategies for Learning and Teaching

Students should identify the mole ratios of reactants and products in a chemical reaction to the coefficients in a balanced equation through experiments and calculations. Students should do calculations using mole-to-mole stoichiometric problems. Students should state and use the Law of Conservation of Mass.

Teachers might use this opportunity for students to look at various types of chemical equations, balance them, and compare masses and mole ratios. This might be done through worksheets, chemical models, or balancing games. This will allow students to practise the mole ratio while they refresh their memories about equations. Students could read chemical equations to identify the conditions of the chemical reaction, the information about the reactants and products, and the number of molecules or moles involved. Students might use a chart to organize the information and to check the total mass of reactants and of products.

Balanced Chemical Equation Information: Air Bag Inflation Reaction

equation	$2NaN_3(s)$	$\rightarrow 2Na(s) + 3N_2(g)$
molar mass (g/mol)		$\rightarrow$
mass (g)		$\rightarrow$
moles	2	$\rightarrow$ 2 + 3
total mass (g)		$\rightarrow$
words	2 moles of solid sodium azide decompose to 2 moles of solid sodium plus 3 moles of nitrogen gas	

Students might increase or decrease the number of moles of substances in an equation and check to see that the ratio stays the same. They could check the Law of Conservation of Mass. They might ask why a small amount of NaN_3 gives a large amount of gas. This solid-to-gas reaction further illustrates differences in molar volumes associated with molar mass.

Multiples of Moles of Air Bag

$2NaN_3(s)$		$2Na(s)$	+	$3N_2(g)$
2	$\rightarrow$	2	+	3
6	$\rightarrow$	6	+	9
10	$\rightarrow$	10	+	15

Calculations and Chemical Equations

10 hours

Tasks for Instruction and/or Assessment

Informal Observation

- Look for evidence in the problem solutions of variables identified, answers in correct units, logical sequence of steps, information needed to be collected elsewhere, and completed solutions to word problems. (323-10)

Paper and Pencil

- What information does the following balanced chemical equation provide about the cellular respiration equation:

  $C_6H_{12}O_6(aq) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l) + heat$

  (323-10)
- For each of the following equations
  - balance the equation
  - compare the mass of reactants to the mass of products
  - write the equation in words (323-10)

  $NaCl(aq) + AgNO_3(aq) \rightarrow NaNO_3(aq) + AgCl(s)$

  $H_2(g) + N_2(g) \rightarrow NH_3(g)$

  $Pb(NO_3)_2(aq) + Al_2(SO_4)_3(aq) \rightarrow PbSO_4(s) + Al(NO_2)_3(aq)$

  $NaOH(aq) + H_3PO_4(aq) \rightarrow Na_3PO_4(aq) + H_2O(l)$

  $C_3H_8(g) + O_2(g) \rightarrow CO_2(g) + H_2O(l) + heat$

Resources/Notes

Curriculum Correlation

- *McGraw-Hill Ryerson Chemistry* (23700), Chapter 4.1: Introducing Stoichiometry, pp. 111–126

Calculations and Chemical Equations *(continued)*

Outcomes

Students will be expected to

- identify mole ratios of reactants and products from balanced chemical equations (323-10)
- identify practical problems that involve technology where equations were used (214-13)
- state a prediction and a hypothesis based on available evidence and background information (212-4)

Elaborations—Strategies for Learning and Teaching

Students should calculate mole-to-mole gravimetric stoichiometric problems by doing an experiment to show the ratio of reactants to products. The equation using limestone, $CaCO_3(s)$, yielding quicklime, $CaO(s)$, and carbon dioxide, $CO_2(g)$, or the equation using anhydrous Na_2CO_3 plus $HCl(aq)$ could be used. The reaction between antacid tablets and stomach acid might be used in the lab as a relevant example for students:

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(s) + H_2O(l) + CO_2(g)$$

antacid + stomach acid → a salt + water + carbon dioxide

calcium carbonate + hydrochloric acid → calcium carbonate + water + carbon dioxide

Appropriate safety equipment should be worn at all times. See *Science Safety Guidelines* for more information. Students might need demonstrations and information on safety for these experiments.

Students could look at industrial processes that solved practical problems. Students should discuss a prediction and a hypothesis based on collected information about the process. For example, students could discuss any excess mass making lime from limestone, sulfuric acid from sulfur, ammonia from its constituent elements (Haber process), and ethanol from sugars or ethene. Removing CO_2 from a spacecraft could be another example.

Students might look at different equations that produce the same product for an industrial application. Students might predict which equation would be the best to use to produce a certain product(s). Students, in groups, might collect information about the reactants and products for the various equations and decide which equation would be the most cost efficient to use (evidence might include the availability of materials, the cost of production, and the demand for the products). Some students might favour the equation, with evidence, that makes the most money. Others might look at health or safety as a goal. Information about a chemical process in an industrial/technological application connects chemistry to their lives. It describes how industries use stoichiometric principles in their day-to-day functions. Teachers could demonstrate the slaking of lime,

$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s)$ + heat.

Other examples include synthesizing of esters for flavouring, bubble gum, $RCOOH + R^1OH \rightarrow RCOOR^1 + H_2O$, or removing CO_2 in a spacecraft using the equation

$CO_2(g) + 2LiOH(s) \rightarrow Li_2CO_3(s) + H_2O(l)$.

Interesting compounds, such as esters used in flavouring foods, might be introduced to the students here.

Calculations and Chemical Equations *(continued)*

Tasks for Instruction and/or Assessment

Journal

- What is the difficulty in using a calculator for mass-mass problems? (323-10)
- What is the reasoning that does not allow you just to convert grams to grams when doing stoichiometric problems? In other words, why do you first convert to moles? (323-10)

Performance/Presentation

- Using a memo format to your Senior Director of Research, present your findings about the industrial experiment that you researched. (212-4, 214-13)
- Plan a lab on the relationships of reactants and products in a chemical reaction. Show your plan to your teacher. If approved, do the experiment. Present your findings with a purpose, data chart, and analysis. Make a general statement about the relationship of the mole in a chemical reaction. (323-10, 212-4, 214-13)

Resources/Notes

Curriculum Correlation

- *McGraw-Hill Ryerson Chemistry* (23700), Chapter 4.1: Introducing Stoichiometry, pp. 111–126

Appendix D: Memo Format

Print Resource

- *Science Safety Guidelines, Grades Primary–12* (2005)

Video

- *The Reactivity of Elements* (23564)

Calculations and Chemical Equations *(continued)*

Outcomes

Students will be expected to

- perform stoichiometric calculations related to chemical equations (323-11)

Elaborations—Strategies for Learning and Teaching

Students should perform mole-to-mass, mass-to-mole, and mass-to-mass stoichiometric calculations. Students should perform experiments and perform calculations involving theoretical, actual, and percent yield. Students should perform calculations involving limiting species in chemical reactions.

Teachers might use strategies to help students organize their calculations: the mole triangle, the mole highway, the mole heart, g of X to mol of X, mol of Y to g of Y, or combining steps. Students could use the factor-label method, or dimensional analysis. They could set up several problems without doing the calculations to practise with numbers and units. Students could work in groups to practise their problems and calculations. This would help them develop their problem-solving strategies. Students should predict stoichiometric results before doing the calculations.

Students should define theoretical, actual, and percent yield based on an experiment. They could use a 2.0 g sample of magnesium ribbon reacting with hydrochloric acid. Following the reaction, the mass of magnesium chloride produced can be found. Students could calculate the percent yield for this reaction.

Students could use a chart to show variations in the amounts of reactants and the effect on the yields and the difference between a theoretical and actual yield. Actual yield might be done in the lab with groups of students testing different amounts of reactants. Students could use their industrial example to predict or test for purity and cost effectiveness. A possible example is methanol, CH_3OH, produced from CO and H_2, with a catalyst, giving an 80% yield.

Students might design their own industrial experiments to identify the limiting species in chemical reactions. Such planning can show students connections between chemistry and industry. By varying the amount of one reactant while the other is constant, students could calculate the effect on the product yield. Students could perform stoichiometric calculations to show the limiting reagent, the amount of excess remaining, and the conservation of mass in a chemical change. For example, tin(II) fluoride is added to some dental products to help prevent cavities. A question in an experimental design could be, What mass of tin(II) fluoride can be made from 100.0 g of hydrofluoric acid, HF, if there is excess tin? This is a paper-and-pencil activity only.

Students should explain quantitative analysis in words and charts, perhaps writing out their industrial example as information for a company to examine for possible decisions.

Calculations and Chemical Equations *(continued)*

Tasks for Instruction and/or Assessment

Paper and Pencil

- Propane, C_3H_8(g), burns in oxygen, O_2, to produce CO_2(g) and H_2O(l). What mass of propane is needed to burn 25.0 mol of oxygen? (323-11)
- Calculate the mass of CaO(s) produced when 40.0 g of $CaCO_3$ is heated. (323-11)
- How many moles of NH_3(g) are formed when 42.0 g of nitrogen gas react with excess hydrogen gas? (323-11)
- Explain, in words, how you would intend to solve the problem: How many grams of NaCl are needed to react with 50.0 g of HCl? (323-11)
- In a reaction between sodium sulphide and nickel(II) nitrate, 18.3 g of nickel(II) nitrate reacted to produce 15.4 g of sodium nitrate. What was the percent yield? (323-11)
- If 16.6 g of lead(II) nitrate reacts with excess potassium chromate to produce 9.8 g of potasium nitrate, what is the theoretical yield, the actual yield, and the percent yield? (323-11)
- The equation to make aspirin is acetic anhydride plus salicylic acid yields aspirin plus acetic acid

  $C_4H_6O_3 + C_7H_6O_3 \rightarrow C_9H_8O_4 + CH_3COOH$

  Using this information, write the steps to solve the following problem: What mass of salicylic acid is needed to make two aspirin tablets, each 0.35 g? You have 50.0 g of salicylic acid. Is it enough? Justify. (323-11)
- Calculate the theoretical and percent yield if you have 300.0 g of salicylic acid and 240.0 g of aspirin are produced. (323-11)
- Distinguish between the limiting reagent (reaction) and the excess reactant in a chemical equation. (323-11)
- $CO(g) + 2H_2(g) \rightarrow CH_3OH(l)$
  If the yield is 80% and your research project needs 1 L of methanol, how much hydrogen do you need? (323-11)

Performance

- Perform and write-up an experiment on percent yield. (323-11)

Resources/Notes

Experiments

Chemistry 11 and Chemistry 12: A Teaching Resource

- Activity 4: Chemical Reactions in Microscale
- Activity 5: Chemical Reactions

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Chapter 4.2: The Limiting Reactant, pp. 128–135
- Chapter 4.3: Percentage Yield, pp. 137–148
- ThoughtLab: The Limiting Item, p. 129

Video

- *Periodic Table: Reactions and Relationships* (23382)

Stoichiometric Experimentation

8 hours

Outcomes

Students will be expected to

- design stoichiometric experiments identifying and controlling major variables (212-3)
- use instruments effectively and accurately for collecting data (213-3)
- identify and explain sources of error and uncertainty in measurement using precision and accuracy (214-10)
- communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others (215-1)
- identify various constraints that result in trade-offs during the development and improvement of technologies (114-4)

Elaborations—Strategies for Learning and Teaching

The first four outcomes here are discussed as a group for stoichiometric experimentation.

Students should do a number of stoichiometric experiments involving the number of moles, the masses of some reactants and/or products, and the theoretical and percent yield for a reaction. Possible reactions might include the following:

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

$$CaCl_2(aq) + Na_2CO_3(aq) \rightarrow CaCO_3(s) + 2NaCl(aq)$$

Students could design a stoichiometric experiment that is safe to do in the laboratory. Students could identify the variables to be manipulated and controlled, the instruments to be used to collect data, and the possible sources of error that might result. Teachers could give a reaction that students might use, such as the decomposition of $NaHCO_3$, baking soda. Students only do the procedure if the teacher approves. Students could record possible decomposition reactions for $NaHCO_3$ to see which reaction might result. After doing the approved experiment, students should record their data in a table, list their procedures, and analyse their results.

Students should follow safety procedures that have been discussed in class, such as wearing goggles and a lab apron/coat. See *Science Safety Guidelines* for more information. They might need demonstrations and information on safety for these experiments. Students should practice the proper techniques for using lab equipment. Disposal of materials could be discussed with reference to Workplace Hazardous Materials Information System (WHMIS).

Students could evaluate the method used to collect data and what sources of error could be identified, based on class data of experimental results, measurement precision, and accuracy. Discussion could involve the minimum loss of product(s) and techniques used to collect information. Students do not need to do uncertainty of mass in terms of "±" at this level; teachers might want to discuss this with reference to the uncertainty of a student's mass on a balance. Given an accepted value and a table of collected data, students could comment on the precision and accuracy of results. The concept of a range of results should be discussed here. The experiment could be reported in a variety of formats, such as a report, discussion among peers, a memo, or an abstract.

Students might look at safe commercial examples of chemical processes and discuss these reactions in terms of the usefulness to society, technology trade-offs, and the intentions of the producer of the products. The commercial preparation of urea, water softeners, or aspirin, or replacement of chlorofluorocarbons (CFCs) might be examples of interest to students.

Stoichiometric Experimentation

8 hours

Tasks for Instruction and/or Assessment

Performance

- Perform an experiment on theoretical and percent yield. (212-3, 213-3, 214-10, 215-1)
- Demonstrate how to use a crucible, an evaporating dish, and a balance properly. (213-3)

Journal

- Identify industrial constraints where an increased yield is technologically feasible but not cost-effective. (114-4)
- Research a commercial chemical process and discuss the safety considerations involved in the production of the product. (114-4)
- Is the technology involved in chemical production always helpful to society? (114-4)

Paper and Pencil

- Write a summary report of a plan for the production of a chemical. Include the list of equipment needed, the cost, the chemical equation with masses and moles, and the theoretical and percent yields of the product. Include possible sources of error. (212-3, 214-10, 215-1, 114-4)

Presentation

- Present an oral report, with or without multimedia, of two to five minutes detailing your stoichiometric experiment. (212-3, 215-1, 114-4)
- Work in small groups to design a number of experiments to demonstrate stoichiometric relationships. As each group presents its experimental design to the class, classmates should assess the design using criteria developed collaboratively before the activity. Criteria might include correct use of chemistry principles and of lab equipment, identification of variables, creativity, proper vocabulary, safety, and possible error sources. (212-3, 213-3, 214-10, 215-1)

Resources/Notes

Experiment

Chemistry 11 and Chemistry 12: A Teaching Resource

- Activity 6: Limiting Reactants—Student-Designed Experiment

Curriculum Correlation

McGraw-Hill Ryerson Chemistry (23700)

- Investigation 4-A: Limiting and Excess Reactants, p. 132
- Investigation 4-B: Determining the Percentage Yield of a Chemical Reaction, pp. 142–143

Print Resource

- *Science Safety Guidelines, Grades Primary–12* (2005)

Video

- *Catalytic Reactions* (23230)

Applications of Stoichiometry
2 hours

Outcomes

Students will be expected to

- identify various stoichiometric applications (323-12)
- predict how the yield of a particular chemical process can be maximized (323-13)
- explain how data support or refute the hypotheses or prediction of chemical reactions (214-12)
- compare processes used in science with those used in technology (114-7)
- analyse society's influence on science and technology (117-2)

Elaborations—Strategies for Learning and Teaching

Students should identify various applications of stoichiometry and be able to discuss the maximum yield with reference to supporting data. Students should compare experimental work with technology use and decide, with reasons, how society influences chemical production.

Teachers could make the study of stoichiometry interesting by using examples students might be familiar with in their daily activities, such as commercial production of H_2O_2, Kevlar, cis-Pt $(NH_3)_2Cl_2$ (a cancer therapy drug), $CaCO_3$ or $Mg(OH)_2$ antacids; pollution clean-up; or in photography, $I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$.

Students could predict how to maximize the yield of a chemical process. Students could defend a hypothesis or a prediction by explaining supporting data. One example that could be used is the workings of the original Breathalyzer, which uses dichromate to measure the amount of alcohol in the body:

$$16H^+ + 2Cr_2O_7^{2-} + 3C_2H_5OH \rightarrow 3CH_3COOH + 4Cr^{3+} + 11H_2O$$

orange $\rightarrow$ green

The colour change of orange to green indicates the presence of alcohol. Students could discuss the quantitative and qualitative aspects of this reaction. They could explain the differences between the predicted yield and the actual yield and how quantity is not the only factor to consider. This might lead students to look at other factors that can influence a chemical reaction. These will be addressed further in Chemistry 12.

Students might compare stoichiometry used in both science and technology by using chemical reaction examples. In a coal generating plant, for example, SO_3 emissions should be prevented from being released into the atmosphere. The SO_3 is treated with calcium hydroxide to produce gypsum according to the reaction

$$SO_3(g) + Ca(OH)_2(s) + H_2O(l) \rightarrow CaSO_4 \bullet 2H_2O(s)$$

Without this or a similar reaction, SO_3 would be released and would contribute to the problem of acid rain. Knowing how much sulphur trioxide is released from the coal can help the industry provide adequate calcium hydroxide for the reaction. Students might conduct research on a variety of industrial processes, such as extraction of gold (physical and chemical), production of aspirin, and neutralization of acidic lakes, and electroplating. **Note:** This is not an industrial process, but one might have caused a problem in the first place.

Students could report on how society influences science and technology. A report on aspirin could include aspects such as how to maximize purity, commercial potential, costs, and amounts. Students might include chemical equations for evidence in their report.

Applications of Stoichiometry

2 hours

Tasks for Instruction and/or Assessment

Journal

- How does the stoichiometry you have studied help your understanding of chemical processes? (117-2, 323-12)
- Summarize your understanding of theoretical versus actual yield and its relationship to stoichiometry in a flow chart, table, or series of short sentences. Swap summaries with a classmate in order to receive and offer advice on the two summaries. (323-12, 323-13)

Paper and Pencil

- Identify and explain two stoichiometric applications. How does/did society influence the science and technology of the applications? (117-2)

Presentation

- Using multimedia, present an industrial process. Include data, yield of the product, technology information, and the chemistry involved. (323-13, 323-12, 214-12, 114-7)

Resources/Notes

Experiment

Chemistry 11 and Chemistry 12: A Teaching Resource

- Activity 3: Limiting Reagent in a Chemical Reaction

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Careers in Chemistry: Chemical Engineer, p. 144
- Chemistry Bulletin: Nickel Mining at Voisey's Bay, p. 145

From Structures to Properties

Introduction

All matter is held together by chemical bonding. In this unit, we discuss bonding in detail. We will study the different forces of attraction involved in matter and how it influences their properties will be studied. We will consider questions such as Why does water have the formula H_2O? and Why does NaCl have such a high melting point?

Experiments are compulsaory in Chemistry 11 and students should have foty percent of their time in hands-on, minds-on exploration. Specific curriculum outcomes state which experiments should be done.

Focus and Context

This unit is framed around the use of chemicals in society in an inquiry-based approach. Students will begin by identifying and describing properties of ionic and molecular compounds as well as metallic substances. Using chemicals that would be found in their own homes, students will then differentiate among and classify these compounds and substances as being ionic, molecular, or metallic.

Students should use models to build chemical structures. Through the use of laboratory investigations and research, they can investigate and compare the strengths of intermolecular and intramolecular forces.

Science Curriculum Links

There are strong links between the atomic structure unit in grade 9 and the chemical reactions unit of grade 10. The chemical reactions unit forms the foundation for the remaining grade 11 units of stoichiometry and organic chemistry as well as the grade 12 units of solutions, acids, and bases. By the end of the From Structures to Properties unit, students will have studied the theoretical foundation of qualitative aspects in chemistry.

Curriculum Outcomes

STSE	Skills	Knowledge
Students will be expected to	*Students will be expected to*	*Students will be expected to*
114-2 explain the evidence from a bonding experiment and from collected data in the development of bond energies **115-7** explain how knowledge of bonding evolves as new evidence and theories are tested and subsequently revised or replaced **116-4** analyse and describe examples where technologies were developed based on bonding **117-11** analyse examples of Canadian contributions to bonding **118-2** analyse, from a variety of perspectives, the risks and benefits to society and the environment of applying bonding knowledge or introducing a particular technology	**212-5** identify consumer products and investigate the claims made by companies about the products **213-6** use library and electronic research tools to collect bonding information **213-7** select and integrate information from various print and electronic sources or from several parts of the same source **214-2** identify limitations of categorizing bond types based on differences in electronegativity between the elements and compounds **214-3** compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, and graphs	**321-4** illustrate and explain the formation of ionic, covalent, and metallic bonds **321-5** illustrate and explain hydrogen bonds and van der Waals' forces **321-7** identify and describe the properties of ionic and molecular compounds and metallic substances **321-8** describe how the different types of bonds account for the properties of ionic and molecular compounds and metallic substances **321-9** classify ionic, molecular, and metallic substances according to their properties **321-11** explain the structural model of a substance in terms of the various bonds that define it

Properties of Ionic and Molecular Compounds and Metallic Substances
3 hours

Outcomes

Students will be expected to

- select and integrate information from various print and electronic sources or from several parts of the same source (213-7)

Elaborations—Strategies for Learning and Teaching

Students need to make the connection that chemicals are not just substances used in industrialized processes, but a part of their everyday lives. Students might begin this unit by answering the question, How does chemistry affect our lives? This could be done in a concept map, journal, or a graphic organizer. At the end of this unit, the students should reconsider chemicals in light of the theories studied in this section.

Students could research the list of chemical ingredients on food packages found at home. The components are listed in decreasing order of their proportion in the food. **Ingredient** is the technical term applied to such things as oil, flour, sugar, and salt. These are generally thought of as components required to make the product either at home or commercially. They are an integral part of the food product. For example, we use milk and cream in ice cream production, so they are "ingredients."

The term **additive**, or **food additive**, is used to refer to a chemical substance that is added to food to achieve a specific effect, such as texture, colour, or preservation. The F*ood and Drugs Act* regulates the use of such chemicals in foods in Canada. The regulations apply to both domestic foods and imported food products.

Before a chemical is approved by Health Canada for use in a food product, it must pass safety tests. Furthermore, it can only be added to a food product when it has a specific purpose and only at the minimum level that achieves the desired effect. For a complete listing, refer to the *Food Additive Dictionary* (Health Canada).

Teachers should be careful of which foods are considered additives. Sodium chloride and sugars are considered ingredients. In Canada, sodium fluoride is allowed in toothpaste but not in foods. Potassium permanganate is an additive used to oxidize starch so that products such as frozen fruit pies do not go runny after the freeze-thaw cycle. Other metals are permitted in the form of salts.

Properties of Ionic and Molecular Compounds and Metallic Substances

3 hours

Tasks for Instruction and/or Assessment

Journal

- Research a chemical to report on the following:
  - What industry uses the chemical and for what purpose(s)?
  - What are the positive and negative effects of the use of this chemical on society and the environment?

  Based on this information, give your opinion as to whether you would recommend the use of this chemical. (213-7)

Paper and Pencil

- Prepare a chart on how chemistry affects your life. (213-7)

Presentation

- Make a poster or collage of food items highlighting the ingredients and additives. (213-7)

Resources/Notes

Print Resource

- *Food Additive Dictionary* (Health Canada) (www.hc-sc.gc.ca/fn-an/securit/addit/diction/index-eng.php)

Video

- *How to Create a Junk Food* (21202)

Properties of Ionic and Molecular Compounds and Metallic Substances *(continued)*

Outcomes

Students will be expected to

- identify and describe the properties of ionic and molecular compounds and metallic substances (321-7)

Elaborations—Strategies for Learning and Teaching

Students should use the theory of ionic bonding to explain the general properties of ionic compounds. They should compare the strengths of ionic and covalent bonds. They should do an experiment involving different bond types. This experiment might use both ionic and molecular substances, like salt and sugar, to demonstrate their properties. They should use the model for metallic bonding to explain the theory of why metals are malleable, ductile, good conductors of heat and electricity, and have a wide range of melting and boiling points. Students should identify and describe the properties of molecular compounds. Students might look at components from food items, and their formulas, to identify their bond types.

Teachers could provide students with a variety of ionic, molecular, and metallic compounds and ask them to categorize these compounds by properties such as odour, hardness, conductivity, state, solubility, melting/boiling points. Students should recognize a concrete relationship between categories and bond types. This recognition might lead them to the question, What makes a compound behave the way that it does?

Teachers could develop activities for students to learn about or to review naming and writing ionic and covalent molecules and acid information. This would allow students the opportunity to refresh information they might have seen before, to learn and interpret the information, and to study the properties and bonding information in this unit. Working on this in groups allows students to develop problem-solving and communication skills. Students might build their own list of chemical substances that includes the name, formula, picture (if possible), bond type, properties, and useful information about each substance. Putting this information in chart form or on cards for others to view will share the information with others. Relating this information to a food item's ingredients or an industrial process can connect the bonding with student's lives.

Properties of Ionic and Molecular Compounds and Metallic Substances *(continued)*

Tasks for Instruction and/or Assessment

Performance

- Devise criteria to classify the following substances as ionic or not ionic: C (graphite), H_2O, NaBr, Cu, $CaCO_3$. When your criteria are approved, obtain the substances and test them. (321-7)

Journal

- What makes salt melt ice? (321-7)
- If you were transformed into an ionic compound, which would you be? Explain your choice. (321-7)
- What holds a salt together? (321-7)

Paper and Pencil

- How do ionic compounds differ from molecular compounds? (321-7)

Presentation

- Display on the bulletin board the bonding information you collected about your list of chemical substances. (321-7)

Resources/Notes

Curriculum Correlation

- *McGraw-Hill Ryerson Chemistry* (23700), Chapter 5.1: Elements and Compounds,pp. 159–164

Classifying Compounds

4 hours

Outcomes

Students will be expected to

- classify ionic, molecular, and metallic substances according to their properties (321-9)

Elaborations—Strategies for Learning and Teaching

Students should identify and know the properties of substances by building a data table through experiments, a class discussion for patterns, and theory of classifying. Students could rotate through experiment stations to observe the properties of representative substances and compare melting points, conductivity, and solubilities in hot water, cold water, and methanol. Students could make a chart as they look at properties such as malleability, lustre, solubility, and conductivity.

Students should classify representative substances as ionic, molecular, and metallic based on their properties. They should identify the possible bond type, ionic or covalent, from a chemical formula.

Classifying Substances

Property	Describing Words	Possible Bond Type
conductivity	• strong glow on light bulb • weak glow • no light	ionic covalent

Building models might help students deduce the number of bonds an element is likely to form based on its position in the periodic table. Students might look at H_2O, SiH_4, and C_2H_6O and build models to represent bonding. The example C_2H_6O shows students that more than one structure is possible for some formulas.

Teachers could have compounds available that students would find in their homes. A typical household chemicals experiment might allow students to view ionic, molecular, and metallic compounds and the properties exhibited by each. Substances such as sodium chloride, sucrose, aluminium foil, water, an aspirin, and cornstarch are good examples. Students could relate physical properties for metallic, ionic, and covalent solids to the bond type by finding the bond type of the substances in order to classify them.

Classifying Compounds

4 hours

Tasks for Instruction and/or Assessment

Performance

- Given an unknown substance, predict the type of substance and devise a test to verify your hypothesis. (321-9)
- Classify the bond types given substances based on their properties. (321-9)

Journal

- Sodium chloride and sugar have different bond types, yet they both dissolve in water. Explain. (321-9)

Presentation

- Draw diagrams to show sodium and chloride ions being surrounded by water molecules. Draw diagrams to show sucrose molecules surrounded by water molecules. (321-9)
- Choose five chemical compounds found at home or in the school. Fill in the following table for each of the compounds:

	Compounds				
	1	2	3	4	5
MP					
BP					
malleability					
lustre					
possible bond type					
conductivity					
solubility in H_2O					

– What general trends to you notice?
– What conclusions can you draw? (321-9)

Resources/Notes

Experiment

Chemistry 11 and Chemistry 12: A Teaching Resource

- Activity 13: Melting Points

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- ExpressLab: A Metal and a Compound, p. 160
- ThoughtLab: Ionic or Molecular, p. 161

Print Resources

- *Merck Index*
- *CRC Handbook*

Video

- *Atom Bond: The Atom with the Golden Electron* (23193)

Classifying Compounds *(continued)*

Outcomes

Students will be expected to

- identify consumer products and investigate the claims made by companies about the products (212-5)

Elaborations—Strategies for Learning and Teaching

Students should identify a consumer product and investigate the validity of the information they collect is about its history and other criteria or predictions they might have. Students should make decisions on a company's claims about the product's safety, ingredients, and effectiveness. Teachers might engage students in a discussion on the history of consumer foods as it relates to our decisions about which foods to purchase. Students might then choose a food and follow its development from raw material to a consumer product, paying particular attention to preparation and processing. Examples of additives they may choose are monosodium glutamate (MSG), aspartame, caffeine, and nitrites. Food additives, in a particular food chosen by the students, might be investigated to find their bond type. Students might wish to develop a time line on the history of the food being introduced to society.

Classifying Compounds *(continued)*

Tasks for Instruction and/or Assessment

Paper and Pencil

- Can you tell hearsay and science apart? Pick a newspaper article on a consumer product and give evidence from it to support the difference. (212-5)
- From a list of consumer foods your teacher has given you, choose a product. Find and report information on it from a readily accessible source such as the Internet. Links could tie to history, ingredients, additives, and current processing techniques. (212-5)
- Evaluate the validity of an Internet site on food commodity groups based on its links to other sites. (212-5)
- Investigate the development of environmentally friendly paint for use in household renovation projects. Create a time line for the development of paint products, including the major chemical ingredients. Determine the components that environmentally friendly paint have removed (replaced) in order to "protect" society. (212-5)

Resources/Notes

Curriculum Correlation

- *McGraw-Hill Ryerson Chemistry* (23700), Chemistry Bulletin: Chemical Amounts in Vitamin Supplements, p. 61

Bonding

5 hours

Outcomes

Students will be expected to

- illustrate and explain the formation of ionic, covalent, and metallic bonds (321-4)

Elaborations—Strategies for Learning and Teaching

Students should explain the importance of electron transfer in ionic bond formation, and use electron dot diagrams to illustrate ion and ionic bond formation. They should define valence electrons, electronegativity, ionic bond, and covalent bond. Students should describe the bonding continuum from complete electron transfer, which is ionic, to unequal sharing of electrons, which is polar covalent, to equal sharing of electrons, pure covalent. They should define a metallic bond, and use it to explain bonding within metals. They should define and identify single, double, and triple covalent bonds.

Bonding is a continuum from pure covalent to ionic. As compounds are formed from elements closer together in the periodic table, the ionic character decreases and covalent character increases. Students might use hands-on model kits to design covalent and ionic compounds based on their bonding. The crystal structure for an ionic compound such as NaCl could be discussed based on bonding. Students could identify various foods to investigate their types of bonding. They might look at the simple food substances, their properties, and their bonding types. They might practice formula writing for ionic compounds.

Students should also be able to demonstrate ionic, covalent, and metallic bonding using the position of the considered elements in the periodic table.

The periodic table could be used to introduce students to s, p, d, and f blocks to determine electron configurations and valence electrons for the elements. Teachers might start with electronic configurations and then relate these configurations to periodic table blocks. Students could determine the distribution of electrons in the major energy levels for the first 54 elements and for ions in groups 1, 2, 3, 15, 16, and 17. Noble gas structures and the octet rule might be useful for students' understandings of ions and bonds. Students could predict the ionic charge for ions in the main group elements from their group number and using the octet rule.

Teachers could discuss Mendeleev's process in designing the periodic table, specifically his identification of gallium, Ga. Electronic configurations for main group elements should also be related to valence electrons and to electron dot symbols. Students could perform a flame-colour lab to identify metals. They could discuss the results in terms of energy-level jumps.

Bonding

5 hours

Tasks for Instruction and/or Assessment

Performance

- Test the flame colours of certain metals. After your procedure is approved, do the experiment. Report your results in a chart. Test an unknown. (321-4)
- Using ion chips, ion dice, or a game, write balanced chemical formulas for a variety of ionic compounds. (321-4)
- Identify an unknown sample by comparing its properties to a set of known properties. Use the following criteria:
  - follow the recommended outline
  - use chemical and physical properties to classify or identify the unknown sample
  - observe and measure accurately
  - explain conclusions clearly

  (321-4)

Journal

- How can atoms get the noble-gas electron structures? Do they become noble gases? (321-4)
- What does the gain of an electron mean in terms of an atom's charge? What is an ion and how is it formed? (321-4)

Paper and Pencil

- How is the octet rule useful? (321-4)
- List all the atoms and ions that are represented by this electron configuration: $1s^2 2s^2 2p^6 3s^2 3p^6$. (321-4)
- What does the Roman numeral represent in a compound's name? What do the subscript Arabic numerals represent? (321-4)
- Are most metals found in nature as ores? Explain. (321-4)
- Give examples of metals found in foods. Are they elemental or salts? (321-4)
- Select an ion that plays a role in your body. Write a report that includes recent medical information. (321-4)
- Electronegativity difference is a general guide for bond type. Explain. (321-4)

Resources/Notes

Experiments

Chemistry 11 and Chemistry 12: A Teaching Resource
- Activity 7: Ionic and Covalent Compounds Found at Home
- Activity 15: Formation of Ionic Bonds
- Activity 17: Multiple Covalent Bonding
- Activity 18: Metallic Bonding

Curriculum Correlation

- *McGraw-Hill Ryerson Chemistry* (23700), Chapter 5.2: Bond Formation, pp. 165–172

Video

- *Molecular Motion* (23566)

Bonding *(continued)*

Outcomes

Students will be expected to

- illustrate and explain the formation of ionic, covalent, and metallic bonds (321-4)

Elaborations—Strategies for Learning and Teaching

Students should use a periodic chart of electronegativities to understand the relationship between electronegativities of the atoms and the type of bonding in a compound.

Students should define, explain, and write Lewis structures. They could write Lewis symbols for atoms and show how many electrons must be transferred or shared to enable an atom to achieve a completed valence shell. They could write Lewis structures for ionic and molecular compounds, and electronic dot symbols for the ions in ionic compounds.

Videos could be used in this section to show electron transfer and sharing. It helps students to make this abstract concept as visual as possible. The bonding structure of polyatomic ions compared with simple ions might be interesting to show students, although they do not need to practise drawing many of the complex polyatomic ions.

From a label of a household substance, choose an ionic and a covalent substance. Teachers might show structures of some carbohydrates, proteins, or ionic substances found within ordinary food or cleaning products in the home.

Bonding *(continued)*

Tasks for Instruction and/or Assessment

Performance

- Given an unknown substance, predict the type of substance and devise a test to verify your hypothesis. (321-4)

Paper and Pencil

- How are the lattice structure and chemical formula of NaCl related? (321-4)
- What conclusions can be made about the forces holding ionic crystals together and the forces holding molecular crystals together? Use evidence from melting and boiling points of some substances. (321-4)
- How are polyatomic ions the same and different from simple ions? (321-4)
- Draw Lewis structures for H_2O, N_2, F_2, CH_3COOH, H_2 (321-4)

Presentation

- Draw a cartoon explaining why table salt that is sold is not pure NaCl. (321-4)
- Design a model to show the crystals of NaCl. (321-4)
- Use a concept map to show how energy changes occur in the formation of ionic compounds. (321-4)
- In small groups, keep the ingredient labels from all the food products you eat in one day. Make a list of all the ionic and covalent compounds contained in each product. Create a table. Research the properties and uses of the compounds most frequently eaten. Create an information poster describing your research. (321-4)

Resources/Notes

Experiments

Chemistry 11 and Chemistry 12: A Teaching Resource
- Activity 20: Intermolecular Bonding
- Activity 21: Exceptions to the Octet Rule; Isomers; and Drawing Lewis Structures for Ions

Curriculum Correlation

- *McGraw-Hill Ryerson Chemistry* (23700), Chapter 5.3: Bonds as a Continuum, Electronegativity of Elements; Bond Type and Electronegativity, pp. 174–178

Structural Models of Bonding

3 hours

Outcomes

Students will be expected to

- explain the structural model of a substance in terms of the various bonds that define it (321-11)
- explain how knowledge of bonding evolves as new evidence and theories are tested and subsequently revised or replaced (115-7)
- analyse examples of Canadian contributions to bonding (117-11)
- analyse and describe examples where technologies were developed based on bonding (116-4)
- analyse, from a variety of perspectives, the risks and benefits to society and the environment of applying bonding knowledge or introducing a particular technology (118-2)

Elaborations—Strategies for Learning and Teaching

Students should explain the structure of substances based on bonds formed. They could analyse and give examples of useful bonding information based on bonding theories, technologies, and society.

Students could name an everyday substance and the elements involved in it. They might draw the substance to help give information about its structure. They could use molecular model kits for covalent bonded materials. Each student could choose a model to be built using building materials to demonstrate the bonding structure.

Students could explain the three-dimensional geometry of molecules using VSEPR theory. They could determine the shapes about central atoms in simple molecules by applying VSEPR theory to electron dot diagrams. Students could discuss the relationships between electronegativity of atoms and the degree of bond polarity. As an extension or enrichment activity, teachers and students might calculate the bond polarity and its effect on percentage ionic character.

Teachers might begin a class discussion about our understanding of chemical bonds. Questions could include "How did we think about chemical bonds before superconductivity?" "Do more advanced technologies help us know more about atoms?" "Tell me how we understand chemical bonds today."

Students might be introduced to three-dimensional lattice structure by use of models or through a research article or the Internet.

Students should state how scientists contributed to the understanding of the elements in the periodic table. Students might analyse and describe examples of how science and technology are related. They could read about John Polanyi's work on spectroscopy to see how a Canadian contributes to our world's view of science. An alternate example might be Neil Bartlett, who at the University of British Columbia (UBC) in 1962, was the first to oxidize Xenon. He was responsible for the name change of Group 18 from "inert" to "noble" gases.

Students should investigate the structural model of bonding in materials such as titanium alloys and composites used in manufacturing. They could defend the popularity of these materials, based on properties that relate to their bonding structure, and explain why they are so costly. Students might research mercury amalgams used in dentistry or aluminium and its relationship to Alzheimer's disease.

Structural Models of Bonding

3 hours

Tasks for Instruction and/or Assessment

Performance

- Given unknown compounds, develop a plan to identify the bond type based on observed properties and defend the methods used to test for their chosen properties. (321-11)

Journal

- Keep a section of your portfolio available for issues that arise related to the relationship between science and technology. A bonding topic, such as materials used in dentistry, is one that could be discussed. Follow up this discussion with a summary or piece of reflective writing for your portfolio. (115-7, 117-11, 116-4, 118-2)

Paper and Pencil

- Explain VSEPR theory. Use diagrams if you feel these will be helpful. (321-11)
- Define bonding. Trace the development of bonding with reference to how technology helped us in our understanding of bonding. (115-7, 116-4)

Presentation

- Individually or in groups, present research on a Canadian chemistry winner and that person's contribution to science locally, nationally, and globally. This could be presented orally, in written form, or developed as a multimedia presentation. (115-7, 117-11, 116-4, 118-2)
- Draw on everyday compound and explain its bonding. (321-11)

Resources/Notes

Experiments

Chemistry 11 and Chemistry 12: A Teaching Resource

- Activity 8: Building Molecular Models
- Activity 19: Predicting Shapes of Molecules—VSEPR Theory

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Chapter 6.1: Covalent Bonds and Structures, pp. 185–200
- Investigation 6-A: Modelling Molecules, pp. 197–198

Structural Models of Bonding *(continued)*

Outcomes

Students will be expected to

- analyse, from a variety of perspectives, the risks and benefits to society and the environment of applying bonding knowledge or introducing a particular technology (118-2)

Elaborations—Strategies for Learning and Teaching

Students could analyse the risks and benefits of using fertilizers and pesticides as they tie into the food chain. Students might find their own examples for research such as biotechnology, organic farming, and food irradiation. These could be related to pharmacy, food production, and agriculture.

Structural Models of Bonding *(continued)*

Tasks for Instruction and/or Assessment

Portfolio

- Include a piece of reflective writing in your portfolio. It might analyse a particular technology useful in bonding, or it might talk about risks and benefits or the use of bonding knowledge. (118-2)

Resources/Notes

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Tools and Techniques: AIM Theory and Electron Density Maps, p. 194
- Chemistry Bulletin: Ionic Liquids: A Solution to the Problem of Solutions, p. 223

Bond Energies

3 hours

Outcomes

Students will be expected to

- identify limitations of categorizing bond types based on differences in electronegativity between the elements and compounds (214-2)
- explain the evidence from a bonding experiment and from collected data in the development of bond energies (114-2)
- describe how the different types of bonds account for the properties of ionic and molecular compounds and metallic substances (321-8)

Elaborations—Strategies for Learning and Teaching

Students should identify the limitations of using electronegativity values to determine the polar nature of a specific covalent bond. They should look at bonding structure, properties, and electronegativity for elements, covalent molecules, and acids.

Students could look at the polar covalent nature of an acid in solution. Perhaps they might choose a type of juice to describe its bond nature and energy. They might be able to identify the need for a separate classification scheme for these types of compounds. Electronegativity within periods and families could be plotted using the first 36 elements to identify the trends.

Students should each do a melting point experiment on a molecular substance and compare their data. Paradichloro-benzene or a similar chemical is an example of a compound to use in a melting point experiment.

Appropriate safety equipment should be worn at all times. See *Science Safety Guidelines* for more information. Students might need demonstrations and information on safety for these experiments.

Students should explain the energy changes for exothermic and endothermic reactions in terms of bond breaking and bond formation. They could look at changes that are exothermic and endothermic, but the study of the heat of reaction is done in Chemistry 12. Students could do a molecular polarity lab to determine the polarity of an unknown solute.

Bond Energies

3 hours

Tasks for Instruction and/or Assessment

Performance

- Do an experiment on polarity. Report your findings. (214-2, 321-8, 114-2)

Journal

- How does chemistry affect your life? Identify chemicals and discuss their bond type in terms of electronegativity. (214-2)
- Reflect on the outcomes from this unit. Chose a title for your reflection, perhaps the "muddiest point(s)" for this unit. (114-2)

Resources/Notes

Curriculum Correlation

- *McGraw-Hill Ryerson Chemistry* (23700), Chapter 5.3: Bonds as a Continuum, Bond Length and Strength, pp. 179–180

Print Resource

- *Science Safety Guidelines, Grades Primary–12* (2005)

Bond Energies *(continued)*

Outcomes

Students will be expected to

- describe how the different types of bonds account for the properties of ionic and molecular compounds and metallic substances (321-8)
- identify limitations of categorizing bond types based on differences in electronegativity between the elements and compounds (214-2)

Elaborations—Strategies for Learning and Teaching

Using the theory of ionic bonding, students should explain the general properties of ionic compounds: brittleness, high melting and boiling points, and the ability to conduct electricity when molten or in aqueous solution. Using the theory of metallic bonding, students should explain why metals are malleable, ductile, and good conductors of heat and electricity, and why they have a wide range of melting and boiling points. They should compare the strengths of ionic and covalent bonds of various food substances they have previously identified.

In small groups, students might join hands to represent intramolecular forces. As they move around to increase kinetic energy, they will see how intramolecular forces break first.

Polarity and molecular arrangement might be demonstrated using vectors and forces in a specific direction. When a molecule is drawn, the differences in electronegativity might be written as a vector. Using bond angles for direction, vector addition for each bond could be used to determine if the molecule is polar or non-polar.

Students could compare acetic acid with hydrochloric acid or sodium acetate with ethyl acetate or ethanol with ethane. On the basis of properties such as conductivity, students could differentiate among ionic and molecular compounds, including acids and bases. Students could discuss the types of bonds, electronegativity, and hydrogen bonding. Properties of substances might be discussed by looking at the types of bonds, single and double, to see if the bonds make a difference. The forces that affect atoms in bonds might be described and explained for ionic and molecular compounds.

Bond Energies *(continued)*

Tasks for Instruction and/or Assessment

Paper and Pencil

- Is hexane non-polar? Explain. What does bond type have to do with this? (214-2, 321-8)
- Devise your own classification in a flow chart for bonding in all compounds. Use a list of supplied compounds. (214-2, 321-8)
- Describe the relationship between electronegativity and hydrogen bonding. (321-8)
- Draw and label the forces that affect atoms in a covalent bond. (321-8)

Resources/Notes

Curriculum Correlation

- *McGraw-Hill Ryerson Chemistry* (23700), Chapter 6.3: Structure Determines Properties, pp. 216–224

Polar and Pure Covalent Bonding

3 hours

Outcomes

Students will be expected to

- illustrate and explain hydrogen bonds and van der Waals' forces (321-5)

Elaborations—Strategies for Learning and Teaching

Students should identify types of intermolecular forces between molecules in a substance. They should define polar and pure covalent bonds. They should explain the special nature of hydrogen as an exception to the octet rule. They should explain van der Waals' forces.

Students could look at the boiling and melting points of group 16 hydrides. They might research boiling points of a variety of phase-change compounds with similar molecular mass but varying bond types (electronegativities).

Students could compare other properties of these compounds or other similar groups (N, P, As) to see the effect of bonding on the other physical and chemical properties. In doing this, they could note the special nature of the three highly electronegative elements—nitrogen, oxygen, and fluorine.

Polar and Pure Covalent Bonding
3 hours

Tasks for Instruction and/or Assessment

Paper and Pencil

- Describe the electron distribution in a polar covalent bond and in a pure covalent bond. (321-5)
- Determine the shape of the compounds ClF, OF_2, and NH_3. (321-5)
- Draw the shapes of NH_4^+ and CO_3^{2-}. (321-5)
- Plot a graph of boiling points or melting points of group 16 hydrides. Explain discontinuity of the graph. (321-5)

Resources/Notes

Experiments

Chemistry 11 and Chemistry 12: A Teaching Resource
- Activity 9: Intermolecular Forces
- Activity 16: Pure and Polar Covalent Bonding—Co-ordinate Covalent Bonding

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)
- Chapter 6.2: Intermolecular Forces, pp. 202–215
- Investigation 6-B: Investigating the Properties of Water, pp. 207–208
- ThoughtLab: Properties of Liquids, p. 210

Print Resources

- *Merck Index*
- *CRC Handbook of Chemistry and Physics*

Video

- *Ionic and Covalent Bonding: Part 2* (21338)

Polar and Pure Covalent Bonding *(continued)*

Outcomes

Students will be expected to

- use library and electronic research tools to collect bonding information (213-6)
- select and integrate information from various print and electronic sources or from several parts of the same source (213-7)
- compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, and graphs (214-3)

Elaborations—Strategies for Learning and Teaching

A final activity for this unit involves finding the chemical formula of an unknown ionic compound. This works extremely well for all students as they practise their strategies for planning, their reasoning skills, and their perseverance to answer a question. This activity also involves inquiry, problem solving, and decision making.

Students could be given a sample of an ionic solid in a container. A film container three-quarters full is a good amount. Students have to plan their strategies to find the identity of the substance, given possible cations, positive ions, anions, and negative ions (Na^+, K^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, NH_4^+, NO_3^-, HCO_3^-, Cl^-, Br^-, I^-, CO_3^{2-}, and SO_4^{2-}). Students might use any library or electronic research to collect information. They should document their sources, organize them, and keep a log of all their notes and experiments. This log—their private science—is to be submitted with their final report—public science—on their substance. Their reports are considered to be public science. Students' notes should include evidence they have found through observation and tests. Diagrams, flow charts, tables, and graphs could be helpful in their final reports. Each report includes a repeat of purpose, what was done, results for each experiment/activity, and a final analysis of the results, finishing with an identification of the compound.

Possible strategies include looking at the compound's properties; doing experiments previously used throughout the course, such as flame tests and precipitates (using solubility tables); and asking for and using teacher-approved experiments. Confirmation tests help eliminate possible cations and anions.

Appropriate safety equipment should be worn at all times. See *Science Safety Guidelines* for more information. Students might need demonstrations and information on safety for these experiments.

Students enjoy laboratory experiences, which provide a great sense of accomplishment of their skills. It takes all of their talents—inquiry, decision making, research, logical thinking, communication (verbally with peers and their teacher), and problem-solving and requires them to apply the science concepts they have learned.

Polar and Pure Covalent Bonding *(continued)*

Tasks for Instruction and/or Assessment

Presentation

- Silicon, a covalently bonded solid, is harder than pure metals. Research theories that explain the hardness of covalently bonded solids and their usefulness. Present your findings as a newspaper article or memo. (213-6, 213-7, 214-3)
- Identify your unknown ionic solid and submit your report. (213-6, 213-7, 214-3)

Resources/Notes

Experiments

Chemistry 11 and Chemistry 12: A Teaching Resource

- Activity 10: Flame Tests
- Activity 12: Polymers Found at Home

Curriculum Correlation

- *McGraw-Hill Ryerson Chemistry* (23700), Investigation 6-C: Properties of Substances, p. 222

Print Resource

- *Science Safety Guidelines, Grades Primary–12* (2005)

Video

- *Covalent Bonding* (23195)

Organic Chemistry

Introduction

In this unit, the bonding capacity of carbon, hydrogen, oxygen, nitrogen, and the halogens will be reviewed, as will the potential for these atoms to form covalent compounds. The vastness of the number of organic molecules will be explored using isomers and polymers as examples. With so many different organic molecules to consider, students will come to appreciate the need for a systematic naming scheme. The students will be given opportunities to discover how the classification of organic molecules into different family groups depends on the type of bonding and atoms present. The students will also examine how these factors influence the reactivity of representative molecules from each of the different families. Organic chemistry is the study of molecular compounds of carbon.

Experiments are compulsaory in Chemistry 11 and students should have foty percent of their time in hands-on, minds-on exploration. Specific curriculum outcomes state which experiments should be done.

Focus and Context

Humans and all living organisms are made up of molecules that contain carbon. Carbon provides the backbone for many molecules essential for life. Deoxyribonucleic acid (DNA), proteins, carbohydrates, cellulose, fats, and petroleum products all contain organic molecules. Having students consider the chemistry that exists within their own bodies can make the study of organic molecules more relevant and interesting. By studying the impact of technological applications of organic chemistry on the world around them, students will develop an appreciation for the nature of science and technology, of the relationships between science and technology, and of the social and environmental contexts of science and technology. Using a context such as the problem of ozone depletion provides students with an opportunity for attitudinal growth. Furthermore, students should develop a sense of personal and shared responsibility for maintaining a sustainable environment. Ultimately, students should be aware of the direct and indirect consequences of their actions. Other contexts could work just as well.

Science Curriculum Links

Organic chemistry is a topic that fits in well toward the end of the grade 11 course because it provides an opportunity to review outcomes in the From Structures to Properties unit. The organic unit will help students reinforce their understanding of valence electrons, chemical bonding, and intermolecular and intramolecular forces.

This unit also reinforces and expands upon the study of natural and synthetic compounds containing carbon that was introduced in grade 10 science. As well, the grade 9 science program introduced students to the chemistry of petrochemicals. Petrochemicals form the basis of the grade 12 thermochemistry unit.

Curriculum Outcomes

STSE	Skills	Knowledge
Students will be expected to **114-4** identify various constraints that result in trade-offs during the development and improvement of technologies **115-1** distinguish between scientific questions and technological problems **115-3** explain how synthesizing organic molecules revolutionized thinking in the scientific community **115-6** explain how organic chemistry has evolved as new evidence has come to light **116-6** describe and evaluate the design of technological solutions and the way they function using scientific principles **116-7** analyse natural and technological systems to interpret and explain the influence of organic compounds on society **117-4** debate the merits of funding specific scientific or technological endeavours and not others **117-5** provide organic chemistry examples of how science and technology are an integral part of their lives and their community **118-2** analyse from a variety of perspectives the risks and benefits to society and the environment of applying organic chemistry knowledge or	*Students will be expected to* introducing a particular technology **118-4** evaluate the design of a technology and the way it functions, on the basis of a variety of criteria that they have identified themselves **212-2** define problems to facilitate investigation of polymers **212-3** design an experiment identifying and controlling major variables **213-7, 215-3** select, integrate, and synthesize information from multiple sources including various print and electronic sources, and make inferences on this information **213-8** select and use apparatus and material safely **214-2** identify limitations of the IUPAC classification system and identify alternative ways of classifying to accommodate anomalies **214-9** identify and apply criteria, including the presence of bias, for evaluating evidence and sources of information on an organic topic **214-11** provide a statement that describes the relationship between	*Students will be expected to* bonding and organic chemistry investigated in light of the link between data and the conclusion **215-1** communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others **215-5** develop, present, and defend a position or course of action on organic chemistry based on findings **319-4** explain the large number and diversity of organic compounds with reference to the unique nature of the carbon atom **319-5** write the formula and provide the IUPAC name for a variety of organic compounds **319-6** define isomers and illustrate the structural formulas for a variety of organic isomers **319-7** classify various organic compounds by determining to which families they belong, based on their names or structures **319-8** write and balance chemical equations to predict the reactions of selected organic compounds

319-9 describe processes of polymerization and identify some important natural and synthetic polymers

Outcomes

Students will be expected to

So Many Compounds

1 hour

- explain the large number and diversity of organic compounds with reference to the unique nature of the carbon atom (319-4)

Elaborations—Strategies for Learning and Teaching

Students should describe carbon's bonding capacity and carbon's ability to form multiple bonds and to bond in a variety of stable structures. Students should identify the geometry of carbon compounds, the strong bonds between carbon atoms, and the low reactivity of carbon compounds.

Teachers might wish to introduce here the section at the end of this unit, Risks and Benefits of Organic Compounds, pages 100–103, to give students an overview of the unit. Throughout this unit, teachers might refer to the research project students will undertake. An alternative suggestion to address the outcomes would be for students, in groups of two, to develop an STSE question based on a controversial compound.

Teachers could begin this topic with a problem relating organic compounds to students' lives. Students could try to explain the diversity of organic compounds. Of the millions of compounds known to humans, the vast majority are molecular compounds of carbon. To develop an appreciation for the scope of organic chemistry, students could brainstorm a list of different molecules they have heard about from biology courses, food sources, pesticides, petroleum products, pharmaceuticals, and other everyday sources.

Teachers could explain the difference between the use of "organic" in organic chemistry and in organic farming and food.

So Many Compounds

1 hour

Tasks for Instruction and/or Assessment

Performance

- Using the models, make some structures of the organic compounds you found. (319-4)
- Draw Lewis structures for an organic compound. (319-4)

Journal

- Carbon bonding is important in organic compounds. Explain why. (319-4)
- Are all carbon-containing compounds organic compounds? Discuss. (319-4)

Paper and Pencil

- Make a chart to list the compounds you found and the elements contained in the compounds according to the following groupings: C and H only; C, H, and O only; C, H, and N only; C, H, and halogens only; and others. (319-4)

Resources/Notes

Curriculum Correlation

- *McGraw-Hill Ryerson Chemistry* (23700), Chapter 9.2: Representing Hydrocarbons, pp. 324–330

So Many Compounds *(continued)*

Outcomes

Students will be expected to

- explain the large number and diversity of organic compounds with reference to the unique nature of the carbon atom (319-4)

Elaborations—Strategies for Learning and Teaching

Students could be asked to search reference materials, such as a chemistry handbook (example: *The Merck Index*, *CRC Handbook of Chemistry and Physics*, chemical dictionary) or the Internet, to try to discover the structural formulas of these different compounds. They could find molecules that contain carbon and look at relative molecular size and mass of the molecules. Once the students compile an array of the molecules they have found, they should be asked to determine which of these come from living organisms and which are artificial or synthesized by humans. From this activity, the students should realize that many organic molecules are derived from living sources, and they should understand the historical significance of the name "organic chemistry."

Students might consider what makes carbon compounds different from other compounds. Because students have studied some bonding, organic chemistry offers an opportunity for them to explore the spatial characteristics of simple organic compounds. They could use model kits to investigate the symmetry of simple organic compounds. For example, the nature of methane's tetrahedron or the ends of ethane rotating could be examined with the models. Students might compare properties of C_4H_{10} with Si_4H_{10} or CCl_4 with $SiCl_4$. They might look at the structures of graphite and diamond to demonstrate the layering of hexagons and the strength of a tetrahedron.

So Many Compounds *(continued)*

Tasks for Instruction and/or Assessment

Paper and Penil

- Look at models of graphite and diamond. Suggest a reason why graphite is more chemically reactive than diamond. (319-4)
- Research and make a model for buckyballs. How is it different from or similar to that of diamond and graphite. Compare the properties of all three forms of carbon. (319-4)

Presentation

- On a large index card, write one compound's formula or structure and its name. Put the card on the bulletin board to be viewed by your classmates. (319-4)
- Develop a class time line across one wall of the room of the dates various organic compounds were discovered or developed. Add a compound with the following information: the chemical formula, when it was developed, and one or two interesting facts about it, such as its use and if it was ever banned. (319-4)

Resources/Notes

Curriculum Correlation

- *McGraw-Hill Ryerson Chemistry* (23700), Chapter 9.1: Introducing Organic Compounds, pp. 321–323

Print Resources

- *Merck Index*
- *CRC Handbook of Chemistry and Physics*
- chemistry dictionary

Influences of Organic Compounds on Society

1 hour

Outcomes

Students will be expected to

- explain how synthesizing organic molecules revolutionized thinking in the scientific community (115-3)
- explain how organic chemistry has evolved as new evidence has come to light (115-6)
- identify various constraints that result in trade-offs during the development and improvement of technologies (114-4)
- provide organic chemistry examples of how science and technology are an integral part of their lives and their community (117-5)

Elaborations—Strategies for Learning and Teaching

Students should consider the significance of being able to synthesize organic molecules. The fact that this was not always possible could be explored with students. Students have probably heard that it is now possible to synthesize the insulin molecule, which is needed in the treatment of diabetes. Since insulin had previously been isolated from the pancreas of cows and pigs, the discovery of a method to produce it artificially was a welcome innovation. It is possible to synthesize many molecules, and there are pros and cons. For example, CFCs have allowed the storage of food for long periods of time but are also destroying the ozone layer.

Students should explain how organic compounds evolved as more information about production increased. They could explain how Kekulé's concept of the ring structure of benzene revolutionized thinking in chemistry. They could debate the advantages and disadvantages of synthesizing molecules.

Students should be exposed to today's world of rapid technological development in which the concepts of organic chemistry are being applied to everything. They could analyse the numerous steps involved in the refining of petroleum to obtain gasoline and a variety of other products. They might look at technologies that allow us to produce organic chemicals and the societal implications of the science and technology involved in this.

Students should give the pros and cons that resulted from the technology developed to make organic compounds. They could explore examples of organic compounds used in their daily lives, such as the leaded gasoline, which was banned, because of its impact on the environment, resulting in consumers using unleaded gasoline. Students could consider such issues as cost and care of the environment. Examples of organic compounds and the relationship of these compounds to students' lives and their community help them understand the influence science and technology have on society.

Influences of Organic Compounds on Society

1 hour

Tasks for Instruction and/or Assessment

Informal Observation

- Create observation criteria with your teacher to consider from a number of different perspectives, the synthesizing of organic molecules. Weigh conflicting information. Think about and articulate the kinds of knowledge, skills, and attitudes needed to analyse and critique this major scientific issue. (115-3, 115-6)

Journal

- What are the societal implications of the use of organic chemicals in agricultural chemistry to control pests ? (114-4, 117-5)
- How are open-mindedness, critical thinking, and decision-making skills necessary for deciding how science and technology relate to organic compounds and your life? (117-5)

Paper and Pencil

- What technologies allow us to mass produce organic chemicals? (115-3, 115-6, 114-4)
- Investigate the technology of designing new synthetic schemes to prepare important organic compounds. Report your findings in a brochure, newspaper article, or memo. (114-4, 115-3, 117-5)

Presentation

- Debate the advantages and disadvantages of synthesizing molecules. (115-3, 115-6)
- Debate the use of synthetic chemistry versus naturally occurring limited resources. (115-3, 114-4, 117-5)

Resources/Notes

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Tools and Techniques: Oil Refining in Newfoundland and Labrador, p. 369
- Chapter 9.4: Refining and Using Hydrocarbons, pp. 365–368
- ThoughtLab: Risk Benefit Analyses of Organic Products, p. 448
- ThoughtLab: Problem Solving with Organic Compounds,p. 451

Influences of Organic Compounds on Society *(continued)*

Outcomes

Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

Students should look at an organic compound's influence on society—whether it is a natural or technological substance.

Teachers might initiate a class discussion about synthesized organic molecules. Questions can be designed to help the students brainstorm their ideas, students might use a flow chart, diagrams, or computer software. Many synthesized organic molecules are originally extracted from living sources, and this might provide an interesting context for discussion.

Synthesized molecules are both helpful and harmful. A balanced approach could help students understand the relationship of chemistry to their everyday activities. For example, acetylsalicylic acid, or aspirin, is derived from the white willow tree but is now produced almost exclusively in a laboratory. Ozone has many harmful properties and is actually poisonous at ground level, whereas in the stratosphere it is essential for filtering UV radiation from sunlight. Teachers might provide students with the opportunity to consider the factors surrounding the ozone debate that will allow them to consider a real problem that has an impact on us all.

Influences of Organic Compounds on Society *(continued)*

Tasks for Instruction and/or Assessment

Performance

- Debate the pros and cons of being able to manufacture organic molecules. Debate or assume roles that scientists play in changing the directions of chemical research. Friedrich Wöhler may be one scientist to refer to. (116-7)

Paper and Pencil

- Address the problem of ozone depletion. This is not a problem with a single correct solution, but once evidence is assessed, decisions must be made and measures taken. With evidence, describe a possible solution. (116-7)
- Research and report on Canadian Raymond Lemieux and the synthesis of sucrose. (116-7)

Resources/Notes

Video

- *The Atmosphere* (20976)

Classifying Organic Compounds
6 hours

Outcomes

Students will be expected to

- classify various organic compounds by determining to which families they belong, based on their names or structures (319-7)

Elaborations—Strategies for Learning and Teaching

Students should classify alkanes, alkenes, alkynes, cycloalkanes, aromatics, and organic halides. They should classify alcohols, ethers, aldehydes, ketones, carboxylic acids, and esters. This should do activities/experiemtns to help classify.

If teachers have spent time on the typical bonding of carbon, hydrogen, nitrogen, and oxygen, classification should be easier for students. Students' general spatial awareness and understanding of chemical bonds might be developed by using model kits.

Teachers should create an Organic Chemistry Passport, and students could rotate through the following organic compound centres or stations (described below: a) composition of hydrocarbons and derivatives, b) bonding and electron dot diagrams, c) molecular model activities, d) benzene and related compounds, e) paper and pencil activities, f) defining and identifying functional groups, and g) computer activities. Teachers could develop each centre so that it can be checked by each student and verified by the teacher to ensure that the student has a plan to follow. Separate folders of information on the tasks work well and help students organize. Because of different learning styles, a variety of classification activities helps all students learn.

a) Students could look at the composition of hydrocarbons and derivatives through a classification activity based on names and structures. They would have an opportunity to recognize the need for classification schemes and be given time to devise their own schemes. Students could work in groups whose task is to organize into categories cards that contain the structures of alkanes, alkenes, alkynes, cycloalkanes, aromatics, and organic halides. They could compare the structures on the cards and group them into six different groups according to their similarities. Students should name all the prefixes for one to ten carbons in a compound or alkyl group. The hydrocarbon prefixes could be listed and the connection made between the prefix and the number of carbon atoms. Teachers could remind students of familiar hydrocarbon molecules such as methane, propane, and octane. Students should spend time on the International Union of Pure and Applied Chemistry (IUPAC) naming system for branched hydrocarbons and those with double and triple bonds.

b) Students could do an activity that looks at organic compounds and bonding, and then draw electron dot diagrams showing the bonding in alkanes, alkenes, alkynes, aromatics, cycloalkanes, and organic halides.

c) Students could use molecular models for the same groups as in the bonding activity. They could draw bonds and use molecular models for hydrocarbons and their derivatives.

Classifying Organic Compounds

6 hours

Tasks for Instruction and/or Assessment

Journal

- Compare and contrast aldehydes and ketones. (319-7)

Paper and Pencil

- Draw electron dot diagrams for seven compounds that you randomly draw from the deck of cards on alkanes, alkenes, alkynes, cycloalkanes, aromatics, and organic halides. (319-7)
- Make a chart of the classes of organic compounds. For each, include the class, functional group, and an example. (319-7)
- Make a chart to compare different classes of organic compounds based on the same prefix. For example, your compounds might be propane, 1-propanol, propanoic acid, propanone, and dimethyl ether. The chart should include the formula, melting point, boiling point, and density of each compound. (319-7)
- What is an alkane? an alkene? an alkyne? (319-7)
- Draw the different representations of benzene. (319-7)
- How are organic compounds classified? (319-7)
- List elements that can bond to carbon in organic compounds. (319-7)

Presentation

- Pass in your Organic Chemistry Passport. (319-7)

Resources/Notes

Experiment

Chemistry 11 and Chemistry 12: A Teaching Resource
- Activity 22: Classifying Organic Compounds

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)
- Chapter 9.3: Classifying Hydrocarbons, pp. 331–362
- Investigation 9-C: Structures and Properties of Aliphatic Compounds, p. 359

Video

- *Synthesis of an Organic Compound* (V9072)

Classifying Organic Compounds *(continued)*

Outcomes

Students will be expected to

- classify various organic compounds by determining to which families they belong, based on their names or structures (319-7)

Elaborations—Strategies for Learning and Teaching

d) In the benzene and related compounds centre, molecular kits could be provided so students could make three-dimensional models of the structures and examine bond angles and shape. Students could build and describe the bonding in benzene. They could define aromatics as compounds that have a benzene ring as part of their structure and, given their names, draw structures for simple monosubstituted and disubstituted benzene.

e) The centre of paper-and-pencil activities could include exercises, diagrams, formulas, names, and charts about hydrocarbons, hydrocarbon derivatives, aromatics, and functional group names and structures. This centre might be done in stages throughout the other centres because it includes all families, names, and structures.

f) Students should identify alcohols, ethers, aldehydes, ketones, carboxylic acids, organic halides, and esters from their names and the functional groups in their structural formulas. Planning this centre using a variety of formats from models, card classification, bonding, and charts keeps students learning by doing as opposed to memorization.

Teachers or students could prepare a set of playing cards for groups of four students to use for classifying organic compounds. Sets of cards that contain the structural formulas of a variety of organic molecules from different hydrocarbon families and the organic halides could be provided for the students to use as a reference. Students could use these cards to play games such as Concentration or Fish. Since the cards provide samples of different molecules within the same class, students should recognize a need for a systematic naming scheme. This activity uses reasoning skills and patterns to help with classification, and students feel in charge of their learning.

g) Computer activities could include completing a web quest, working on various organic sites, or doing a multimedia presentation of information on classification of organic compounds.

Once students have worked through the centres, teachers should help them consolidate their knowledge by a class overview of the organic compounds. Students might need this overview because of their different learning styles.

Classifying Organic Compounds *(continued)*

Tasks for Instruction and/or Assessment

Paper and Pencil / Presentation

- In small groups, create a concentration-, Jeopardy-, or memory-type game surrounding the naming or properties of organic chemicals you have studied to date. Swap games with your classmates to test the games and provide constructive feedback or suggestions for improvement. Use the Internet, if desired, as opposed to hand-drawn versions of the game. A variety of downloadable templates are available. (319-7)

Resources/Notes

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Chapter 10.1: Functional Groups, pp. 377–383
- Chapter 10.2: Single-Bonded Functional Groups, pp. 386–400
- Chapter 10.3: Functional Groups with the C=O Bond, pp. 402–419

Naming and Writing Organic Compounds

6 hours

Outcomes

Students will be expected to

- write the formula and provide the IUPAC name for a variety of organic compounds (319-5)

Elaborations—Strategies for Learning and Teaching

This section should be easier for students to follow once they have done the centres described in the Classifying Organic Compounds section. Students should name all the prefixes for one to ten carbons in a compound or alkyl group. They should write names and molecular formulas and draw structural formulas, complete structural diagrams, condensed structural diagrams, skeletal structural diagrams, and line diagrams using the IUPAC rules for the organic compounds they have been introduced to in the previous section.

Students could look at the bonding shapes around carbon atoms involved in single, double, or triple bonds. They could describe these bonding shapes. They could describe the composition, bonding, and structural formulas for aliphatic hydrocarbons. Students could write the general formulas for alkanes, alkenes, alkynes, cycloalkanes, and cycloalkenes. They could define and give examples of saturated and unsaturated hydrocarbons. They should name simple monosubstituted and disubstituted benzene structures.

Teachers could introduce this section with cards that contain structures of alcohols, ethers, aldehydes, ketones, carboxylic acids, and esters. Students should recognize that the presence of oxygen and its bonding arrangement with carbon and hydrogen influence the family to which the compound belongs. Familiar compounds such as ethanol, formaldehyde, acetic acid, and diethyl ether could be discussed. Students could look at the properties of these substances and gain an appreciation of the diversity and use of organic molecules.

Students should name and draw structures for derivatives of hydrocarbons with only one functional group: alcohols, ethers, aldehydes, ketones, carboxylic acids, organic halides, and esters. Organic halides could be multi-substituted. Branching of the parent chain should be limited to a methyl, an ethyl, a propyl, and an isopropyl alkyl group. Students could look at the same molecular formula for both an alcohol and ether and name and draw the compounds.

Naming and Writing Organic Compounds

6 hours

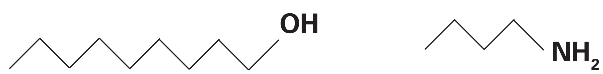
Tasks for Instruction and/or Assessment

Performance

- Design and present a flow chart, poem, story, or song to summarize the IUPAC rules for naming and writing organic compounds. (319-5)

Paper and Pencil

- Identify the compound and define the functional group from compound models made from a model kit. (319-5)
- Draw complete structural diagrams that show the difference between 1-propanol and ethyl methyl ether. (319-5)
- Name the following straight-chain alkanes: $C_{10}H_{22}$, C_3H_8, C_8H_{18}, C_4H_{10}. (319-5)
- Name the following organic compounds:



(319-5)

- Draw the structure of C_5H_{10}. Classify it. Explain your choice. (319-5)
- What is the chemical formula of an alkyne with 15 carbons? (319-5)
- Compare structural formulas with chemical formulas. Are there any advantages for either? (319-5)
- Draw structural formulas and give the molecular formulas for 2-pentanone, a solvent; butanoic acid, a component of butter; and chloroethene, used in plastics. (319-5)
- List the rules for assigning numbers to carbon atoms. (319-5)
- Using the molecular formula C_3H_8O, draw one structural formula for an alcohol and one for an ether. Name each one. (319-5)
- The names of aldehydes or organic acids do not always contain numbers indicating their position. Explain. (319-5)

Resources/Notes

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Chapter 9.1: Introducing Organic Compounds, pp. 321–323
- Chapter 9.3: Classifying Hydrocarbons, pp. 331–362
- Chapter 10.2: Single-Bonded Functional Groups, pp. 386–400
- Chapter 10.3: Functional Groups with the C=O Bond, pp. 402–419

Applications of Organic Chemistry
3 hours

Outcomes

Students will be expected to

- identify limitations of the IUPAC classification system and identify alternative ways of classifying to accommodate anomalies (214-2)
- distinguish between scientific questions and technological problems (115-1)
- select and use apparatus and material safely (213-8)

Elaborations—Strategies for Learning and Teaching

Students should identify IUPAC and non-IUPAC names for the same substance. Teachers could provide examples of common organic compounds for the students to observe. A discussion about the uses of the IUPAC name and common name might help the students understand how classifying can vary. Students could identify examples of the persistence of non-IUPAC names such as “acetone,” and “acetic acid.” They should identify problems with the IUPAC system.

Students should distinguish between science and technology questions and problems that deal with applications of organic chemistry. Students might distinguish between questions such as “How are polychlorinated byphenyls (PCBs) converted into dioxins?” and technological problems such as “How can we dispose of PCB-laden oils?” Students might suggest questions and problems related to organic chemistry and discuss them. They might suggest whether or not the use of Freon and leaded gasoline should be encouraged in developing countries.

Organic materials are susceptible to oxidation, while some inorganic materials are powerful oxidizers. Many organic materials are flammable, while others dissolve rubber or plastic or pass through cork. Many organic compounds are highly toxic. Storage of organic compounds can be a challenge. Given this information, teachers and students should consider how to handle storage of all their chemicals. Teachers and students may reference WHMIS and their resources.

Applications of Organic Chemistry

3 hours

Tasks for Instruction and/or Assessment

Performance

- What apparatus is needed to do a boiling point experiment? (213-8)
- Select and safely use the apparatus and materials for a boiling point experiment in the laboratory. (213-8)

Paper and Pencil

- Generate your own example of a scientific question or technological problem on an application of organic chemistry. Trade with another student and suggest answers to each other's question or problem. (115-1, 214-2)

Resources/Notes

- How would you transport organic materials? (213-8)
- WHMIS
- Material Safety Data Sheets (MSDS)

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)
- Safety in your Chemistry Laboratory and Classroom, pp. x–xiii
- ThoughtLab: Problem Solving with Organic Compounds,p. 451

Applications of Organic Chemistry *(continued)*

Outcomes

Students will be expected to

- provide a statement that describes the relationship between bonding and organic chemistry investigated in light of the link between data and the conclusion (214-11)
- evaluate the design of a technology and the way it functions, on the basis of a variety of criteria that they have identified themselves (118-4)
- identify and apply criteria, including the presence of bias, for evaluating evidence and sources of information on an organic topic (214-9)

Elaborations—Strategies for Learning and Teaching

Students should describe carbon's unique bonding capability and how this is the basis of organic chemistry. They might examine the effect structure has on the boiling points of several alcohols in a simple laboratory experiment and thus discover the existence of isomers. In planning for this experiment, students could examine Material Safety Data Sheets (MSDS) for the alcohols involved and outline safe laboratory procedures. Of primary concern is the flammability of the alcohols. Do not use flames. Alcohols of progressively higher molecular mass could be used, but attempts could be made to include at least a couple of sets of isomers. For example, isopropyl alcohol and n-propyl alcohol are readily available. Tert-amyl and n-amyl alcohols are another possibility. For each alcohol, students could determine the molecular and structural formulas. After finding the boiling points of the alcohols, students could address questions such as:

- How does the structure of the chain affect the boiling point?
- Using what you know about intermolecular forces, explain these results.

Students could evaluate various environmental aspects of the impact of organic chemistry; for example, environmental impact of various refrigerants and the function of a herbicide that is not toxic to humans and does not accumulate in the environment.

Students should evaluate information and give their informed opinions based on evidence from an article on an organic chemistry topic. This article could be one they have found in the media or on the Internet or through STSE questions. In groups of two to four, students might set criteria to determine whether the evidence and the sources of information are reliable, unbiassed, clearly explained, and specific. Students could analyse the risks and benefits of using insecticides. A good historical example is dichlorodiphenyltrichloroethane (DDT). Students could find provincial regulations governing the emission outputs of vehicles. They might continue their STSE assignment by preparing articles and questions about organic chemistry topics that could be controversial but useful.

Applications of Organic Chemistry *(continued)*

Tasks for Instruction and/or Assessment

Paper and Pencil

- Evaluate the environmental impact of a herbicide on food production. Identify and evaluate the criteria that you select. (118-4, 214-9)
- Compare your results with those in a data book, such as *The Merck Index* or the *CRC Handbook of Chemistry and Physics*. Look up results for other alcohols. Evaluate your results and the data book's. Comment on trends. (214-11)

Resources/Notes

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Investigation 9-B: Comparing the Reactivity of Alkanes and Alkenes, pp. 350–351
- Investigation 9-C: Structures and Properties of Aliphatic Compounds, p. 359
- ThoughtLab: Comparing Intermolecular Forces, p. 380

Video

- *Organic Chemistry 2: Industrial Application* (20970)

Isomers in Organic Chemistry

2 hours

Outcomes

Students will be expected to

- define isomers and illustrate the structural formulas for a variety of organic isomers (319-6)

Elaborations—Strategies for Learning and Teaching

Students should have the opportunity to explore isomers by drawing structural formulas, using models to build isomers, and naming the isomers of a variety of organic molecules. Students should define and give examples of structural isomerism. They should be able to draw structural isomers of alkanes, alkenes, alkynes, and cyclic compounds up to ten carbons.

Teachers could have various models of isomers from the same chemical formula available for the students to see. Models described on an overhead transparency would show the class the structures and initiate discussion. From this, students could practise drawing and naming isomers. Through an activity, students could gain practice in making the models and drawing the structures.

If students have actually considered the effect that isomerism has on the properties of alcohols from the experiment on their boiling points, they should be able to extend this understanding to isomers of other organic families. They should be able to draw structural isomers E and Z (trans and cis) for alkenes. Opportunity should be provided for the students to draw, model, and name the isomers of a variety of organic molecules.

Isomers in Organic Chemistry

2 hours

Tasks for Instruction and/or Assessment

Paper and Pencil

- Draw two structural formulas for an alcohol with the molecular formula $C_4H_{10}O$. (319-6)
- Draw structural isomers for butane and for butene. (319-6)

Resources/Notes

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Investigation 9-A: Modelling Organic Compounds, p. 328
- Chapter 9.2: Representing Hydrocarbons, pp. 324–329
- Chapter 9.3: Classifying Hydrocarbons, pp. 331–362

Writing and Balancing Chemical Equations

3 hours

Outcomes

Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

Students should know what types of reactions various classes of organic compounds will undergo and be able to predict what the products will be. Students should draw structural diagrams of all organic reactants and products in addition, substitution, esterification, complete and incomplete combustion, and cracking reactions. Reactions should be limited to the formation of no more than two structural isomers. If more isomers are possible, students could indicate that this is so. Students should determine the name and structure of a missing reactant given an organic reaction with one reactant missing. They should predict the products of a chemical reaction based on the reaction type.

Teachers could introduce organic equations through a variety of different experiments in which students can examine the reactivity of organic molecules. For example, bromine water could be used to test for unsaturation, or esters could be made by condensing an alcohol with a carboxylic acid.

Appropriate safety equipment should be worn at all times. See *Science Safety Guidelines* for more information. Students might need demonstrations and information on safety for these labs. Due to the often strong odours of organic molecules, all experiments should be carried out with proper ventilation, and students should be required to follow all safety procedures. Some students might be too sensitive to the odours even to participate in the experiments, and special notification might be required if the school is deemed a scent-free environment.

An alternative might be to provide a list of scents and ask students how to make that smell. They should then develop balanced equations.

Writing and Balancing Chemical Equations

3 hours

Tasks for Instruction and/or Assessment

Performance

- Perform an ester experiment in the laboratory and write a report on it. (319-8)

Paper and pencil

- Design a checklist of safety procedures for the ester experiment. This list should check for your knowledge and application of the procedures. (319-8)
- Write a balanced chemical equation for the addition reaction involving hydrogen bromide and ethene. (319-8)
- Write a balanced chemical equation for the complete combustion of C_4H_{10}. (319-8)
- Write a balanced chemical equation for the substitution reaction involving one molecule of methane and one molecule of chlorine. (319-8)

Presentation

- Interview a person, in person or via e-mail, whose occupation involves organic chemistry. Determine an organic chemical reaction involved in their occupation and talk about the equation. (319-8)
- Discuss, in small groups, the following problems that face a research or industrial chemist:
  - How are products recognized and isolated?
  - How are yields optimized?
  - What commercial uses are there for the products made? (319-8)

Resources/Notes

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Chapter 9.3: Classifying Hydrocarbons, pp. 331–362
- Chapter 10: Hydrocarbon Derivatives, pp. 377–419

Polymerization

1 hour

Outcomes

Students will be expected to

- define problems to facilitate investigation of polymers (212-2)
- design an experiment identifying and controlling major variables (212-3)
- describe processes of polymerization and identify some important natural and synthetic polymers (319-9)

Elaborations—Strategies for Learning and Teaching

Students should find a polymer, define the substances needed to make it, and list problems associated with its formation, structure, and use.

Students should decide on a polymer problem to investigate. They could do research to design an experiment of the production of a polymer such as Plexiglas, nylon, Gortex, or polyvinylchloride (PVC). This is an organizational activity to plan, not to do, an experiment.

Students should define and outline the structures of monomers, polymers, and polymerization. They should identify addition and condensation polymerization reactions and the structural features that monomers must have in order for this to occur. Students could provide examples of polymerization in living or non-living systems. They could integrate their understanding of functional groups and reactivity and extend this to the production of polymers.

Polymerization

1 hour

Tasks for Instruction and/or Assessment

Performance

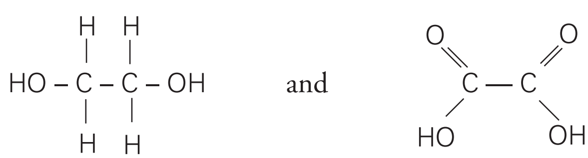
- Design an experiment to produce a polymer. What variables are there, and how might they be controlled? List any safety precautions that would have to be taken. (212-2, 212-3)

Journal

- If you could be any polymer, which polymer would you be? Explain. (212-2, 319-9)
- Write the autobiography of a functional group. (212-2, 319-9)

Paper and Pencil

- List some examples where polymers have replaced metals. What properties are polymers capable of having that makes them so useful? Are there any properties that might not be beneficial? Do this as a memo. (319-9)
- A simple polyester can be made from the reaction of



What type of polymerization is this? Write a structural formula for a portion of the polymer chain. (319-9)

Resources/Notes

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Chapter 11.1: Polymer Chemistry, pp. 427–435
- Chapter 11.2: Natural Polymers and Other Biomolecules, pp. 437–444
- Chemistry Bulletin: Degradable Plastics: Garbage That Takes Itself Out, p. 435

Appendix D: Memo Format

Risks and Benefits of Organic Compounds: STSE Perspectives

2 hours

Outcomes

Students will be expected to

- communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others (215-1)
- describe and evaluate the design of technological solutions and the way they function using scientific principles (116-6)
- analyse from a variety of perspectives the risks and benefits to society and the environment of applying organic chemistry knowledge or introducing a particular technology (118-2)
- develop, present, and defend a position or course of action on organic chemistry based on findings (215-5)

Elaborations—Strategies for Learning and Teaching

This section could be based on an STSE question prepared by groups of students as mentioned in So Many Compounds or on an organic molecule synthesized for commercial use. Either strategy covers the outcomes as a group.

Teachers could introduce students to different issues relating organic chemistry to their lives. These issues could also be presented by students at the end of the unit. Teachers could have students choose one organic molecule that is synthesized for commercial use. It could be a polymer, or it might belong to one of the families that were studied earlier. If the molecule contains functional groups that have not been studied in this unit, the students could research these groups.

The three outcomes 116-6, 118-2, and 215-5 are discussed as a group.

Students should undertake an independent research project and write a research paper about the following environmental impact(s) of a particular organic compound. They should follow appropriate research guidelines. The two-page research paper should include

- the structure of the compound
- the intended use of the compound
- a list and explanation of the benefits and risks to society and the environment according to its manufacturer
- a list and explanation of the benefits and risks to society and the environment according to other sources
- a recommendation on the basis of the risks and benefits whether this product should continue to be marketed
- a list of all reference materials used

These outcomes could be given to the students as guidelines for their paper. The students should locate additional resources on the Internet or at the local library. Time should be taken in class to examine the elements of a research paper. Examples should be used to show students how information is referenced in a paper. This is an opportunity to review various formats and conventions of research papers and reports. The purpose of the paper is to have the students experience the process of formulating a thesis and supporting it with evidence. *Secondary Science: A Teaching Resource* (1999) provides helpful suggestions for engaging students in science writing.

Risks and Benefits of Organic Compounds: STSE Perspectives

2 hours

Tasks for Instruction and/or Assessment

Paper and Pencil

- Freidrich Wöhler is the person who is considered to have first synthesized an organic chemical without use of living organisms. This occurred in the early 1800s but was not generally accepted by the scientific community until the 1870s. Today many thousands of organic chemicals are synthesized from crude oil on a routine basis and are used in all areas of life (foods, medicines, commerce, etc.). There are many advantages to being able to make specific compounds but there are also disadvantages (pollution of air or water, toxicity to humans and animals, etc.). Discuss the information, commenting on
  - risks and benefits to society and the environment
  - technological solutions involved
  - scientific principles involved (118-2, 116-6, 215-5)
- Undertake an independent research project on the environmental impact of an organic chemical and write a research paper. (116-6, 118-2, 215-5)

Presentation

- As a team, choose an organic chemistry-related issue and discuss how it is related to your life. Describe the impact of technology and express your opinion on the impact of your issue on society. Some suggestions are poisons, chemical warfare, starch, and proteins. Present this as a laboratory activity, a debate, or a talk accompanied with visuals. (213-7, 215-3, 117-4, 215-1)

Resources/Notes

Print Resource

- *Secondary Science: A Teaching Resource* (1999)

Risks and Benefits of Organic Compounds: STSE Perspectives *(continued)*

Outcomes

Students will be expected to

- select, integrate, and synthesize information from multiple sources including various print and electronic sources, and make inferences on this information (213-7, 215-3)
- debate the merits of funding specific scientific or technological endeavours and not others (117-4)

Elaborations—Strategies for Learning and Teaching

Students could be asked to prepare a presentation in which they discuss the features of a molecule of choice. The presentation should include visual aids in which the students build a model of their molecule and collect samples of products that contain the molecule. The presentation should discuss the history of the molecule, its means of production, its uses, and any risks associated with its use. The presentation could be designed as a boardroom presentation in which the students are trying to persuade shareholders to invest in the production of their molecule.

Students could research information on their molecules using recent publications and the Internet. Questions and answers should follow each presentation, with other students challenging the presenter if the presentation lacked details or credibility. Class members should act as if they have money to invest and want to know all the relevant information before making a choice.

The extent to which this activity proceeds will be limited by time and interests of the class, but the potential for extension is great. For example, the students could write grant proposals, forecast production costs, create budget summaries, monitor stock prices of actual investments, and investigate existing chemical research and development companies.

Risks and Benefits of Organic Compounds: STSE Perspectives *(continued)*

Tasks for Instruction and/or Assessment

Paper and Pencil

- Design assessment criteria for the presentation. Have the class arrive at consensus. (213-7, 215-3)
- Develop and defend your position on the development and use of CFCs and their replacements. (117-4)
- When chemical engineers are doing a cost-benefit analysis on a chemical they have just synthesized, what questions might they ask? Include the costs associated with using up our natural resources. (213-7, 215-3, 117-4)

Presentation

- Debate the positive and negative effects of an organic compound or a group of organic compounds. (117-4, 215-1)

Resources/Notes

Magazines

- *Chem 13 News*
- *Journal of Chemical Education*
- *Education in Chem*
- *ChemMatters*

Chemistry 12 Outcomes

Thermochemistry

Introduction

Energy is the essence of our existence as individuals and as a society. An abundance of fossil fuels has led to a world appetite for energy. There are pros and cons to using fossil fuels. To help us find alternative fuels, we have to explore the relationship between energy and chemistry. Thermochemistry includes energy changes that occur with physical and chemical processes. The study of energy production and the application of chemical change related to practical situations has helped society to progress.

Experiments are compulsaory in Chemistry 11 and students should have foty percent of their time in hands-on, minds-on exploration. Specific curriculum outcomes state which experiments should be done.

Focus and Context

Thermochemistry focusses on energy in various systems. Fuels for energy provide the context for student research and projects. These fuels could include energy for industry, energy from foods, or any other relevant context. This unit will help students to develop an interest in global energy issues and to appreciate the idea of possible solutions to a problem. It will also help them develop skills involving planning, recording, analysing, and evaluating energy changes. Doing lab work and performing calculations allows students to discuss their evidence and problem solving in order to consolidate their understanding of energy change.

Science Curriculum Links

Science 10 outcomes included balancing chemical equations. Heat and temperature were discussed in the weather unit. Chemistry 11 outcomes useful for this unit include measuring numbers of moles.

Curriculum Outcomes

STSE	Skills	Knowledge
Students will be expected to	*Students will be expected to*	*Students will be expected to*
114-5 describe the importance of peer review in the development of their knowledge about thermochemistry **116-4** analyse and describe examples where technologies were developed based on understanding thermochemistry **117-6** analyse why scientific and technological activities take place in a variety of individual and group settings **117-9** analyse the knowledge and skills acquired in their study of thermochemistry to identify areas of further study related to science and technology **118-2** analyse from a variety of perspectives the risks and benefits to society and the environment by applying thermochemistry **118-8** distinguish between questions that can be answered using thermochemistry and those that cannot, and between problems that can be solved by technology and those that cannot **118-10** propose courses of action on social issues related to science and technology, taking into account an array of perspectives, including that of sustainability	**212-3** design a thermochemistry experiment identifying and controlling major variables **212-8** evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making **213-6** use library and electronic research tools to collect information on a given topic **213-7** select and integrate information from various print and electronic sources or from several parts of the same source **214-3** compile and display evidence and information on heats of formation in a variety of formats, including diagrams, flow charts, tables, and graphs **214-6** apply one of the methods of predicting heats of reactions to their experimentally determined values **214-15** propose alternative solutions to solving energy problems and identify the potential strengths and weaknesses of each **215-4** identify multiple perspectives that influence a science-related decision or issue involving their thermochemistry project **215-6** work co-operatively with team members to develop and carry out thermochemistry experiments	**324-1** write and balance chemical equations for combustion reactions of alkanes, including energy amounts **324-2** define endothermic reaction, exothermic reaction, specific heat, enthalpy, bond energy, heat of reaction, and molar enthalpy **324-3** calculate and compare the energy involved in changes of state in chemical reactions **324-4** calculate the changes in energy of various chemical reactions using bond energy, heats of formation and Hess's law **324-5** illustrate changes in energy of various chemical reactions, using potential energy diagrams **324-6** determine experimentally the changes in energy of various chemical reactions **324-7** compare the molar enthalpies of several combustion reactions involving organic compounds

Thermochemistry STSE
3 hours

Outcomes

Students will be expected to

- analyse why scientific and technological activities take place in a variety of individual and group settings (117-6)
- analyse from a variety of perspectives the risks and benefits to society and the environment by applying thermochemistry (118-2)
- compare the molar enthalpies of several combustion reactions involving organic compounds (324-7)
- write and balance chemical equations for combustion reactions of alkanes, including energy amounts (324-1)
- distinguish between questions that can be answered using thermochemistry and those that cannot, and between problems that can be solved by technology and those that cannot (118-8)
- propose courses of action on social issues related to science and technology, taking into account an array of perspectives, including that of sustainability (118-10)

Elaborations—Strategies for Learning and Teaching

The outcomes listed here are discussed in terms of an STSE ongoing project for students. References to this project occur throughout the unit. The section Science Decisions wraps up this project or can be used as a separate discussion. The outcomes are addressed as an STSE question with connections from the Organic Chemistry unit in Chemistry 11. Chemical experiments that complement outcomes should be done as part of this unit.

Teachers should assign a research project for this unit based on an instruction such as “Describe a scenario where a community or family has to select a fuel and justify which is best for a long-term plan.” Students might work in groups for their research project. Teachers should refer to the research project throughout the unit.

Teachers might begin by asking students to make a list of fossil fuels, specifically alkanes, describe where they see the fuels used, and write combustion equations for the fuels.

Students and their teachers should discuss the impact of fuel on science and technology. Analysis of the fuels impact from different perspectives, such as health, economic, environmental safety, and chemical, could refer to the fuel’s benefits and risks. Perhaps students could make a list to help with their planning.

Students should balance complete alkane combustion reactions using up to ten carbon atoms. Equations, including molar enthalpies of possible combustion reactions, could be identified. As students become familiar with energy and thermochemistry throughout this unit, they could add to their project information. The complete combustion of hydrocarbons produces carbon dioxide (CO_2), water (H_2O) and energy. Showing students the molar enthalpies will help them realize the importance of energy.

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l) + 890\text{ kJ}$$

$$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l) + 5752\text{ kJ}$$

Students should make decisions based on questions that they have identified, and on answers that have supporting evidence. As students look at their proposal in terms of science, technology, society, and the environment, they will gain confidence in their proposal, and they will have more unanswered questions.

Thermochemistry STSE

3 hours

Tasks for Instruction and/or Assessment

Performance

- Which has more heat: 250 mL of water in a mug at 40 °C or 200 mL of water in a flask at 40 °C? Qualitatively and quantitatively explain your result. (118-8)

Journal

- In your science log, respond to the following questions:
  - Explain why, on a hot, summer day at the beach, the sand can be unbearably hot on bare feet, yet the water is very cold.
  - What happens when direct sunlight is blocked by a cloud? How does this affect the sand's temperature versus the water's? (324-7)

Paper and Pencil

- Write a balanced chemical equation for the combustion reaction of each of these alkanes: methane, ethane, propane, butane, and octane. (324-1)
- Look up the molar enthalpies of the combustion of butane and octane. What do they have in common? (324-7)

Presentation

- Present your project using multimedia, audiovisual, or other suitable format. Present your scenario to the class. The following questions might be helpful with your thinking:
  - What are the characteristics of a good chemical fuel?
  - What makes your fuel a good choice?
  - What is the most common method of producing your fuel?
  - What are some advantages of your fuel? Some disadvantages?
  - Outline the process of your fuel's development.
  - Can you find information on the efficiency of your fuel?
  - What impact will the fuel have on the local environment?

  (117-6, 118-2, 118-8, 118-10, 324-7, 324-1)

Portfolio

- Include thermochemisty activities, assignments, and experiments in your portfolio. (118-10)

Resources/Notes

Experiment

Chemistry 11 and Chemistry 12: A Teaching Resource
- Activity 23: Measuring the Energy Given Off by a Burning Candle

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)
- Chapter 9.3: Classifying Hydrocarbons (reactions of alkanes), pp. 340–343
- Chapter 16.2: Enthalpy Changes, pp. 639–649
- Chapter 17.3: Fuelling Society, pp. 692–702

Print Resource

- *CRC Handbook of Chemistry and Physics*

Videos

- *Energy Choices* (23305)
- *Reactions and their Driving Forces* (20977)

Experiments with Energy Changes
7 hours

Outcomes

Students will be expected to

- define endothermic reaction, exothermic reaction, specific heat, enthalpy, bond energy, heat of reaction, and molar enthalpy (324-2)
- calculate and compare the energy involved in changes of state in chemical reactions (324-3)
- design a thermochemistry experiment identifying and controlling major variables (212-3)

Elaborations—Strategies for Learning and Teaching

Teachers should ensure that specific heat capacity, molar enthalpy, endothermic, and exothermic changes are defined. Bond energy, enthalpy, and heat of reaction should be discussed. They will come up again later in this unit.

Students should perform an experiment in the laboratory on specific heat capacity of a metal and heat of combustion. They should select appropriate materials to be used in the experiment. They should identify the variables being used in the experiment.

Teachers might begin by having students pose questions about energy changes in a system. Students should discuss heating and cooling and phase changes in terms of forces between particles, particle movement, heat content, and changes in potential energy. Teachers could identify these areas if they are not mentioned by students. Changes to particle movement in systems in terms of change in temperature could be introduced. Changes in potential energy in matter could be discussed.

Teachers could ask students for everyday examples involving endothermic and exothermic changes. Examples might include heating and freezing of ice, hot and cold packs, evaporation and condensation of water, and production and decomposition of ammonia.

Students should write thermochemical equations to represent enthalpy notation, ΔH_c and ΔH_f. Teachers should include calculations involving the heat gained or lost from a system using formulas $q = mc\Delta T$ and $q = n\Delta H$. For the heat of combustion activity, substances that might be used are a burning candle or various nuts, such as peanuts, Brazil, or walnuts.

Experiments with Energy Changes

7 hours

Tasks for Instruction and/or Assessment

Performance

- Design and do a lab on specific heat capacity of a metal and heat of combustion. (212-3)

Journal

- A Scottish chemist, Joseph Black (1728–1799), differentiated between temperature and thermal energy. Discuss how these are different. Give an example of an experiment to show that two objects at the same temperature do not necessarily have the same thermal energy. (324-2, 212-3)

Paper and Pencil

- Distinguish between temperature and heat by relating these to the energy of the atoms and molecules. (324-2)
- Calculate the heat gained or lost from the following system:
  - A cold piece of metal having a mass of 100 g, originally a –30 °C, was dropped in 300 g of warm water at 35 °C. The temperature of the water went down to 32 °C. Calculate the specific heat of that metal. (324-2, 324-3)
- $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$
  When 50.0 mL of 1.00 mol/L HCl(aq) and 50.0 mL of 1.00 mol/L NaOH(aq) are mixed in a Styrofoam cup calorimeter, the temperature of the resulting solution increases from 21.0 °C to 27.5 °C. Calculate the heat of this reaction measured in kilojoules per mole of HCl(aq). (324-2, 324-3)
- Linda wants to know how much heat energy is released when 25 kg of steam at 100 °C is cooled to 25 kg of ice at –15 °C. Calculate the total heat energy released. (324-3)
- Heat lost equals heat gained. Explain this assumption. (324-3)
- Liquid water turns to ice. Is this endothermic or exothermic? Explain. (324-2)
- Explain what is meant by the following terms: specific heat, heat of reaction, and molar enthalpy. (324-2)
- What would cause a more severe burn: 100 g of water at 100 °C or 100 g of steam at 100 °C. Give reasons to support your decision. (324-3)
- Explain how a cold pack works. (324-2, 212-3)

Resources/Notes

Experiment

Chemistry 11 and Chemistry 12: A Teaching Resource

- Activity 24: Measuring the Energy Transferred by Copper Pennies

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Chapter 16.1: Temperature Change and Heat, pp. 627–637
- Chapter 16.2: Enthalpy Changes, pp. 639–649
- Chapter 16.3: Heating and Cooling Curves, pp. 651–656
- Investigation 17-B: The Enthalpy of Combustion of a Candle, pp. 671–672

Experiments with Energy Changes *(continued)*

Outcomes

Students will be expected to

- work co-operatively with team members to develop and carry out thermochemistry experiments (215-6)
- evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making (212-8)
- determine experimentally the changes in energy of various chemical reactions (324-6)
- analyse the knowledge and skills acquired in their study of thermochemistry to identify areas of further study related to science and technology (117-9)
- propose alternative solutions to solving energy problems and identify the potential strengths and weaknesses of each (214-15)

Elaborations—Strategies for Learning and Teaching

Students should do a heat of fusion experiment involving either ice or wax. A heat of fusion chart might be useful here to give students other choices. They might look at theoretical situations to determine what mass of a fuel must be burned to produce a given amount of energy. For example, by using the molar heat of combustion of methane, students could determine the mass of methane required to change the temperature of 250 g of water by 20 °C.

Students should calculate the total heat required for a multi-step process such as heating 50 g of ice at –20 °C to steam at 120 °C.

Student should do an experiement involving energy changes to determine experimentally the changes in energy. Students could draw and label a heating/cooling curve that shows changes in kinetic versus potential energy. Students could explain in words what is happening with the heat and interpret, with words, various curves. Teachers might discuss with students the motion of particles as the substance undergoes a temperature change, and relate each phase to the kinetic theory of matter.

Students should explore practical situations involving heat and energy transfer, such as a fire in a fireplace, solar collectors, eating food to fuel our bodies, or photosynthesis.

Students should identify science and technology areas that use energy and thermochemistry kowledge and skills. Students should propose solutions to problems perhaps their STSE project) with suggestions as to the pros and cons of each.

Experiments with Energy Changes *(continued)*

Tasks for Instruction and/or Assessment

Performance

- With a partner, design an experiment to calculate the molar heat of solution of NH_4Cl and of NaOH. Include safety issues that should be addressed. After your plan is approved, carry out your procedure and collect evidence (data) and report your findings. (215-6, 212-8)
- Select and use appropriate equipment to make an inexpensive hand warmer. (Hint: Use these substances: powdered iron, H_2O, NaCl, and vermiculite.) Design your experiment. Consider safety precautions. If approval is obtained, do this experiment. Have someone test your results. (215-6, 212-8, 214-15, 117-9)
- Do a heat of fusion experiment. (215-6)

Journal

- The calorimeter is a basic instrument for measuring heat transfer. Explain what a calorimeter is, how it measures heat transfer, and how it works. (324-6)

Paper and Pencil

- As you plan one of your experiments for this unit, list the skills and knowledge needed to perform it properly. (117-9)
- Report your experiment findings in chart form. (324-6, 117-9)
- Define a practical problem with an energy change. Propose a solution. (214-15)

Resources/Notes

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Chapter 17.1: The Technology of Heat Measurement, pp. 661–675
- Investigation 17-A: Determining the Enthalpy of a Neutralization Reaction, pp. 668–669

Thermochemistry and Potential Energy

2 hours

Outcomes

Students will be expected to

- illustrate changes in energy of various chemical reactions, using potential energy diagrams (324-5)
- compile and display evidence and information on heats of formation in a variety of formats, including diagrams, flow charts, tables, and graphs (214-3)

Elaborations—Strategies for Learning and Teaching

Teachers should ensure that calculations in energy include identifying exothermic and endothermic processes from the sign of ΔH , from thermochemical equations, and from labelled enthalpy / potential energy diagrams as well as labelling enthalpy diagrams given either the ΔH for a process or a thermochemical equation. Teachers might show examples that students are considering for their research project. There should be discussion and diagrams involving catalysts both as a reaction enhances and reaction inhibitors should occur.

Teachers should be sure to include a standard heat of formation table to predict heat of reaction. Students should be able to write thermochemical equations including the quantity of energy exchanged, given either the value of ΔH or a labelled enthalpy diagram, and vice versa.

All of these might be explored through written explanations with the diagrams. Sample tables and graphs are useful visual tools that might help students to clarify the concepts. Whether the diagrams are prepared by hand or computer, the presentation must focus on clarity, content, and readability for the understanding of others.

Thermochemistry and Potential Energy
2 hours

Tasks for Instruction and/or Assessment

Journal

- What types of potential energy have I used during this day? Make a chart. (214-3)
- As a living person, my energy exchange position is exothermic. Discuss this statement. (324-5, 214-3)

Paper and Pencil

- Draw and label a potential energy (enthalpy) diagram for each of the following:
  - exothermic reaction
  - endothermic reaction
  - inhibitor (negative catalyst) involved in a biochemical reaction
  - catalyst added to the exothermic reaction (324-5, 214-3)
- Look at various potential energy diagrams showing heat content of products and of reactants. Draw and interpret the potential energy graphs and determine whether the reaction is exothermic or endothermic. Identify the reactants and products, and determine the amount of energy involved. Draw and correctly label the axis. Write a verbal interpretation. (324-5, 214-3)
- Rewrite the following thermochemical equations into ΔH notation:

  $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g) + 197.8\ KJ$

  $H_2O_2(g) \rightarrow H_2O(l) + \frac{1}{2}\ O_2(g) + 98\ KJ$

  $CaCO_3(s) + 178\ KJ \rightarrow CaO(s) + CO_2(g)$

  $C_5H_{12}(g) + 8O_2(g) \rightarrow 5CO_2(g) + 6H_2O(g) + 90\ KJ$

  $N_2(g) + 2O_2(g) + 67.8\ KJ \rightarrow 2NO_2(g)$
- Rewrite the above equations for 1 mole of the underlined compound.

Presentation

- For a selected reaction, make the case that the Law of Conservation of Energy has been upheld. (324-5, 214-3)

Resources/Notes

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Chapter 16.2: Enthalpy Changes, pp. 639–650
- Table E.13: Standartd Molar Enthalpies of Formation, p. 848

Video

- *Introduction to Reaction Kinetics* (V9075)

Bonding and Hess's Law
6 hours

Outcomes

Students will be expected to

- calculate the changes in energy of various chemical reactions using bond energy, heats of formation, and Hess's Law (324-4)
- apply one of the methods of predicting heats of reactions to their experimentally determined values (214-6)
- analyse and describe examples where technologies were developed based on understanding thermochemistry (116-4)

Elaborations—Strategies for Learning and Teaching

Teachers should include the following in these kinds of calculations: the method of adding chemical equations and corresponding enthalpy changes to compute the enthalpy change of the overall process, Hess's Law, different ways of determining ΔH , average bond energy, heats of formation, use of calorimeters, and bond energies to calculate the enthalpy change for an overall process.

Students should conduct a Hess's Law experiment.Before doing their experiment involving Hess' Law, students should be aware of the instruments involved in their experiment. Students could explore new instruments and technologies that would help them to do the experiment more accurately and efficiently.

For example, teachers might start with propanol. Calculate the total energy required to break the compound into atoms. Students could calculate the overall energy change for the reaction, which is the heat of combustion reaction for propanol. This might be a good application to include in students' ongoing STSE research projects. Another lab to include is the steps to make MgO.

Students should explain or describe various examples used in technology that are based on thermochemistry.

Students might address the question "Is Hess's Law useful?" and give reasons for their answers. Teachers might point out that Hess's Law could be used to determine ΔH of a reaction that otherwise might be too difficult, expensive, or dangerous to perform.

Bonding and Hess's Law

6 hours

Tasks for Instruction and/or Assessment

Performance

- Conduct an experiment on Hess's Law. (324-4)
- Demonstrate correct use of chemical disposal after doing a Hess's Law experiment. (324-4, 214-6, 116-4)

Journal

- It is very important to wait for a substance to obtain room temperature before finding the mass. Explain this statement. (116-4)
- Define, showing an example, $\Delta H°_{(f)}$.

Paper and Pencil

- Given the following reactions and $\Delta H°_f$ values,

  $2NH_3(g) + 3N_2O(g) \rightarrow 4N_2(g) + 3H_2O(l)$ $\Delta H°_f = -1012kJ$

  $2N_2O(g) \rightarrow 2N_2(g) + O_2(g)$ $\Delta H°_f = -164kJ$ (324-4)

  calculate ΔH, using Hess's Law, for

  $4NH_3(g) + 3O_2(g) \rightarrow 2N_2(g) + 6H_2O(l)$
- From your knowledge of standard states and from an enthalpy of formation chart, list the standard enthalpy of formation of each of the following substances:

  a) $Cl_2(g)$
  b) $H_2O(l)$
  c) $C_3H_8(g)$
  d) $Na(s)$
  e) $H_2O(g)$
  f) $P_4(s)$ (324-4)
- Calculate $\Delta H°_{fxn}$ for the following reaction:

  $2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l)$ (324-4)
- Calculate the heat of formation, $\Delta H°_{fxn}$, of NO_2 in this reaction:

  $N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$ $\Delta H = +16.2kJ$ (324-4)
- Using bond energies, calculate $\Delta H°_{fxn}$ for the following reaction:

  $C_5H_{12}(l) + PO_2(g) \rightarrow 5CO_2(g) + 6H_2O(g)$ (324-4)

Resources/Notes

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Chapter 17.2: Hess's Law of Heat Summation, pp. 677–691
- Investigation 17-C: Hess's Law and the Enthalpy of Combustion of Magnesium, pp. 682–683

Video

- *Lab Sense: Lab Safety for Science Students* (V1714, 21793)

Science Decisions Involving Thermochemistry

3 hours

Outcomes

Students will be expected to

- describe the importance of peer review in the development of their knowledge about thermochemistry (114-5)
- use library and electronic research tools to collect information on a given topic (213-6)
- select and integrate information from various print and electronic sources or from several parts of the same source (213-7)
- identify multiple perspectives that influence a science-related decision or issue involving their thermochemistry project (215-4)

Elaborations—Strategies for Learning and Teaching

Teachers could use these outcomes as a part of their students' research projects as identified in the STSE section, or as a separate discussion.

Students, could look at their peer's projects or scientific information and identify and describe sources of energy including present sources and possible new ones.

Examples might be nuclear, hydrogen, biomass (for example, wood), garbage, coal, peat, hydro, petroleum, natural gas, wind, and solar. Groups of two to four students could identify the influence science has on the development of the energy source by collecting information and presenting it to their peers. Other groups could question the development and the plans for the energy.

For their STSE research project or for a particular question the class wishes to discuss, students should collect information through their library using books and electronic research tools.

Students should cite the evidence in their research to support their positions. They should address the credibility, reliability, and specificity of their sources. For example, is a government source more or less believable than a consumer source? Suggested perspectives include governments, industry, industrial labour force, and consumers. Teachers and students should go to lrt.EDnet.ns.ca/PD/pd_curr_it.shtml to look for advice on how to evaluate a website. Web literacy, including an awareness of possibilities for misinformation, must be considered an integral part of web usage.

Students might present their findings not as a written paper but as a speech, brochure, short story, cartoon, or whatever form they choose. Their presentations should give the class an overview of possibilities when deciding issues based on science.

Science Decisions Involving Thermochemistry

3 hours

Tasks for Instruction and/or Assessment

Journal

- Why do you think it is helpful to fill your thermos bottle with hot water before filling it with a hot beverage? (114-5, 215-4)
- Fire in a fireplace is started by lighting crumpled paper under logs with a match. Explain the energy transfers using the terms **potential energy**, **kinetic energy**, **kindling temperature**, **system surroundings**, **endothermic**, and **exothermic**. (213-6, 213-7)

Paper and Pencil

- Select one of the following energy sources and collect and organize information about it: coal, petroleum, natural gas, sun biomass (for example, wood), synthetic fuels, nuclear hydrogen, seed oil, methanol, geothermal (heat pumps), and bituminous sands. Describe the science needed to commercially develop the energy source. (213-6, 213-7)
- Prepare a newspaper article about your energy source and its potential for energy production. Include information in your article about your energy source, such as its useable lifetime as a commercial source, impact on the environment, appeal to an individual consumer, and appeal to a community of consumers. (114-5, 213-6, 213-7, 215-4)
- Consider climatic, economic, and supply factors in your search for an energy source for the future. Include these in the research project that you began at the beginning of this unit. (114-5, 213-6, 213-7, 215-4)

Resources/Notes

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- ThoughtLab: Comparing Energy Sources, p. 701
- Chemistry Bulletin: Hot Ice, p. 695

Solutions, Kinetics, and Equilibrium

Introduction

Investigation of change in the context of solutions helps students to develop their understanding about mixtures, solutions, bonding, and stoichiometry. This investigation leads to factors that affect the rates of chemical reactions, chemical equilibrium, and a quantitative treatment of reaction systems. The balance of opposing reactions in chemical equilibrium systems has issues relating to commercial or industrial production.

Experiments are compulsaory in Chemistry 11 and students should have foty percent of their time in hands-on, minds-on exploration. Specific curriculum outcomes state which experiments should be done.

Focus and Context

Many factors affect the rate of chemical reactions. Reactions can be described as dynamic equilibrium systems by criteria, equations, calculations, concentrations, and experiments within the context of everyday phenomena. This is the focus here. The context might be hemoglobin at high altitudes, ammonia in the Haber process, $CaCO_3$ in caves, acids corroding metals, sodium carbonate in the Solvay process, or any other relevant context.

Problem-solving skills are used throughout this unit. Identifying variables and performing experiments to test equilibrium shifts and reaction rates are valuable to understanding this unit.

Science Curriculum Links

In Science 10, students will have studied interpreting and balancing chemical equations. Chemistry 11 introduced ions, ionic compounds, and molecular structure, as well as measuring amounts in moles. In Chemistry 12, before doing equilibrium, the concentration of solutions should be addressed.

Curriculum Outcomes

STSE	Skills	Knowledge
Students will be expected to	*Students will be expected to*	*Students will be expected to*
116-2 analyse and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology **116-4** analyse and describe examples where technologies were developed based on scientific understanding **117-7** identify and describe science- and technology-based careers related to solutions and equilibrium	**212-9** develop appropriate sampling procedures for equilibrium expressions **213-1** implement appropriate sampling procedures **213-5** compile and organize solution data, using appropriate formats and data treatments to facilitate interpretation of solubility **214-10** identify and explain sources of error and uncertainty	**ACC-1** identify, through experiments and graphing, factors that affect the rate of the reaction **ACC-2** describe collision theory and its connection to factors involved in altering reaction rates **ACC-3** describe a reaction mechanism and catalyst's role in a chemical reaction **323-3** define the concept of equilibrium as it pertains to solutions **323-4** explain solubility, using the concept of equilibrium **323-5** explain how different factors affect solubility, using the concept of equilibrium **323-6** determine the molar solubility of a pure substance in water **323-7** explain the variations in the solubility of various pure substances, given the same solvent **323-8** use the solubility generalizations to predict the formation of precipitates

Concentration, Properties, and Solubility

6 hours

Outcomes

Students will be expected to

- compile and organize solution data, using appropriate formats and data treatments to facilitate interpretation of solubility (213-5)
- determine the molar solubility of a pure substance in water (323-6)

Elaborations—Strategies for Learning and Teaching

Students should do an experiment to plot a solubility curve. This should include plotting the average data of the class. This includes determining the concentration of solutions.

Students might begin this unit by listing what they know about solutions in their lives. They might question similarities and differences between solutions and terms they have heard before. From a simple demonstration during class, the general properties of a solution could be identified and discussed. Students could make a chart of the properties and the evidence to support the properties. Conductivity could be used here to determine electrolytes and non-electrolytes. Suspensions such as milk might be discussed.

Teachers should give opportunities for students to make generalizations and apply the properties of solubility. Students should explain and give examples of solutes, solvents, solutions, diluted, concentrated, saturated, unsaturated, electrolytes, non-electrolytes, and intermolecular forces of attraction between solute particles and between solvent particles.

Crosswords, puzzles, diagrams, and activities could be helpful in the understanding of the solubility terms. These could be obtained from various chemistry magazines; for example, *Chem 13 News*. Students could design their own and share them with others. Diagrams showing the interaction between solute and solvent particles during the solution process could be helpful.

Concentration, Properties, and Solubility

6 hours

Tasks for Instruction and/or Assessment

Performance

- Prepare 1.0 L of a 0.50 M solution of NaOH. (323-6, 213-5)
- Outline the steps required to prepare or dilute a solution to a specific concentration. (323-6, 213-5)
- Do a lab on solubility and plot the data. (323-6, 213-5)

Journal

- What do I need to know in order to calculate the molarity of a solution? Explain. (323-6)
- How do you prepare 500 ml of a 0.25 molar solution of sodium hydroxide? (213-5)

Paper and Pencil

- Which solution would contain the largest mass of solute? The solute is Na_2SO_4 and the solvent is H_2O. (323-6)
  a) 500 mL of 0.12 mol/L c) 199 mL of 0.67 mol/L
  b) 200 mL of 0.23 mol/L d) 1000 mL of 0.080 mol/L
- Which solution would contain the largest mass of solute? The solvent is H_2O. (323-6)
  a) 100 mL of 0.13 mol/L Na_2SO_4 c) 500 mL of 0.62 mol/L $AlCl_3$
  b) 100 mL of 0.42 mol/L NaCl d) 1200 mL of 0.87 mol/L AlF_3
- Calculate the molarity, mol/L, of a sodium chloride solution that has a volume of 300.0 mL and contains 25.0 g of NaCl. (323-6)

Presentation

- With a partner, take different-sized beakers and make a solution of $CuSO_4 \cdot 5H_2O$ of a known molarity. Pour the blue liquid into the beakers using various volumes. Answer the following questions:
  - Which contains the most solute? Explain.
  - Which has the highest concentration? Explain.
  - Do these solutions have the same or different number of ions per unit volume?
  - Are there varying depths of colour? (213-5, 323-6)

Resources/Notes

Experiment

Chemistry 11 and Chemistry 12: A Teaching Resource

- Activity 25: Properties of Solutions and Solubility

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Chapter 7.1: Types of Solutions, pp. 237–241
- Investigation 7-A: Plotting Solubility Curves, pp. 249–250

Print Resource

- *Chem 13 News*

Concentration, Properties, and Solubility *(continued)*

Outcomes

Students will be expected to

- compile and organize solution data, using appropriate formats and data treatments to facilitate interpretation of solubility (213-5)
- determine the molar solubility of a pure substance in water (323-6)

Elaborations—Strategies for Learning and Teaching

Students could do an experiment involving sodium hypochlorite ($NaClO$) used as household bleach. They could compare different brands of bleach to find the concentrations of each and determine a value for money. Teachers could use one brand of bleach and dilute it instead of using three types.

Students should experience doing experiments with specific kinds of calculations and experiences about molar solubility: (a) calculate the molar concentration in mol/L, of solutions based on mass or moles of the solute and volume of the solution, (b) make solutions in the laboratory and then calculate their concentrations, and (c) perform dilution experiments and relevant calculations. From this, molarity, mol/L, should be evident. These solutions could be saved for use in titrations with acids and bases.

The most common solutions are aqueous, and concentrations are expressed in units such as mL/L, mol/L, µg/mL (ppm), g/L, and mol/cm^3. Students could investigate the different ways that concentrations of solution are used in chemical, biological, medical, and industrial research. The different concentration units can be interconverted. A chart of solutions available to consumers with their concentrations might have interesting and useful information to discuss. Students could contribute to the development of such a chart by collecting information sheets from various sources, such as contact lens solution, pharmaceutical products, dental products, and pesticides. An example of use of a solution used in medicine is a solution of glucose and electrolytes given orally instead of intravenously to cholera patients. The solution is a simple combination of sodium chloride (3.5 g/L), trisodium citrate (2.9 g/L), potassium chloride (1.5 g/L), and glucose (20.0 g/L).

Concentration, Properties, and Solubility *(continued)*

Tasks for Instruction and/or Assessment

Paper and Pencil

- You have a solution of table salt in water. What happens to the salt concentration as the water is evaporating? Draw pictures to show the particles at different times during this process. (213-5, 323-6)
- You must make a solution of NaCl with equipment found in your chemistry lab. Describe in detail how you would make 500.0 mL of a 0.50 mol/L solution of NaCl. (323-6, 213-5)
- Draw a concept map to show the links among solutions, solvents, solutes, saturated, and electrolytes. Add other terms if needed. Write an explanation of the links among the terms. (323-6)

Presentation

- Make a chart of various solutions and their concentrations. (323-6)

Resources/Notes

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)
- Chapter 7.3: The Concentration of Solutions, pp. 255–270
- Investigation 7-B: Determining the Concentration of a Solution, p. 269
- Chapter 7.4: Preparing Solutions, pp. 271–276
- Investigation 7-C: Estimating Concentration of an Unknown Solution, pp. 274–275

Solubility and Precipitates

6 hours

Outcomes

Students will be expected to

- explain the variations in the solubility of various pure substances, given the same solvent (323-7)
- use the solubility generalizations to predict the formation of precipitates (323-8)

Elaborations—Strategies for Learning and Teaching

Students should do an experiment on solubility curves; plot the data and discuss error and source of error. This would be a good opportunity to discuss results and compare class data.

Students should investigate when a substance will dissolve in another substance. Teachers might wish to have a discussion about one of the following, relating it to how a solution forms: solubility of vitamins in water or oil; cleaning clothes with water and with tetrachloroethene, C_2Cl_4; and oil spills.

Students should be able to explain how ionic and molecular compounds form solutions, by relating solutions to intermolecular forces and forces of attraction. Situations such as salt heated on a stove or soda pop in the refrigerator might be used as examples. Predictions might include whether a given solute will dissolve in a given solvent. Teachers should include discussions about solutions as mixtures formed by physically mixing at the particle level and that do not involve a chemical change.

Students could begin by looking at solubility data of concentrations of sugar or salt at various temperatures. Interpretation of data tables or graphs could be used to help make generalizations about pure substances and their solubility. Polar compounds dissolve in polar solvents. It is important to realize that not all organic compounds are non-polar. Sugar is polar and is very soluble in water. This may be useful in a discussion of non-diet pop. The hidden calories in non-diet pop might be interesting to students and might prompt a discussion about the high concentration of sugar in pop (about the equivalent of 40 g of sugar in a 355 mL drink).

Students could describe the bonding forces related to the question, Where is the best place to go trout fishing? This would depend on the solubility of O_2 in the H_2O.

One possible experiment students could perform in the laboratory is to dissolve known masses of solute in equal amounts of warm solvent and allow the solutions to cool until a solid begins to form. Temperatures are recorded at this point. Do two or more trials. Use class data to draw or plot a solubility curve, perhaps of NH_4Cl or KCl. By doing a qualitative analysis experiment, such as analysis of simple anions, students might identify unknowns based on their experimental results. Using a solubility table, students might think of ways to separate different combinations of two or three ions.

Solubility and Precipitates
6 hours

Tasks for Instruction and/or Assessment

Performance

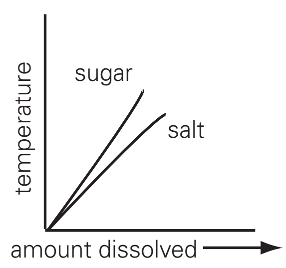
- Do an experiment to separate combinations of two or three ions. Produce a table of solubilities for your report that includes organized data, accurate observations, and logical reasoning used to determine the identity of the ions. (323-8, 214-10)

Journal

- Gases become less soluble as the temperature of the solution increases. For solids, this trend is reversed. Explain this phenomenon with reference to your understanding of solubility. (323-7)
- If like dissolves like, why does sodium chloride dissolve in water? (323-7)
- Are large doses of vitamin A potentially more toxic than large doses of vitamin C? Explain. (323-8)

Paper and Pencil

- Balance the following using dissociation equations:
  - Aqueous potassium hydroxide is mixed with aqueous iron(II) nitrate. A precipitate of iron(II) hydroxide is formed. (323-8)
- Write a report on your solubility curve experiment. (323-7)
- Write all the equations for dissociation for the precipitate experiment. (323-8)
- Do a class data table of all results. Discuss. (323-8)
- A dog eats a cod liver oil capsule. What happens to the oil components in the dog's body? (323-7, 323-8)
- Compare the solubility of salt and sugar with reference to the graph. (323-7)



- List ten (10) mixtures you encounter in everyday life and include the components of each. (323-7)

Resources/Notes

Experiments

Chemistry 11 and Chemistry 12: A Teaching Resource
- Activity 37: The Formation of a Solution
- Activity 38: Polar and Non-polar Molecules

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)
- Chapter 7.2: Factors That Affect Rate of Dissolving and Solubility, pp. 243–254
- Chapter 8.1: Making Predictions about Solubility, pp. 281–286
- Investigation 8-A: The Solubility of Ionic Compounds, p. 283
- Chapter 8.2: Reactions in Aqueous Solutions, pp. 288–298
- Chapter 8.3: Stoichiometry in Solution Chemistry, pp. 299–307
- Investigation 8-B: Qualitative Analysis, pp. 296–297

Solubility and Precipitates *(continued)*

Outcomes

Students will be expected to

- identify and explain sources of error and uncertainty (214-10)
- identify and describe science- and technology-based careers related to solutions and equilibrium (117-7)

Elaborations—Strategies for Learning and Teaching

Students should conduct a precipitate experiment that includes recording, observing and collecting data, writing ionic equations, and analysing results.

Students could write ionic and net ionic equations for all reactions to provide evidence for which substances produce precipitates. Through deductive reasoning, students might see patterns from their data and identify, with explanations, how solubility and precipitation are related.

Students should identify a career related to solutions, solubility, and precipitation.

A description of the career, the importance of solubility, and the technology involved could be presented in creative formats. Issues where people are employed with such careers might include preventing lead poisoning by removing lead from paint, destroying a fish shipment containing a higher than legal limit of mercury, mixing gasoline and oil for boat motors, or any other relevant context.

Solubility and Precipitates *(continued)*

Tasks for Instruction and/or Assessment

Performance

- Design and conduct an experiment on precipitates. Report your qualitative operations and write ionic equations. (323-8, 214-10)
- Plot the solubility curve of NH_4Cl. Compare the solubility at a given temperature with the accepted value. (214-10)
- Choose a career related to working with solutions. Present to the class the part of the career that involves solubility. Your presentation could be actual, audio-visual, or multimedia. You should act the part of your career by dressing appropriately. (117-7)

Journal

- Do fruit juices contain vitamin C but not vitamin A? Explain. (117-7)

Presentation

- In a pictorial or photo-essay, demonstrate the use of solutions and precipitates as related to a career of your choice. (117-7)

Resources/Notes

Experiments

Chemistry 11 and Chemistry 12: A Teaching Resource

- Activity 26: Formation of a Precipitate
- Activity 27: Formation of a Precipitate in Microscale
- Activity 39: The Formation of Solutions by Ionic and Molecular Compounds

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Chemistry Bulletin: Solvents and Coffee: What's the Connection? p. 253
- Careers in Chemistry: Product Development Chemist, p. 265
- Chemistry Bulletin: Water Quality, p. 309

Kinetics and Rate of Reaction
3 hours

Outcomes

Students will be expected to

- identify, through experiments and graphing, factors that affect the rate of the reaction (ACC-1)
- implement appropriate sampling procedures (213-1)

Elaborations—Strategies for Learning and Teaching

In groups, students should do a rate-of-reaction experiment. Interpreting their data might require a graph. Suggested reactions include a metal with an acid, yeast with sugar, baking soda with vinegar, or antacid with water. This would be a good opportunity to discuss experiment results and compare class results. Discussion about slow and fast chemical reactions might give information about why it is important to control the rates of reactions. Society has the need for both slow and fast reactions; for example, rust prevention and an air bag reaction.

Teachers should ensure that students identify factors that affect rate of reaction and the ways these factors can be controlled (temperature, concentration, surface area, catalysts, and inhibitors) and apply their knowledge to explain reactions in different situations.

Here is a good opportunity for discussion of food storage. Lowering the temperature extends the shelf life of a food. Students could discuss how using the refrigerator at 4 °C increases the life of a food. They could discuss other temperatures, such as a freezer at –15 °C or an ultrafreezer at –80 °C.

Discussion in terms of reaction kinetics would be appropriate here.

Kinetics and Rate of Reaction
3 hours

Tasks for Instruction and/or Assessment

Performance

- Do a rate-of-reaction experiment. Do a class data table of all results. Write a report. (213-1)
- Compare and contrast storage of food at different temperatures. How does this affect the rate of decomposition? (ACC-1)

Journal

- Why do you think it is better to use a catalyst to speed up a reaction rather than increase the temperature? (ACC-1)

Paper and Pencil

- When is it desirable to speed up a chemical reaction? (ACC-1)
- Why do you think it is easier to light pieces of kindling wood for a fire than a log? (ACC-1)

Resources/Notes

Experiments

Chemistry 11 and Chemistry 12: A Teaching Resource
- Activity 28: The Effect of Temperature on the Rate of a Chemical Reaction
- Activity 29: The Effect of Surface Area and a Catalyst on the Rate of a Chemical Reaction
- Activity 42: Factors That Affect the Rate of a Chemical Reaction

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)
- Chapter 12.1: Factors That Affect Reaction Rates, pp. 463–467
- Investigation 12-A: Studying Reaction Rates, pp. 464–465

Web Resource

- TI website (downloadable activities for calculator)

Videos

- *Introduction to Reaction Kinetics* (V9075)
- *Chemical Kinetics* (20978)
- *Catalysts* (20979)

Collision Theory, Reaction Mechanisms, and Catalysts

2 hours

Outcomes

Students will be expected to

- describe collision theory and its connection to factors involved in altering reaction rates (ACC-2)
- describe a reaction mechanism and catalyst's role in a chemical reaction (ACC-3)

Elaborations—Strategies for Learning and Teaching

The roles of the nature of reactants, surface area, temperature, and concentration should be discussed in reaction rates. The collision theory should be discussed. Students might calculate the average rate of a chemical reaction.

Students could use data from their rate-of-reaction experiment. Using a potassium permanganate solution to react with different ions, such as iron(II) or oxalate, students can discuss the role reactants play in the rates of reactions. Students might discuss the fundamentals of collision theory using potential energy diagrams and energy considerations. Controlling reaction rates is important in many commercial and industrial processes. By applying collision theory to the rates of fast and slow reactions, teachers might look for complete and detailed explanations using the correct terminology.

When drawing and interpreting potential energy diagrams for various reactions, students' interpretations should include exothermic, endothermic, enthalpy, activation energy, activated complex, reactants, products, and ΔH. Students could draw, label, and interpret energy diagrams or reaction profile diagrams for exothermic and endothermic reactions and label these.

Students should define reaction mechanisms and show how a catalyst affects the rate of a chemical reaction by providing a different reaction mechanism.

An activation energy diagram to show the effect of a catalyst on the rate of reaction gives students the opportunity to understand the role of a catalyst on the rate of reaction. The steps of a reaction mechanism should be given and students asked to identify the rate-determining step, reaction intermediates, and catalysts, and to add the steps of the overall reaction taking place to show that it is equivalent to the overall reaction.

As an extension, students might discuss the details of reaction mechanisms.

Collision Theory, Reaction Mechanisms, and Catalysts

2 hours

Tasks for Instruction and/or Assessment

Paper and Pencil

- Draw, label, and interpret energy diagrams. (ACC-2)
- Draw a potential energy diagram with correct labelling for an endothermic and an exothermic reaction. Include the shape of the curve, correct labelling for activation energy and energies of reactants, products, and activated complex. (ACC-3)
- Given a reaction, how could you tell that it is endothermic or non-spontaneous? For example,

  $C_2H_5OH + 3O_2 \rightarrow 3H^2O + 2CO_2 + 1367$ KJ

- Draw a potential energy diagram illustrating the following reaction sequence:

  C(graphite) $+O_2(g) \rightarrow CO_2(g)$ $\Delta H = -393.5$ KJ

  $CO_2(g) \rightarrow$ C(diamond) $+ O_2(g)$ $\Delta H = +395.4$ KJ

Resources/Notes

Experiments

Chemistry 11 and Chemistry 12: A Teaching Resource

- Activity 40: Explaining Chemical Reactions—Collision Theory
- Activity 41: Potential Energy (Activation Energy) Diagrams

Curriculum Correlation

- *McGraw-Hill Ryerson Chemistry* (23700), Chapter 12.2: Collision Theory and Reaction Mechanism, pp. 469–483

Videos

- *Reaction Kinetics* (V9466)
- *Introduction to Reaction Kinetics* (V9075)

Equilibrium
2 hours

Outcomes

Students will be expected to

- compile and organize solution data, using appropriate formats and data treatments to facilitate interpretation of the data (213-5)
- define the concept of equilibrium as it pertains to solutions (323-3)

Elaborations—Strategies for Learning and Teaching

Students should use the data compiled from an experiment activity to discuss observations that indicate when equilibrium is reached.

Students might list examples of various solutions they think are in equilibrium. They could begin with a class demonstration of equilibrium. A simple demo uses a coloured solution, beakers, a ruler, and a graduated cylinder. Students should discuss the observations and connect them with equilibrium. Teachers might show a video on equilibrium.

Teachers should ensure that equilibrium is defined and that students describe an equilibrium system of a solid in a saturated solution in terms of equal rates of dissolving and crystallizing.

Students could draw a diagram illustrating particles entering and leaving the solution phase. They should explain, with the help of a diagram, the forces of attraction between solute and solvent particles.

Equilibrium
2 hours

Tasks for Instruction and/or Assessment

Performance

- Collect and graph data from an activity that reaches equilibrium. (213-5, 323-3)

Journal

- What is the general meaning of "dynamic"? What is meant by dynamic equilibrium? Give examples. (323-3, 213-5)
- Make a list of the terms used in your video on equilibrium. (213-5)

Paper and Pencil

- A chemical equilibrium is a dynamic equilibrium in which opposite processes are occurring at equal rates. Discuss the statement. What would help us to infer that the amounts of reactants and products are remaining constant at equilibrium? (323-3)

Resources/Notes

Experiment

Chemistry 11 and Chemistry 12: A Teaching Resource
- Activity 43: Writing the Equilibrium Constant Expression

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)
- Chapter 13.1: Recognizing Equilibrium, pp. 489–493
- ExpressLab: Modelling Equilibrium, p. 491

Video

- *Equilibrium* (V9063)

Print Resource

- *Secondary Science: A Teaching Resource* (1999)

Le Châtelier's Principle and Equilibrium Constant

10 hours

Outcomes

Students will be expected to

- explain how different factors affect solubility, using the concept of equilibrium (323-5)
- develop appropriate sampling procedures for equilibrium expressions (212-9)

Elaborations—Strategies for Learning and Teaching

Teachers should ensure that students use Le Châtelier's Principle to determine how the concentrations of reactants and products change after a change is imposed on a system at equilibrium. Students should explain how a catalyst and the surface area have an effect on the time it takes to reach equilibrium even though neither causes the equilibrium to shift. An experiment should be done with the above.

Factors such as concentration, pressure, temperature, and catalyst should be studied in light of Le Châtelier's Principle.

Students should write equilibrium-constant expressions. Students should know that solids and liquids are *not* included in the equilibrium expression. They should discuss how the equilibrium constant will vary with temperature.

Teachers should include the following in these types of calculations: calculate equilibrium constant for chemical systems when

(a) concentrations at equilibrium are known or (b) when initial concentrations and one equilibrium concentration are known.

Students could use a table or chart to help with problems involving equilibrium changes. Consider this problem: What is the equilibrium constant value for the following reaction at equilibrium, at 25 °C?

$$\left[H_2CO_3\right] = 3.3 \times 10^{-2}\,M$$

$$\left[HCO_3^-\right] = 1.19 \times 10^{-4}\,M$$

$$\left[H_3O^+\right] = 1.19 \times 10^{-4}\,M$$

$$H_2CO_3(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HCO_3\ (aq)$$

When solving equilibrium-constant problems , students could list what they know, including the concentrations and what they want to find. Students should write the equilibrium expression, substitute values into the expression, and solve it.

Le Châtelier's Principle and Equilibrium Constant

10 hours

Tasks for Instruction and/or Assessment

Performance

- Open a bottle of pop and explain what you see. Write a chemical equation for when equilibrium is reached between CO_2(aq) and H_2O(l) to form H_2CO_3(aq) when the container is open. Write the equation for the physical equilibrium of CO_2(g) and H_2O(l) when the container is closed. (323-5, 212-9)

Paper and Pencil

- In which direction will the equilibrium be shifted by an increase in (1) the concentration of O_2, (2) pressure, and (3) temperature in each of the following reactions:

  a) $2CO(g) + O_2(g) \rightleftharpoons 2CO_2(g) + \text{heat}$

  b) $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) + \text{heat}$

  c) $N_2(g) + O_2(g) + \text{heat} \rightleftharpoons 2NO(g)$ (323-5)
- List the factors that can disturb an equilibrium system. (323-5, 212-9)
- How does removing a product from an equilibrium system help to produce maximum yield of that product? Refer to this example: $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) + \text{heat}$ (323-5)
- Benzoic acid is used in food preparation. It is slightly soluble in water. The K_C for the reaction below is 6.30×10^{-5} at 25 °C. $[C_6H_5COOH]$ is 0.020 M. The reaction is
  $C_6H_5COOH \rightleftharpoons H_3O^+ + C_6H_5COO^-$.
  What are the concentrations of $[H_3O^+]$ and $[C_6H_5COO^-]$? (323-5)
- Does the K_C value of the reaction above tell you about which side is favoured. Explain. (323-5, 212-9)
- Write an equilibrium constant expression for this equation: $CO_2(g) + H_2(g) \rightleftharpoons H_2O(g) + CO(g)$ $K_C = 1.57$ (323-5)

Resources/Notes

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Chapter 13.2: The Equilibrium Constant, pp. 494–516
- Investigation 13–A: Measuring an Equilibrium Constant, pp. 501–504
- Chapter 13.3: Predicting the Direction of a Reaction, pp. 517–532
- Investigation 13-B: Perturbing Equilibrium, pp. 521–524

Le Châtelier's Principle and Equilibrium Constant *(continued)*

Outcomes

Students will be expected to

- explain solubility, using the concept of equilibrium (323-4)

Elaborations—Strategies for Learning and Teaching

Teachers should include calculations of this type: solve equilibrium problems involving the initial concentrations, the changes that occur in each substance, and the resulting equilibrium concentrations. They might use a chart like the one pictured below to organize their data.

Sample problem: What is the equilibrium concentration of this reaction: $CO_2(g) + H_2(g) \rightleftharpoons CO(g) + H_2O(g)$?

Equilibrium Table

equation	$CO_2 + H_2 \rightarrow CO + H_2O$			
initial concentration				
change occurred				
final equilibrium concentration				

Le Châtelier's Principle and Equilibrium Constant *(continued)*

Tasks for Instruction and/or Assessment

Journal

- Name one reversible reaction you might encounter every day. (323-4)
- Is this instruction chemically correct: "Add 5 grams of sugar to your tea/coffee/lemonade, and stir until the sugar stops dissolving"? Explain. (323-4)
- Make a list of what you have learned about chemical equilibrium. List any new questions that you may have found for further exploration. (323-4)
- How are solubility and equilibrium related? (323-4)

Paper and Pencil

- Calcium fluoride is commonly known as fluorspar. It is used to fluoridate drinking water. The equilibrium constant for the dissociation of solid calcium fluoride is 3.9×10^{-11} at 25 °C. Assuming complete dissociation, what is the solubility of calcium fluoride in g/L? (323-4)

Presentation

- Research the use of solubility principles and equilibrium to remove a pollutant, such as Pb^{2+}, Cl^{-}, PO_4^{3-}, or SO_4^{2-}, from waste water. Present your research as a memo to a company. (323-5)

Resources/Notes

Appendix D: Memo Format

Print Resources

- *Merck Index*
- *CRC Handbook of Chemistry and Physics*

Equilibrium Applications

3 hours

Outcomes

Students will be expected to

- analyse and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology (116-2)
- analyse and describe examples where technologies were developed based on scientific understanding (116-4)

Elaborations—Strategies for Learning and Teaching

Students should research how our ideas of solutions and equilibrium have changed over time. Topics might include the Haber process, scuba diving, or high-altitude training.

Students could analyse an industrial example by discussing how the technology developed was based on scientific understanding. They could discuss factors that control the position of a chemical equilibrium. For example, when a chemical is manufactured, the chemists and chemical engineers in charge of production want to choose conditions that favour the desired product as much as possible. They want the equilibrium to go to the right. Teachers could introduce the Haber process, $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g) +$ heat.

Teachers could ask questions about the process: “How would increasing the pressure of the reaction to produce ammonia affect the ammonia yield?” and “How would increasing the reaction temperature affect the amount of ammonia produced in this exothermic reaction?” The optimum conditions for the Haber process could be outlined.

Students could explain one of the following situations using their understanding of equilibrium: limestone caves, water softeners and hard water, acclimatizing to high altitudes, and hemoglobin.

Students could view videos on various processes. Discussion before and after the video is appropriate.

Equilibrium Applications

3 hours

Tasks for Instruction and/or Assessment

Journal

- If a process is in equilibrium, does that mean nothing is changing? (116-2, 116-4)
- If a reversible reaction favours the formation of the products, are any reactants still present? (116-2, 116-4)

Paper and Pencil

- Design a water softener. How would you deal with the problem of hard water? (116-4, 116-2)
- Write a report about the video. (116-4)
- In the early 1900s an endothermic process was demonstrated by Birkeland and Eyde for fixing nitrogen by passing air through a high-temperature electric arc. If cheap electric power were available, it promised to be a rival of the Haber-Bosch process.

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g) \quad \Delta H = +43.2 \text{ kJ}$$

  According to Le Châtelier's principle, how could the yield of NO be increased? Explain. (116-2, 116-4)

Resources/Notes

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Chapter 13.3: Predicting the Direction of a Reaction; Applying LeChâtelier's Principle: Manufacturing Ammonia, pp. 530–532
- Chemistry Bulletin: LeChâtelier's Principle: Beyond Chemistry, p. 525

Acids and Bases

Introduction

Acids and bases have an effect on aqueous systems. Acid-base systems involve proton transfer and are described quantitatively. Students will be encouraged to value the role of precise observation and careful experimentation while looking at safe handling, storage, and disposal of chemicals. In this unit, we will explore several ways of defining acids and bases.

Experiments are compulsaory in Chemistry 11 and students should have foty percent of their time in hands-on, minds-on exploration. Specific curriculum outcomes state which experiments should be done.

Focus and Context

Problem solving and decision making are used throughout this unit. Student laboratory skills will be developed. Teachers could provide examples of products and processes that use knowledge of acids and bases. They could emphasize through WHMIS the proper handling of these chemicals. There are many opportunities to discuss the relationships among science, technology, society, and the environment in this acid-base chemistry unit.

Science Curriculum Links

In Science 10, students will have studied writing formulas and balancing equations and be introduced to acid-base concepts. Students will have studied moles and stoichiometric calculations in Chemistry 11. The nature of solutions and expressing solution concentration will be addressed in Chemistry 12 before this acids and bases unit.

Curriculum Outcomes

STSE	Skills	Knowledge
Students will be expected to	*Students will be expected to*	*Students will be expected to*
114-2 explain the roles of evidence, theories, and paradigms in acid-base theories **114-9** explain the importance of communicating the results of acid-base reactions using appropriate language and conventions **115-7** explain how acid-base theory evolves as new evidence and laws and theories are tested and revised, or replaced **116-2** analyse and describe examples where acid-base understanding was enhanced as a result of using titration curves **117-2** analyse society's influence on acid and base scientific and technological endeavours **117-7** identify and describe science- and technology-based careers related to acids and bases **118-6** construct arguments to support a decision using examples and evidence and recognizing various perspectives	**212-4** state a prediction and a hypothesis based on available evidence and background information **212-8** evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making **213-3** use instruments effectively and accurately for collecting titration data **213-8** select and use apparatus and materials safely **213-9** demonstrate a knowledge of WHMIS standards by selecting proper techniques for handling and disposing of materials **214-1** describe and apply classification systems and nomenclature used in acids and bases **214-4** identify a line of best fit on a scatter plot and interpolate or extrapolate based on the line of best fit **214-5** interpret patterns and trends in data, and infer or calculate relationships among variables from titration data **214-17** identify new questions or problems that arise from what was learned **215-2** select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, titrations, and results **215-6** work co-operatively with team members to develop and carry out a plan for a titration experiment, and troubleshoot problems as they arise	**320-1** describe various acid-base definitions up to the Brønsted-Lowry definition **320-2** predict products of acid-base reactions **320-3** compare strong and weak acids and bases using the concept of equilibrium **320-4** calculate the pH of an acid or a base given its concentration, and vice versa **320-5** describe the interactions between H^+ ions and OH^- ions using Le Châtelier's principle **320-6** determine the concentration of an acid or base solution using stoichiometry **320-7** explain how acid-base indicators function

Properties and Definitions of Acids and Bases
3 hours

Outcomes

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)

Elaborations—Strategies for Learning and Teaching

Students should conduct an experiment to try to classify various chemicals into groups based on their properties using the following tests: conductivity, litmus paper, pH paper, and reaction with Mg ribbon and $CaCO_3$ chips. After summarizing the results in a table, students could identify each solution as acidic, basic, neutral ionic, or neutral molecular.

From various activities, students should define acids and bases operationally in terms of their effect on pH, taste, reactions with metals, neutralization reactions with each other, conductivity, and indicators.

Teachers could begin by having students write a list of all the things they know about acids and bases in their journals. Students could contribute these to a class list by suggesting things they might want to know about acids.

Students could examine the labels on various packaged food to determine which chemicals are present. They could then look up the formulas to determine which are acidic, basic, or neutral. To do this, the students could use the *CRC Handbook of Physics and Chemistry*, *The Merck Index*, or Internet sites.

Teachers should have students compare various acid-base definitions. Students should define and identify Arrhenius acids and write ionization equations for the behaviour of Arrhenius acids in water such as: $HNO_3(l) + H_2O(l) \rightarrow H_3O^+(aq) + NO_3^-(aq)$.

Students should define and identify Arrhenius bases. Stress that an Arrhenius base must produce hydroxide ions in aqueous solutions. Students should write dissociation equations for the behaviour of these bases, such as the following:

$NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$

$Ca(OH)_2(s) \rightarrow Ca^{2+}(aq) + 2OH^-(aq)$

Ionization of weak bases such as NH_3 should be included in discussion, using equations.

Properties and Definitions of Acids and Bases
3 hours

Tasks for Instruction and/or Assessment

Performance

- Classify, using appropriate tests, the following as an acid, a base, or neutral (neither acidic or basic):
  - sodium carbonate
  - hydrochloric acid
  - sulfuric acid
  - potassium hydroxide
  - calcium hydroxide
  - ammonia
  - sugar

  (214-1, 320-1)

Journal

- Compare the conductivity of solutions to that of metals. (214-1, 320-1)

Paper and Pencil

- How do you account for the brightness of the bulb when doing conductivity tests? (214-1, 320-1)
- What must be present in order for a solution to conduct electricity? (214-1, 320-1)
- Write an equation for $Mg(OH)_2(s)$ dissolved in water. How does this reaction fit the Arrhenius definition of a base? (320-1)
- Write an equation for the ionization of $HClO_3(aq)$. How does this reaction fit the Arrhenius definition of an acid? (320-1)

Presentation

- Prepare an oral presentation from the list of all the things you know about acids and bases generated in class. Use a graphic organizer. (214-1)

Resources/Notes

Experiment

Chemistry 11 and Chemistry 12: A Teaching Resource
- Activity 44: Definitions of Acids and Bases

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)
- Table E.15: Summary of Naming Rules for Acids, p. 848
- Chapter 14.1: Defining Acids and Bases, pp. 545–558
- Investigation 14-A: Observing Properties of Acids and Bases, p. 545

Print Resources

- *Merck Index*
- *CRC Handbook of Chemistry and Physics*

Video

- *Acids and Alkalis* (23229)

Properties and Definitions of Acids and Bases *(continued)*

Outcomes

Students will be expected to

- explain how acid-base theory evolves as new evidence and laws and theories are tested and revised, or replaced (115-7)
- explain the roles of evidence, theories, and paradigms in acid-base theories (114-2)

Elaborations—Strategies for Learning and Teaching

Teachers should introduce the Brønsted-Lowry acid-base theory to account for non-hydroxide bases, such as a carbonate and/or hydrogen phosphate ion.

Students should interpret equations in Brønsted-Lowry terms and identify the acid and base species. Examples should include

$HCl(aq) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$

$H_2SO_4(aq) + H_2O(l) \rightarrow H_3O^+(aq) + HSO_4^-(aq)$

Students could compare the Arrhenius and Brønsted-Lowry definitions by using a chart to help with their organization of the information. Students should define a Brønsted-Lowry acid and a Brønsted-Lowry base. By writing single-step and overall equations for the acid-base reactions of a substance that can donate or accept more than one proton, students see how each species acts as an acid or base.

Students should explain how some substances helped revise Arrhenius' theoretical definition of acids.

The development of the acid-base theories up to Brønsted-Lowry might be traced to show how knowledge and thinking changed to explain new observations.

Students should define and identify amphiprotic and amphoteric substances. Examples are given below:

$NH_3(aq) + H_2O(l) \rightarrow NH_4^+ + OH^-(aq)$

$H_2O(l) + H_2O(l) \rightarrow OH^-(aq) + H_3O^+ (aq)$

$HCO_3^-(aq) + OH^-(aq) \rightarrow CO_3^{2-}(aq) + H_2O(l)$

$HCOOH(aq) + HCO_3^-(aq) \rightarrow HCOO^-(aq) + H_2O(l) + CO_2(g)$

Properties and Definitions of Acids and Bases *(continued)*

Tasks for Instruction and/or Assessment

Paper and Pencil

- What characteristics make a substance amphiprotic? Give an example. (114-2)
- Give an example of a base that can be defined as a Brønsted-Lowry base but not an Arrhenius base. Write the dissociation equation to illustrate your example. (115-7, 114-2)

Presentation

- Using a concept map, organize the Arrhenius and Brønsted-Lowry acids and bases definitions. Use definitions in your concept map to help illustrate the definitions. (114-2, 115-7)

Resources/Notes

Curriculum Correlation

McGraw-Hill Ryerson Chemistry (23700)

- Chapter 14.1: Defining Acids and Bases; The Brønsted-Lowry Theory of Acids and Bases, pp. 553–556
- Chapter 14.1: Defining Acids and Bases; Acting Like an Acid or a Base: Amphoteric substances, pp. 557–558

Video

- *Acids and Bases* (23227)

Acids/Base Reactions
3 hours

Outcomes

Students will be expected to

- predict products of acid-base reactions (320-2)
- identify new questions or problems that arise from what was learned (214-17)
- explain the importance of communicating the results of acid-base reactions using appropriate language and conventions (114-9)

Elaborations—Strategies for Learning and Teaching

Students should write balanced chemical, ionic, and net ionic equations specific to acid-base reactions. Students should identify questions or problems that they might have about acids and bases combining in an experiment.

Students might wonder why neutralization occurs between acids and bases. They should identify the Brønsted-Lowry acid and Brønsted-Lowry base in strong acid-base neutralization reactions. Students should define and identify Brønsted-Lowry conjugate acid-base pairs.

$H_2O(l) + NH_3(aq) \rightarrow NH_4^+(aq) + OH^-(aq)$

acid + base → conjugate acid + conjugate base

Students might remember doing these various types of equations when studying solutions. They might compare the net ionic equations from a few reactions to look for patterns. They could identify the products of an acid-base neutralization. The net ionic reaction should be $H_3O^+(aq) + OH^-(aq) \rightarrow 2H_2O(l)$.

This is a neutralization reaction. A clean-up of an acid spill, the antacid reaction in your stomach, or neutralizing the soil acidity in your lawn could be helpful in explaining acid-base neutralization reactions. Many of these reactions involve carbonates.

Students should, in small groups, discuss the usefulness of acid-base reactions.

Acid-base reactions involve water, hydrogen ions, hydronium ions, and hydroxide ions. Students could compare the nature of $[H^+(aq)]$ and $[H_3O^+(aq)]$ and explain if they are the same or different. Teachers might show, how $[H_3O^+]$ is a hydrated ion.

Acids/Base Reactions

3 hours

Tasks for Instruction and/or Assessment

Journal

- Neutralization is a process that is controlled in lab experiments. How do you think this process works? Does it work in other environments, such as a lake or your stomach? (214-17, 320-2, 114-9)

Paper and Pencil

- Identify which reactant is the Brønsted-Lowry acid and which is the Brønsted-Lowry base. (320-2)

  $HSO_4^-(aq) + H_2O(l) \rightarrow H_3O^+(aq) + SO_4^{2-}(aq)$

  $HCN(aq) + H_2O(l) \rightarrow H_3O^+(aq) + CN^-(aq)$

- Write an equation for each of the three ionization steps where phosphoric acid would donate three hydrogen (protons) ions. (320-2)

Presentation

- Identify the acid, base, conjugate acid and conjugate base in the following: $H_2O(l) + NH_3(aq) \quad NH_4^+(aq) + OH^-(aq)$. (320-2)
- Illustrate the donation of a proton from an acid to a base using HCl(aq) and NaOH(aq); HCl(aq) and $H_2O(aq)$; $NH_3(aq)$ and $H_2O(aq)$. Write the balanced, ionic, and net ionic equations, and identify the conjugate acid-base pair. (114-9)

Resources/Notes

Experiment

Chemistry 11 and Chemistry 12: A Teaching Resource

- Activity 31: Acid-Base Neutralization

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Chapter 8.2: Reactions in Aqueous Solutions, pp. 292–294
- Chapter 14.1: Defining Acids and Bases, pp. 545–558

Video

- *Acids and Bases* (20980)

Using the Equilibrium Concept with Acids and Bases

11 hours

Outcomes

Students will be expected to

- identify a line of best fit on a scatter plot and interpolate or extrapolate based on the line of best fit (214-4)
- select and use apparatus and materials safely (213-8)
- demonstrate a knowledge of WHMIS standards by selecting proper techniques for handling and disposing of materials (213-9)
- state a prediction and a hypothesis based on available evidence and background information (212-4)

Elaborations—Strategies for Learning and Teaching

Students should interpret and extrapolate what a titration graph curve means in terms of neutralization through experiments.

Students could graph sample data collected from one of the titration experiments or data provided by the teacher. As they become more familiar with acid-base data throughout this unit, students could plot and interpret their own graphs.

Students' selection of apparatus should be appropriate for use in an acid-base titration.

Using a pH probe in one of the experiments would reflect the drastic change in pH at the equivalence point. Students could discuss weak acids and how they do not completely react with water; for example, the weak acid CH_3COOH.

Students should recognize the usefulness of WHMIS standards. They could do a project on WHMIS standards. In the lab, they could be shown apparatus that might be used in a future acid-base titration experiment and decide on the safe and proper use of the apparatus. Teachers could demonstrate the proper use of the equipment. Students could be asked to think about how they would safely dispose of acids and bases. Then, information collected could help students know how to use apparatus safely. The proper way to handle and dispose of acids and bases is part of WHMIS knowledge that is useful in the laboratory, workplace, and home.

Students should predict acid-base strength of various foods or liquids based on their knowledge. Substances might include milk, red cabbage, coffee, pop, apple juice, and liquid soap. Students could prepare a chart to show their predictions, and later they could find the pH and compare their predictions with actual results.

Predict Whether Acidic or Basic and Strength

Substance	Prediction	Strength	pH Value
milk	basic	low	6.6
red cabbage			

Using the Equilibrium Concept with Acids and Bases

11 hours

Tasks for Instruction and/or Assessment

Informal Observation

- Watch the use of the equipment used in an acid-base titration and practise the safe and efficient use of the equipment. (213-8, 213-9, 214-4)

Performance

- Create a poster illustrating both proper and improper acid-base disposal. (213-9)
- Show the proper care and maintenance of a burette. (213-8)

Journal

- How can a pH be negative? (212-4)
- How does the K_a value of an acid relate to the pH of its solution? (212-4)
- How does the pH of human blood remain extremely constant? (Hint: [HCO_3^-(aq)] ions are present.) (212-4)

Paper and Pencil

- Examine diagrams of apparatus used in titrations and describe the use of each. Examples should include the burette and Erlenmeyer flask. (213-8, 213-9)

Resources/Notes

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Safety in your Chemistry Laboratory and Classroom, pp. x–xiii
- Chapter 14.2: Strong and Weak Acids and Bases, pp. 560–578
- Investigation 14-B: The Effect of Dilution on the pH of an Acid, p. 575

Using the Equilibrium Concept with Acids and Bases *(continued)*

Outcomes

Students will be expected to

- compare strong and weak acids and bases using the concept of equilibrium (320-3)
- calculate the pH of an acid or a base given its concentration, and vice versa (320-4)

Elaborations—Strategies for Learning and Teaching

Students should define both a weak acid and a weak base. They should identify the special nature of water as an amphoteric substance by writing the equilibrium equation for the self-ionization of water. They should identify that the presence of [H_3O^+(aq)] or [OH^-(aq)] from an added strong, or reasonably strong, acid or base will not be affected to any significant extent by the self-ionization reaction for water that avoids having to account for the [H_3O^+(aq)] or [OH^-(aq)] ions produced. The self-ionization of water produces a system at chemical equilibrium for which we can write an equilibrium constant for water, K_w. Students should define K_w, also known as the ion product constant for water.

Problem solving using K_w might be done here. Students could solve for either [H_3O^+(aq)] or [OH^-(aq)] using K_w at 25 °C. Additional problems could include the determination of the molarity, of these ions. Teachers might use the following example: calculate the [H^+(aq)] or [H_3O^+(aq)] if 5.0 g of NaOH is dissolved in 200 mL solution.

Students should define K_a and K_b qualitatively and relate their values to their strengths. Students should write appropriate K_a and K_b equilibrium constant expression from the equations, knowing that water as a liquid is omitted in the equilibrium expression. For example, the acetic acid in vinegar in water:

$$CH_3COOH(aq) + H_2O(l) \rightarrow H_3O^+(aq) + CH_3COO^-(aq)$$

$$K_a = \frac{[H_3O^+][CH_3COO^-]}{[CH_3COOH]} - \quad = 1.75 \times 10^{-5}$$

Students should calculate the value of one of K_a or equilibrium concentration given all other values. They should define the pH and pOH of solutions. They should define the relationships among [H_3O^+], [OH^-], pH, and pOH. They should perform calculations in which they make conversions among the four values. Solving problems could be practised in small groups. Group discussion of problem-solving strategies would help students to better understand the relationships. When given pH for acids or pOH and the acid concentration, students should calculate the K_a value. Qualitative observations with quantitative evidence could be used to compare strengths of strong and weak acids and bases. The equilibrium concept could be used for the explanations provided in the lab and in calculations.

Students should calculate the pH or pOH of a diluted solution. They should calculate [H_3O^+(aq)] given the concentration of strong acids. They should calculate [OH^-(aq)] given concentrations of strong bases. They should calculate the pH given the initial concentration of a weak acid and K_a.

Using the Equilibrium Concept with Acids and Bases *(continued)*

Tasks for Instruction and/or Assessment

Journal

- Explain why a 0.10 M HCl solution has a low pH. (320-4)

Performance

- Act out the ionization of water. (320-3)

Paper and Pencil

- The pH of a 0.072 mol/L solution of benzoic acid, $HC_7H_5O_2$, is 2.68. Calculate the numerical value of K_a for this acid. (320-3)
- What is the pH of a solution formed by mixing 100 mL of 0.150 mol/L HCl(aq) with 150 mL of 0.0900 mol/L NaOH(aq)? (320-3)
- HF ($K_a = 6.6 \times 10^{-4}$) and HCN ($K_a = 6.2 \times 10^{-10}$) are two weak acids that appear in this equilibrium:
  $HCN(aq) + F^-(aq) \quad HF(aq) + CN^-(aq)$
  - Use this information to explain qualitatively which equilibrium direction is favoured. Which acts like an acid and which acts like a base in this reaction?
  - Using K_a expressions and the K_a values provided, calculate the numerical value of the equilibrium constant for the reaction. (320-3)
- What is the pH of a 0.025 M NaOH solution? (320-4)
- The pH of the rain precipitation near a power plant is 4.35. What is the $[OH^-]$ in this precipitation? (320-4)
- What is the pH of a 0.026 M solution of $Ba(OH)_2$? (320-4)
- What are the concentrations for all the components of a benzoic acid solution of K_a if 6.5×10^{-5}, pH is 2.96, and C_6H_5COOH is 0.02 M? (320-4)

Resources/Notes

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Chapter 15.1: Revisiting Acid-Base Strength, pp. 583–595
- Chapter 15.2: Acid-Base Reactions and Titration Curves, pp. 599–616
- Chapter 15.2: Acid-Base Reactions and Titration Curves; Titration Step by Step, pp. 603–605
- Investigation 15-A: The Concentration of Acetic Acid in Vinegar, pp. 606–607

Indicators and Acids and Bases
2 hours

Outcomes

Students will be expected to

- explain how acid-base indicators function (320-7)
- analyse and describe examples where acid-base understanding was enhanced as a result of using titration curves (116-2)

Elaborations—Strategies for Learning and Teaching

Students should have opportunities by doing experiments for comparing the qualitative term (endpoint) with the quantitative term (equivalence point), identifying the pH of a solution using indicators, and choosing appropriate acid-base indicators given the pH at the equivalence point and a table of effective pH ranges for various acid-base indicators.

Students could do a microlab experiment that determines the pH of various acids and bases using indicators.

Students could do an activity representing the reversible nature of an acid-base indicator equilibrium system and write chemical equations representing this reversible nature. Using Le Châtelier's principle, students could predict the colour change when a strong acid or a strong base is added.

Indicators and Acids and Bases

2 hours

Tasks for Instruction and/or Assessment

Performance

- Perform, record, and report your experiment that used indicators to find pH. (320-7, 116-2)
- Study the reversible nature of an acid-base reaction using indicators. (320-7, 116-2)

Paper and Pencil

- What is the key about choosing an indicator in order to have an accurate titration? (320-7)
- What indicators could you use when a solution of HCl, a strong acid, is added to if a solution of Na_2CO_3, a weak base? (320-7, 116-2)
- What is the equivalence point? endpoint? Why is it important that both occur at approximately the same pH in a titration? (320-7)
- If a titration between a weak acid and a strong base has an equivalence point pH of 9.5, which indicators could be used to detect the equivalence point of the titration? (320-7, 116-2)
- What is the determining factor when selecting an indicator to use in a titration? (320-7, 116-2)
- For the following titrations, select the best indicator from these choices: bromophenol blue, bromothymol blue, phenol red.
  - HCOOH, formic acid, with NaOH
  - HCl with potassium hydroxide
  - ammonia with hydrochloric acid

  (116-2, 320-7)
- Which indicators would work best for a titration with
  - an endpoint at a pH of 4.0
  - a weak base with a strong acid

  Use your indicator chart as a reference. Justify your choice. (116-2, 320-7)

Resources/Notes

Experiment

Chemistry 11 and Chemistry 12: A Teaching Resource

- Activity 30: A Homemade Acid-Base Indicator

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Table E.19: End-point Indicators, p. 849
- Chapter 15.2: Acid-Base Reactions and Titration Curves, pp. 599–616

Video

- *Acid-Base Indicators* (V9071)

Acid/Base Titrations

5 hours

Outcomes

Students will be expected to

- determine the concentration of an acid or base solution using stoichiometry (320-6)
- use instruments effectively and accurately for collecting titration data (213-3)
- interpret patterns and trends in data, and infer or calculate relationships among variables from titration data (214-5)
- work co-operatively with team members to develop and carry out a plan for a titration experiment, and troubleshoot problems as they arise (215-6)
- evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making (212-8)
- select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, titrations, and results (215-2)

Elaborations—Strategies for Learning and Teaching

Students should perform experiments involving stoichiometric titration calculations where one unknown—molarity of acid, molarity of base, volume of acid, or volume of base—is to be determined from knowledge of others. This activity could help with questions and stoichiometry problems.

Students should perform a minimum of two titration experiments that would address outcomes 213-3, 214-5, 215-6, and 212-8.

Students have seen the apparatus that could be used in various titration experiments. Teachers could choose from titration experiments such as HCl and NaOH, CH_3COOH, and NaOH, or the effectiveness of various antacid tablets. Students should know the terminology involved with titrations: pipette, burette, endpoint, equivalence point, standard solution, and indicator. They should differentiate between indicator endpoint and equivalence (stoichiometric) point. Planning the experiment from the question requires co-operation with the student's partner. From teacher information and their own, students could organize the steps that are required in the process for the titration experiment.

Students could explain the titration graph involving a base with a strong acid; for example, hydrochloric acid, a strong acid, with sodium carbonate. They should explain the results of a titration graph involving a polyprotic acid with a strong base; for example, phosphoric acid with sodium hydroxide. They should explain the pH at the equivalence point when strong acids are mixed with weak bases, and vice versa. Teachers might mention hydrolysis here to help explain titration curves.

Students should report experiment results. They could present their results so that their understanding of pH and titrations is clearly shown. They might use graphs, videos, charts, a computer, activities, or oral reports to consolidate their titration information.

Acid/Base Titrations

5 hours

Tasks for Instruction and/or Assessment

Performance

- Your teacher will give you a solution to test for pH. Describe exactly how you would test the solution. Show your plan to your teacher. If approved, conduct the test and report the results. (215-2, 213-3, 214-5, 215-6, 212-8)
- Design an experiment to test the neutralization effectiveness of various brands of antacid. Show your procedure to your teacher for approval. Include all safety procedures and cautions. Write an advertisement for the antacid you judge to be the most effective. If the experiment is performed, include data from your experiments in your ad. (215-2, 213-3, 214-5, 215-6, 212-8)

Journal

- A NaOH solution has a pH of 10.5. What volume of 0.01 M HCl would be required to titrate this solution to the equivalence point? What additional information is required to solve this problem? (320-6, 215-2, 215-6)
- In the titration of a weak acid with a strong base, the pH of the equivalence point is higher than 7. Use the concept of conjugate acids and bases to explain why the pH is in the basic hydrolysis range. (320-6, 215-2)

Paper and Pencil

- A burette, not a graduated cylinder, is used in a titration. Explain why. (213-3)
- Andrew and Lindsay use 2.00 g of a solid potassium hydrogen phthalate, to titrate with 34.7 mL of a NaOH solution. The molar mass of the acid is 204.2 g/mol. What is the molarity of the NaOH solution? (320-6, 215-6)
- Donna and Dan titrated 1.0 mL of liquid drain cleaner, containing NaOH, with 10.1 mL of 0.06 M HCl to reach the equivalence point. What is the concentration of the base in the cleaner? Would a computer analysis be helpful here? Explain. (320-6, 215-6)
- How is the colour change of an indicator related to pH? (213-3, 212-8)
- Rachel and Desmond want to find the molarity of a lactic acid solution. A 15.0 mL sample of lactic acid, $CH_3CHOHCOOH$, is titrated to the equivalence point with 25.0 mL of 0.075 M NaOH. What is the molarity of the acid sample? (215-6, 320-6)

Resources/Notes

Experiments

Chemistry 11 and Chemistry 12: A Teaching Resource

- Activity 32: Acid-Base Neutralization: Microscale and Probeware
- Activity 33: Acid-Base Neutralization Smorgasbord
- Activity 45: Titration or pH Curves

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Chapter 15.2: Acid-Base Reactions and Titration Curves, pp. 599–616
- Investigation 15-A: The Concentration of Acetic Acid in Vinegar, pp. 606–607
- Investigation 15-B: K_a of Acetic Acid, p. 613

H^+, OH^-, and Le Châtelier
4 hours

Outcomes

Students will be expected to

- describe the interactions between H^+ ions and OH^- ions using Le Châtelier's principle (320-5)
- analyse society's influence on acid and base scientific and technological endeavours (117-2)
- construct arguments to support a decision using examples and evidence and recognizing various perspectives (118-6)
- identify and describe science- and technology-based careers related to acids and bases (117-7)

Elaborations—Strategies for Learning and Teaching

Students should perform experiements that use Le Châtelier's principle to predict, qualitatively, shifts in acid-base equilibrium caused by changes in pressure, temperature, volume, or concentration.

Students could recall their knowledge of equilibrium and of Le Châtelier's principle and focus on acid-base equilibrium using Le Châtelier. Students could support their decisions on acid-base equilibrium shifts through examples and evidence. Students might collect evidence from experiments they have conducted. Teachers could stress that the use of catalysts does not cause a shift in equilibrium and that temperature must be constant.

The interactions between $[H^+(aq)]$ ions and $[OH^- (aq)]$ ions could be revisited. Students might identify the extent of the self-ionization of water and note that the K_w value we use is for the equilibrium at 25 °C. Students should write the equation for the reaction between water and the hydrogen ion to produce the hydronium ion. Students should recognize that all of the available $[H^+(aq)]$ is in the form of $[H_3O^+(aq)]$.

Students could look at society and the ways it influences science and technology by explaining the significance of strength and concentration of acids and bases in chemical spills, in transportation of dangerous goods, or in acid deposition. Another approach might be historical: trace the development of the pH scale as an example of the way scientists have strived to improve communication. The pH scale is logarithmic because historically, people were not used to handling small numbers.

Water is involved in many aspects of our lives. Students might look at various foods and chemicals in their homes to see how water might be involved with each. A list of reactive substances, with equations, might be interesting to show how water is an influence on these substances.

The decision to stop using cheap coal, which is high in sulphur and produces acid rain, was based on evidence that stone and rock on buildings were wasting away. Metal was rusting. Students could research examples of acid rain. They could present arguments for industrial decisions to show various perspectives on environmental problems and their solutions. Presentations or debates on the issues enhances discussion about this everyday occurrence.

Students should identify careers that involve acid-base chemistry. Students could consider careers of interest to them and investigate them. Students might identify the use of acid-base chemistry in a particular career and defend the appropriate use of specific chemicals.

H^+, OH^-, and Le Châtelier

4 hours

Tasks for Instruction and/or Assessment

Performance

- Conduct an experiment focussing on an acid-base equilibrium using Le Châtelier's principle and report your findings. (320-5)

Paper and Pencil

- Describe the significance of pH in one of the following:
  - the maintenance of viable aquatic or terrestrial environments
  - the body fluids of living systems
  - the formation of various products; for example, shampoo, or cleaners

  (117-2, 117-7, 118-6)
- How are acidity and pH related? (320-5)

Presentation

- Write a magazine or newspaper article explaining, with examples, how acid rain is affecting an area of your community. (118-6)

Resources/Notes

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Chemistry Bulletin: Le Châtelier's Principle: Beyond Chemistry, p. 525
- Careers in Chemistry: Dangerous Goods Inspection, p. 615
- Chapter 14.2: Strong and Weak Acids and Bases, pp. 564–566

Video

- *Acids and Bases* (20980)

Electrochemistry

Introduction

Matter is electrical in nature, and some of its most important particles—electrons, protons, and ions—carry electric charge. When an electrical potential is applied between electrodes placed in a solution of ions, ions migrate to oppositely charged electrodes, and chemical reactions take place. Quantitative aspects of this electrolysis are important in analytical chemistry and the chemical industry.

Experiments are compulsaory in Chemistry 11 and students should have foty percent of their time in hands-on, minds-on exploration. Specific curriculum outcomes state which experiments should be done.

Focus and Context

This unit builds on concepts dealing with electric forces, matter and energy in chemical change, and quantitative relationships in chemical changes. Energy is involved in electrochemical changes. Problem solving and decision making in this unit will be helpful in creating an interest in the application of technology. Students should investigate, through laboratory work and relevant problems, the ways in which science and technology advance in relation to each other. The oxidation-reduction reactions that occur in everyday life, the products and processes used in industry, or the relationship of global environmental problems to oxidation-reduction reactions could be investigated.

Science Curriculum Links

Students will have studied the mole and electronegativity in Chemistry 11. Solutions, ionization, and chemical equilibrium in Chemistry 12 should be completed before beginning electrochemistry.

Curriculum Outcomes

STSE	Skills	Knowledge
Students will be expected to	*Students will be expected to*	*Students will be expected to*
115-1 distinguish between scientific questions and technological problems **116-6** describe and evaluate the design of chemical cells and the way they function, including the technological and scientific principles **116-7** analyse natural and technological systems to interpret and explain their structure and dynamics **118-4** evaluate the design of a technology and the way it functions on the basis of a variety of criteria that they have identified themselves	**212-1** identify questions to investigate that arise from practical problems and issues on redox **212-3** design an experiment identifying and controlling major variables **212-7** formulate operational definitions of major variables **213-8** select and use apparatus and materials safely for electrochemistry experiments **214-7** compare theoretical and experimental reduction potential values and account for discrepancies **214-8** evaluate the reliability of data and data collection methods involving reduction potentials **214-16** evaluate a personally designed and constructed cell on the basis of criteria they have developed themselves **214-18** identify and evaluate potential applications of findings	**215-7, 212-2** define problems regarding experimental designs for cells and evaluate the processes used in problem solving and decision making **322-1** define oxidation and reduction experimentally and theoretically **322-2** write and balance half-reactions and net reactions **322-3** compare oxidation-reduction reactions with other kinds of reactions **322-4** illustrate and label the parts of electrochemical and electrolytic cells and explain how they work **322-5** predict whether oxidation-reduction reactions are spontaneous based on their reduction potentials **322-6** predict the voltage of various electrochemical cells **322-7** compare electrochemical and electrolytic cells in terms of energy efficiency, electron flow/ transfer, and chemical change **322-8** explain the processes of electrolysis and electroplating **322-9** explain how electrical energy is produced in a hydrogen fuel cell

Oxidation and Reduction
2 hours

Outcomes

Students will be expected to

- identify questions to investigate that arise from practical problems and issues on redox (212-1)
- distinguish between scientific questions and technological problems (115-1)
- define oxidation and reduction experimentally and theoretically (322-1)

Elaborations—Strategies for Learning and Teaching

Students should perform experiments to observe a redox reaction, such as $AgNO_3$ reacting with Cu.

Students should identify questions about oxidation and reduction to investigate or talk about. In small groups, they might begin by listing things they already know or think they know about electrochemistry. As a class, they could generate a list and pose questions about electrochemistry. Suggestions might include the components of various types of batteries or what happens when iron corrodes or how electroplating occurs.

Students should distinguish between scientific questions and technological problems that involve oxidation and reduction situations. For example, they could discuss such questions as What is an electrochemical cell? and How can a metal be protected from corrosion?

Students should define the terms **oxidation-reduction**, **oxidizing agent**, **reducing agent**, **oxidation number**, **half-reaction equations**, and an **oxidation-reduction (redox) reaction**. Students could put a piece of zinc in copper(II) sulfate solution, represented by the equation $Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$. Discussion might be introduced by the following: "The zinc is said to undergo oxidation because its oxidation state increases from 0 to +2; the copper is said to undergo reduction because its oxidation state decreases from +2 to 0."

Students should identify electron transfer in equations like

$Zn \rightarrow Zn^{2+} + 2e^-$ and $Cu^{2+} + 2e^- \rightarrow Cu$

These are half-reactions. Oxidation (loss of electrons) and reduction (gain of electrons) do not occur separately. Copper ions could not be reduced without a source of electrons, and zinc, when oxidized, needs another substance to take the electrons that are given up. The oxidizing agent would be Cu^{2+}, and Zn, the reducing agent, is oxidized in oxidation-reduction reactions. Other examples allow students to identify the substance oxidized and the substance reduced in a redox equation, and the oxidizing and reducing agents.

Students could write equations for the reaction, describe their observations, analyse the results, and identify the oxidizing and reducing agents. OIL RIG is a mnemonic device that relates analysis to half-reactions. It means "Oxidation Involves Loss, Reduction Involves Gain." Another such device is LEO say GER, "Loss of Electrons, Oxidation and Gain of Electrons, reduction." Using oxidation number rules, students should find the oxidation numbers of the atoms in the molecules or ions. They should write half-reaction equations from their experiment results.

Oxidation and Reduction

2 hours

Tasks for Instruction and/or Assessment

Performance

- Using a list of redox reactions, determine the oxidation number of each atom in each species. Compare your results with your partner's. Identify the oxidizing and reducing agents, and describe the transfer of electrons. (322-1).
- Perform and report on a redox experiment. (322-1)

Journal

- Halogens kill bacteria and other microorganisms. Chlorine is a halogen that is safe enough and readily available for large-scale treatment of public water supplies. What happens to the hypochlorous acid formed when $Cl_2(g)$ is added to $H_2O(l)$? (212-1, 115-1, 322-1)
- What does a study of electrochemistry involve? (115-1, 322-1)

Paper and Pencil

- Show the species that is oxidized and the species reduced. Identify the oxidizing agent, reducing agent, oxidation number of each atom, and electron transfer in each of the following unbalanced equations:

  $Fe^{2+} + MnO_4^- + H^+ \rightarrow Fe^{3+} + Mn^{2+} + H_2O$

  $Cu + NO_3^- + H^+ \rightarrow Cu^{2+} + NO + H_2O$

  (322-1)
- Write a report on your experiment. Include correct oxidation and reduction half-reactions. (322-1)
- Write half-reactions for each of the following:

  $Br_2 + 2Cl^- \rightarrow Cl_2 + 2Br^-$

  $Cu + Cd^{2+} \rightarrow Cu^{2+} + Cd$

  (322-1)

Resources/Notes

Experiment

Chemistry 11 and Chemistry 12: A Teaching Resource

- Activity 34: Rusting, a Redox Reaction

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Chemistry Bulletin: Aging: Is Oxidation a Factor? p. 717
- Tools and Techniques: The Breathalyzer Test: A Redox Reaction, p. 739
- Chapter 18.1: Defining Oxidation and Reduction, pp. 713–720
- Chapter 18.2: Oxidation Numbers, pp. 721–728
- ThoughtLab: Finding Rules for Oxidation Numbers, p. 723

Redox and Half-Reactions

8 hours

Outcomes

Students will be expected to

- compare oxidation-reduction reactions with other kinds of reactions (322-3)

Elaborations—Strategies for Learning and Teaching

Given a group of equations, students should identify redox reactions and differentiate between oxidation-reduction reactions and non-redox chemical reactions by identifying half-reactions and changes in oxidation number. Students could investigate equations to see which ones involve electron transfer. From this, students could determine oxidation-reduction reactions, or "redox" reactions. These involve two half-reactions, one oxidation, the other reduction. Teachers might ask if anyone found an equation involving transfer among more than two species. Sample equations might include the following:

$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + H_2CO_3$

$Cu + H^+ + NO_3^- \rightarrow Cu^{2+} + NO_2 + H_2O$

$CuS + HNO_3 \rightarrow Cu(NO_3)_2 + S + NO + H_2O$

$H_2SO_4 + HBr \rightarrow SO_2 + Br_2 + H_2O$

$NaOH + HCl \rightarrow NaCl + H_2O$

Students should do a titration experiment for

$Fe^{2+} + MnO_4^- + H^+ \rightarrow Fe^{3+} + Mn^{2+} + H_2O$

and, from their calculations, find the balanced equations. They can then discuss how this is different from the acid-base titration they performed previously.

Redox and Half-Reactions

8 hours

Tasks for Instruction and/or Assessment

Performance

- Conduct a redox experiment, and using calculations, find the balanced equation. (322-3)

Journal

- Explain why some reactions are spontaneous and some are not. (322-3)
- Now that you have been introduced to redox, list examples that might occur in your home. (322-3)

Paper and Pencil

- Given 2.00 g of Fe^{2+}, how much $KMnO_4$ is needed to fully oxidize it to Fe^{3+}? (322-3)

Resources/Notes

Experiments

Chemistry 11 and Chemistry 12: A Teaching Resource

- Activity 34: Rusting, a Redox Reaction
- Activity 35: A Two-Metal Redox Reaction
- Activity 36: A Study of Corrosion
- Activity 46: Constructing Relative Reactivity Tables

Curriculum Correlation

- *McGraw-Hill Ryerson Chemistry* (23700), Chapter 18.2, Oxidation Numbers, pp. 721–728

Video

- *Electrochemical Cells* (V9062)

Redox and Half-Reactions *(continued)*

Outcomes

Students will be expected to

- write and balance half-reactions and net reactions (322-2)

Elaborations—Strategies for Learning and Teaching

Students could do a redox experiment activity. They could select five metals and five solutions and determine which react the greatest number of times. They should use half-reaction equations obtained from a standard reduction potential table.

Students should write balanced half-reactions, and the overall reaction, and determine if the reaction is spontaneous. The balanced equation could be obtained by writing half-reactions and adding them. One or both equations might have to be multiplied by appropriate integers so that the number of electrons gained by the oxidizing agent equals the number lost by the reducing agent.

Students should assign oxidation numbers to the atoms undergoing chemical change from examples provided. The lead storage cell in automobile batteries might be used; the reaction is

$$Pb + PbO_2 + 2H_2SO_4 \underset{\text{charging}}{\overset{\text{discharging}}{\rightleftharpoons}} 2PbSO_4 + 2H_2O$$

Another example might be a fuel cell used in a spacecraft. It uses the reaction between hydrogen and oxygen gases. With graphite electrodes, the following reactions occur in the presence of certain catalysts:

anode:	$2H_2 + 4OH^-$	$\rightarrow 4H_2O + 4e^-$
cathode:	$O_2 + 2H_2O + 4e^-$	$\rightarrow 4OH^-$
overall:	$2H_2 + O_2$	$\rightarrow 2H_2O$

Teachers could use the table from the *Nova Scotia Chemistry Data Booklet*. Looking at the table, students should predict whether a reaction occurs based on the relative positions of the oxidizing agent and reducing agent. Examples might include zinc in copper(II) sulfate, silver in copper(II) nitrate, or water contamination. When students have opportunities to observe and balance a wide variety of redox equations, they could create a flow chart to show the steps needed to balance these equations.

Redox and Half-Reactions *(continued)*

Tasks for Instruction and/or Assessment

Performance

- Construct your own activity series table of strongest to weakest oxidizing agents for metals based on an experiment you have designed and completed. Compare it with the standard electrode potential table. (322-2)
- Select the appropriate equipment, and, using it correctly, perform an oxidation-reduction titration experiment to determine unknown concentrations. (322-2)

Paper and Pencil

- Balance the following equations:

  $Al + Cu^{2+} \rightarrow Al^{3+} + Cu$

  $H_2 + Cl_2 \rightarrow H^+ + Cl^-$

  $Fe^{2+} + MnO_4^- + H^+ \rightarrow Fe^{3+} + Mn^{2+} + H_2O$

  (322-2)

Resources/Notes

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Chapter 18.3: The Half-Reaction Method for Balancing Equations, pp. 730–745
- Investigation 18-B: Redox Reactions and Balanced Equations, pp. 740–741

Print Resources

- *Nova Scotia Chemistry Data Booklet*

Electrochemical and Electrolytic Cells

6 hours

Outcomes

Students will be expected to

- describe and evaluate the design of chemical cells and the way they function, including the technological and scientific principles (116-6)
- define problems regarding experimental designs for cells and evaluate the processes used in problem solving and decision making (215-7, 212-2)
- illustrate and label the parts of electrochemical and electrolytic cells and explain how they work (322-4)

Elaborations—Strategies for Learning and Teaching

Students should design and evaluate experimental designs for cells and suggest alternatives and improvements.

Students should describe the construction of various cells and the technology used in them. Students could identify the science equations involved in a cell. They could describe how they think chemical cells are made and what their uses might be. They could look at various cells and evaluate scientifically the way the cells function. Students might start with the components of a typical flashlight. They could use a battery, bulb, and two 30 cm lengths of insulated wire to demonstrate what is needed for a complete circuit. Students might discuss or list problems that could occur with their circuit.

In small groups, they might look at and compare cells. Students might think about the pros and cons of gasoline versus fuel cells for cars. Perhaps the recycling of aluminum, looking at the corrosion and the economic and social contexts, could help students see the connections between the technological solutions and scientific principles involved in electrochemistry.

Space vehicles need electricity. Smaller numbers of high voltage cells give a higher voltage for a lower mass. By referencing a standard electrode potential table, students could determine which cell would give the highest voltage.

Teachers should provide opportunities for students to illustrate, label, define, and identify the parts of an electrochemical cell: anode, cathode, anion, cation, salt bridge / porous cup, and internal and external circuit; to identify the flow of electrons and the migration of ions for both electrochemical and electrolytic cells; to construct, observe, and describe an electrolytic cell and an electrochemical cell, comparing predictions and observations; to illustrate and label the parts of an electrolytic cell and explain how they work; and to define and identify, on a diagram of an electrolytic cell, the following: anode, cathode, anion, cation, and power supply.

Electrochemical and Electrolytic Cells

6 hours

Tasks for Instruction and/or Assessment

Journal

- Explain how the flow of electrons in a flashlight produces light. (116-6, 215-7, 212-2)

Paper and Pencil

- An electric eel can produce a charge of 600 V. It does this by combining the voltages of individual electroplates. If each electroplate produces 150 mV, how many plates are required to develop this voltage? (212-2, 215-7)
- Can you use the space cell to run your CD player? (215-7, 212-2)

Presentation

- Illustrate and label the parts of an electrochemical cell. Explain how it works. (322-4)
- Research and illustrate the familiar flashlight battery, either the acidic version with the central carbon rod or the alkaline version. (116-6, 322-4)
- Illustrate and label the parts of an electrolytic cell. Explain how it works. (322-4)
- Role-play the behaviour of a particle in an electrochemical cell. (322-4)

Resources/Notes

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)
- Chapter 19.1: Galvonic Cells, pp. 757–767
- Investigation 19-A: Measuring Cell Potentials of Galvonic Cells, pp. 762–763
- Chapter 19.3: Electrolytic Cells, pp. 776–789
- Investigation 19-B: Electrolysis of Aqueous Potassium Iodide, pp. 784–785

Electrochemical and Electrolytic Cells *(continued)*

Outcomes

Students will be expected to

- select and use apparatus and materials safely for electrochemistry experiments (213-8)
- evaluate a personally designed and constructed cell on the basis of criteria they have developed themselves (214-16)
- formulate operational definitions of major variables (212-7)

Elaborations—Strategies for Learning and Teaching

Students should deduce from their experiments/activities that electrochemical cells operate on the energy of spontaneous oxidation-reduction reactions. Students should define electrolytic cells as requiring electrical energy to cause non-spontaneous oxidation-reduction reactions to occur.

By constructing several electrochemical cells, students could observe the half-cell reaction at each electrode, measure the voltage, and draw a labelled diagram. Students might construct cells using objects such as pickles or potatoes. Other examples to look at include the lead-storage cell, mercury cell, rechargeable cell, and alkaline cell. Reports on their cells could include explanation of the purpose of the salt bridge, direction of electron flow in the external circuit, and the equation showing how the cell operates. Other criteria might be generated through a class discussion.

Students could construct electrolytic cells and electrolyze some aqueous solutions. Observations of the half-cell reactions include labelling all parts, predicting and writing equations at the electrodes, and the overall redox equations. It might be possible to calculate the minimum voltage to make the cell function. Electroplating an object or demonstrating the electrolysis of a molten salt could also be done. In constructing different cells, students demonstrate their learning and apply their knowledge to explain the function of the cells.

Students should explain the operation of both types of cells in terms of mass and possible colour change. They could look at other variables that might influence cell output, such as size of electrodes. Copper solutions might be used as the example. Students should describe, with the aid of a diagram, how a cell functions. They might use one of the cells they designed as their example.

Electrochemical and Electrolytic Cells *(continued)*

Tasks for Instruction and/or Assessment

Performance

- Design a cell using simple materials such as an orange, a potato, orange juice, or a lemon. (213-8, 212-7)

Journal

- Paper clips are sometimes used as electrodes. Would it make a difference if they were plastic coated? (214-16)

Paper and Pencil

- Report your constructed cell. Include your criteria, procedures, variables, and materials. (214-16, 212-7)
- What is an electrochemical cell? an electrolytic cell? (212-7)
- Draw a concept map for the following terms: anode, cathode, anion, cation, salt bridge, internal circuit, external circuit, power supply. (212-7)

Resources/Notes

Curriculum Correlation

- *McGraw-Hill Ryerson Chemistry* (23700), Investigation 19-C: Electroplating, pp. 794–795

Redox Reactions with Standard Reduction Potentials

5 hours

Outcomes

Students will be expected to

- predict whether oxidation-reduction reactions are spontaneous based on their reduction potentials (322-5)
- predict the voltage of various electrochemical cells (322-6)

Elaborations—Strategies for Learning and Teaching

Students could use the table of standard reduction potentials. They should predict the spontaneity of redox reactions on the basis of calculated standard cell potential values and the relative positions of half-reduction equations on a standard reduction potential table.

Students could write and balance oxidation-reduction reactions using half-reaction equations obtained from a standard reduction potential table. They could explain that the scientific community has universally accepted the values for half-reaction potentials based on 0 volts for the $2H^+ + 2e^- \rightarrow H_2$, under standard conditions of ideal behaviour.

Two manipulations are often required to obtain a balanced redox reaction. One of the reduction half-reactions must be reversed, which means that the sign of the potential for this half-reaction must also be reversed. Since the number of electrons lost must equal the number gained, half-reactions must be multiplied by integers for electron balance. Students should know that the value E° is not changed; the standard reduction potential, E°, does not depend on how many times the reaction occurs. From their cell diagrams that showed electrons flowing from the anode to the cathode, students might describe the cell process.

Students could consider the cell

$Cu(s) + Fe^{3+}(aq) \rightarrow Cu^{2+}(aq) + Fe^{2+}(aq)$

They could develop simple half-reaction equations from information provided about redox changes. So, the following uses the above example:

(1) $Cu^{2+} + 2e^- \rightarrow Cu \quad E° = 0.34V$

(2) $Fe^{3+} + e^- \rightarrow Fe^{2+} \quad E° = 0.77V$

To balance and calculate the standard cell potential, the copper reaction, (1) must be reversed: $Cu \rightarrow Cu^{2+} + 2e^- \quad E° = –0.34V$. Then, to balance the electrons, (2) must be multiplied by 2:

$2Fe^{3+} + 2e^- \rightarrow 2Fe^{2+} \quad E° = 0.77V$

Now, by adding the two reactions, the balanced cell reaction can be found:

$Cu \rightarrow Cu^{2+} + 2e^- \quad E° = –0.34V$ ±

$2Fe^{3+} + 2e \rightarrow 2Fe^{2+} \quad E° = 0.77V$

$Cu(s) + 2Fe^{3+}(aq) \rightarrow Cu^{2+}(aq) + 2Fe^{2+}(aq) \quad E°_{cell} = –0.34V + 0.77V$

Redox Reactions with Standard Reduction Potentials
5 hours

Tasks for Instruction and/or Assessment

Paper and Pencil

- Predict whether the following reactions are possible:
  - oxidation of iron atoms by silver ions
  - oxidation of bromide ions by chlorine
  - reduction of iodine by fluoride ions

  (322-5, 322-6)
- Write the balanced equation for the reaction of copper with dilute nitric acid. Is this reaction spontaneous? Support your answers. (322-5, 322-6)
- Will the reaction of cadmium metal and copper II ions be spontaneous? Support your answer. (322-5, 322-6)

Presentation

- Diagram a cell in which the reaction consists of the displacement of silver from $AgNO_3$ by metallic copper to produce Ag(s). Write the equation for the half-reaction that takes place in each half-cell, identifying each as oxidation or reduction. Then write the equation for the total cell reaction. (322-5)

Resources/Notes

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Chapter 19.2: Standard Cell Potentials, pp. 768–774
- Chapter 19.3, Electrolytic Cells, pp. 776–787

Redox Reactions with Standard Reduction Potentials *(continued)*

Outcomes

Students will be expected to

- compare theoretical and experimental reduction potential values and account for discrepancies (214-7)
- evaluate the reliability of data and data collection methods involving reduction potentials (214-8)

Elaborations—Strategies for Learning and Teaching

Students should define a spontaneous reaction as one that produces a positive cell potential. Using the table, they could predict the voltage of various cells, and determine which reactions should be spontaneous. Some examples:

$Fe^{2+} + MnO_4^- + H^+ \rightarrow Fe^{3+} + Mn^{2+} + H_2O$

or

$Ag^+ + Fe^{2+} \rightarrow Fe^{3+} + Ag$

or

$Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$

Students could assign oxidation numbers to atoms undergoing chemical change, and they could combine their knowledge of cell diagrams with equations. Cell potentials are not altered by the factors used to balance the electrons.

Students might look at examples of redox reactions used in industry and write the equations and calculate the potential of these reactions. Food processing, water treatment, corrosion, metallurgy, or respiration might be used for examples. Students should compare lab and theoretical data and account for possible differences in reduction potentials. They might discuss how we can measure cell potential. The unit of electrical potential is the volt, V. Teachers could present three ways that cell potential has been measured: voltmeter, potentiometer, and digital voltmeter. Students might use instruments in an experiment to collect data in a cell reaction. By making and testing several types of cells, they will have data available for evaluation. They could perform an experiment to test predictions about oxidation-reduction reactions.

Students should evaluate reduction-potential data and the methods used to collect them.

Redox Reactions with Standard Reduction Potentials *(continued)*

Tasks for Instruction and/or Assessment

Performance

- Design and test a basic cell of your choice. Compare your results with the reduction table. Comment. (214-8, 214-7)

Paper and Pencil

- Discuss various methods used to find reduction potential. Compare theoretical and experimental reduction potential values. (214-7, 214-8)

Resources/Notes

Curriculum Correlation

- *McGraw-Hill Ryerson Chemistry* (23700), ThoughtLab: Assigning Reference Values, p. 774

Energy Efficiency of Cells
3 hours

Outcomes

Students will be expected to

- compare electrochemical and electrolytic cells in terms of energy efficiency, electron flow/transfer, and chemical change (322-7)
- explain the processes of electrolysis and electroplating (322-8)
- evaluate the design of a technology and the way it functions on the basis of a variety of criteria that they have identified themselves (118-4)
- explain how electrical energy is produced in a hydrogen fuel cell (322-9)
- analyse natural and technological systems to interpret and explain their structure and dynamics (116-7)
- identify and evaluate potential applications of findings (214-18)

Elaborations—Strategies for Learning and Teaching

Various experiements available for cells. Students should perform at least two experiments that show how cells, electrolysis, and electroplating work.

Students could look at the process of refining metals from their ores. They might compare energy costs of refining a metal versus recycling it.

Students should predict and write balanced equations for reactions at the cathode and the anode of electrochemical and electrolytic cells, and they should recognize that predictions and observations do not always concur.

Students should explain the process of electrolysis. They could discuss the practical importance of electrolysis by using examples such as charging a battery, chrome plating an object, or producing aluminum metal. Electroplating industries are common.

Students should explain the process of electroplating. They could use the example of silver on flatware or jewellery. A sample could be set up depositing copper metal from a copper(II) sulfate solution, on a strip such as zinc.

Students should establish criteria to evaluate different technological designs used in electroplating and electrolysis. They could evaluate how the technology design functions as a reliable source. Students could explain how cells both natural and technological play a role in everyday life. They could evaluate the potential applications of various cells based on criteria they have determined.

Students should explain the energy of a hydrogen fuel cell by analysing its use in various systems and by identifying applications that they find. Students could discuss the liquid hydrogen used to fuel rockets that launch satellites and power spacecraft. Teachers could have students suggest questions such as, What drives the H_2 combustion reaction? and Would the use of hydrogen-powered cars lead to less pollution? Such questions could lead to an explanation of how electrical energy is produced in a hydrogen fuel cell.

Metals in contact with water have a tendency to corrode. This can be costly. For example, an electrical hot-water tank will dissolve and start to leak, and a ship's hull will start to rust and the ship will sink. A sacrificial anode avoids this problem. In the case of a water heater, an extra pipe placed in the tank preferentially dissolves, rather than the tank or the heating elements. For ships, blocks of zinc are attached to the hull to solve this problem. Students could write a letter to the editor of a local newspaper to bring attention to this basic chemistry problem and its simple solution.

Energy Efficiency of Cells

3 hours

Tasks for Instruction and/or Assessment

Journal

- Will corrosion be a greater problem in an acidic or a basic solution? (116-7, 214-18)
- For a week or a day, keep a record of everything you use that is powered by batteries. Record the device used and the number and the type of batteries it contains. (116-7, 214-18, 118-4)
- In a balanced redox reaction, what is being conserved? (322-7)

Paper and Pencil

- A sunken ship is to be lifted from the ocean bottom. Plastic bags, containing seaweed and equipped with an arrangement of inert and internal and external electrodes, are attached to the ship. Electrolysis current is applied to the electrodes, to fill the bags with hydrogen gas. Is the internal electrode the anode or cathode? Explain. What are the products at the other electrode? (322-8, 116-7)
- Should you use zinc or copper or neither to "plate out" nickel metal from a nickel(II) nitrate solution? Explain. (116-7, 322-8, 214-18)
- Write a newspaper article offering ways to reduce the amount of waste produced by batteries. (118-4, 214-18)
- Write a short essay about technology that was not and could not have been available before the development of the nickel-cadmium battery. (118-4, 116-7, 214-18)
- Describe how electrical energy is produced in a hydrogen fuel cell. (322-9)
- What are the benefits and drawbacks associated with hydrogen fuel cells? (322-9)
- Write a letter to the editor of a newspaper about hot-water tanks. (116-7, 214-18)

Presentation

- Sketch a cell that forms iron metal from iron II ions while changing chromium metal to chromium III ions. Calculate the voltage, show the electron flow, label the anode and cathode, and balance the overall cell equations. (322-7)
- In small groups, research the environmental effects of different types of batteries. Analyse both the production and waste costs. Share your research process and findings with your class. (322-7, 118-4, 116-7, 214-18)

Resources/Notes

Curriculum Correlations

McGraw-Hill Ryerson Chemistry (23700)

- Chapter 19.3: Electrolytic Cells, pp. 776–789
- Investigation 19-C: Electroplating, pp. 794–795
- Chapter 19.5: Issues Involving Electrochemistry, pp. 798–806

Appendices

Appendix A: Equipment List

Item	Description	Quantity per School
acid storage cabinet		
apron, rubber, lab	lightweight, extra-heavy rubber coated sheeting plus cotton tapes at the waist and neck. Resists most chemicals, acids, and caustics, 42" x 27"	
Atlantic Canada Science Curriculum: Chemistry 11 and Chemistry 12		
balance, electronic, 410 g x 0.01 g	stainless steel platform, LCD display, multiple weighing modes	2/lab
balance, electronic, 600 g x 0.1 g	stainless steel platform, LCD display, multiple weighing modes	11
battery		
battery electrode, copper		1
beaker tongs	plastic-coated jaws, non-slip grip, holds 50-2000 mL beakers; 9" in length	16/lab
beaker, 400 mL	12/pkg	4 pkg
beaker, 50 mL	12/pkg	2 pkg
beaker, Pyrex, low form, 1000 mL	single	6
beaker, Pyrex, student grade, 100 mL	12/pkg	4 pkg
beaker, Pyrex, student grade,	12/pkg 250 mL	4 pkg
beaker, Pyrex, student grade,	2 pkg (6/pkg) 600 mL	2 pkg
boiling stones	promote boiling to 260°C, 250 g	
bottle, polypropylene, 500 mL		1
bottle, polystop dropper, 60 mL		4
brush, beaker, 33 cm	durable black bristle brush, 16"	4
brush, flask, 31 cm	while brush on flexible plastic shaft and handle	4
brush, test tube, white nylon	non-scratching, white bristles, up to 10 mm (pkg of 12)	
brush, test tube, white nylon	non-scratching, white bristles,16 mm (pkg of 12)	
brush, test tube, white nylon	non-scratching, white bristles,16–25 mm (pkg of 12)	

Item	Description	Quantity per School
burets	acrylic, unaffected by dilute mineral acids and bases except hydrofluoric acid and ammonium hydroxide. Not recommended for use with alcohol and organic solvents, 50 mL capacity	20
capillary tubes, melting point	disposable, wall thickness 0.2 mm, 100/pkg	1 pkg
chart, Periodic Table of Elements		1
chart, spectrum analysis		1
chemical spill kit		1/lab
chemplates	clear, moulded, high-impact plastic, 12 numbered	cavities
clamp support	sturdy, cast-iron, firm tabletop support, rod can be held vertically or horizontally, 5" x 8" base, 3/8" x 20" rod	16/lab
clamp, adjustable rod	aluminum, swivel and lock at any angle on rods up to 1/2" in diameter	16/lab
clamp, thermometer, 14 cm		16/lab
clamp, three-finger extension	vinyl coated, holds 1/32-23/4", can be adjusted to varying angles, corrosion resistant	16/lab
clamps, buret	double, polyethylene	16/lab
conductivity apparatus, student	includes paper for paper chromatography	
corks	assortment fits from small test tubes to 250 mL Erlenmeyer flasks, 100/pkg	
crucible	low form, 30 mL, student grade, porcelain; can be heated at temperatures up to 1150°C, glazed	20
cylinder, plastic, 100 mL	chemically resistant to most acids, bases, alcohols and ketones	12/lab
cylinder, plastic, 250 mL x 2 mL	chemically resistant to most acids, bases, alcohols and ketones	12/lab
cylinder, polypropylene, 1000 mL	chemically resistant to most acids, bases, alcohols and ketones	1/lab
cylinder, Pyrex, 10.0 mL	heat-resistant, white enamel markings	12/lab
cylinder, Pyrex, 25.0 mL	heat-resistant, white enamel markings	12/lab
cylinder, Pyrex, 250 mL	heat-resistant, white enamel markings	12/lab
dishwasher		1
dispensing bottles with spout cap, 30 mL	lightweight, polyethylene dropper bottle with secure, snap-on sealer caps, leakproof. 48/pkg	1

Item	**Description**	**Quantity per School**
distillation apparatus, water		
dropping bottles, amber, 30 mL	heavy flint with glass pipet and rubber bulb in a screw cap, 12/pkg	1
dropping bottles, glass, 30 mL	heavy flint with glass pipet and rubber bulb in a screw cap, 72/pkg	2/lab
drying oven	for drying, baking, sterilizing, evaporating, welded steel, 2 adjustable shelves, on/off switch, circuit breaker, pilot light, temperature dial, 2 cubic feet ±5°	1/school
dust masks	white cone mask with elastic strap, pkg of 50	
dustpan and brush		1/lab
emergency shower	compulsory	
evaporating dish, porcelain, 50 mL		16/lab
eye wash station		
face shield	lightweight, polycarbonate window shield (8" x 12" x 1/2"), ANSI approved	1/lab
filters, student grade	medium retention and flow rate, 1250/pkg	1
fire blanket with wall stand	compulsory	
fire extinguisher	compulsory	
first-aid kit	compulsory; 40-50 person kit	1/lab
flammable storage cabinet	compulsory	
flask, Erlenmeyer, Pyrex, 100 mL	thermal and shock-resistant, white enamel markings, 12/pkg	2 pkg
flask, Erlenmeyer, Pyrex, 1000 mL	thermal and shock-resistant, white enamel markings, each	1
flask, Erlenmeyer, Pyrex, 250 mL	thermal and shock-resistant, white enamel markings, 12/pkg	2 pkg
flask, Erlenmeyer, Pyrex, 500 mL	thermal and shock-resistant, white enamel markings, 6/pkg	1 pkg
flask, Pyrex, volumetric, 100 mL	meet Class B requirements, with snap caps, 6/pkg	1
flask, Pyrex, volumetric, 1000 mL	meet Class B requirements, with snap caps, each	2
flask, Pyrex, volumetric, 250 mL	meet Class B requirements, with snap caps, 6/pkg	1
flask, Pyrex, volumetric, 50 mL	meet Class B requirements, with snap caps, 6/pkg	1
Foundation for the Atlantic Canada Science Curriculum (64311)		

Item	**Description**	**Quantity per School**
fume hood	compulsory	
funnel, plastic, 65 mm	ribbed, 60° angle body facilitates rapid filtration, outside ribs prevent air lock, 36/pkg	1
funnel, powder, 80 mm	external ribbing prevents air lock, 12/pkg	1
gloves, chemical-resistant rubber	powder free nitril disposable gloves, size: medium, box of 100	1 box/lab
gloves, heat-resistant	tough cotton terry cloth that resists heat, one-size fits all	
gloves, solvent-resistant	non-disposable, 15 mil nitrile, flock-lined, pebble embossed, size: medium	2 pair/lab
goggle cabinet and sterilizer	40 goggle capactiy, UV sterilizing light, safety lock, heavy guage cabinet.	1/lab
Hoffman electrolysis apparatus	features graduated arms with stopcocks, 50 mL capacity, 0.2 mL graduations, 24" height	1
hot hand protectors	moulded silicone rubber, fingers and thumb slide into back pockets, nubs prevent slips and spills; one size	2/lab
hot plate	Corning Pyroceram platform, heat transfer up to 700°F, resistant to chemicals and scratches, 10" x 10"	2
hot plate, student	399°C, 8–9 cm	8
inorganic compound kit, instructor set	includes: 2.5 cm balls of black alkane carbon (30), black alkene carbon (20), black alkyne carbon (10) green halogens and monovalient non-metals (25), yellow sulphur/selenium hexavalent (20), orange sodium/potassium monovalent metals (20); 2 cm balls of red oxygen (30), blue nitrogen/phosphorus trivalent and pentavalent elements (30), yellow aluminum/chromium trivalent metals(30), orange calcium/magnesium bivalent metals (30); 1 cm balls of white hydrogen with integral bonding lugs (125), bonding lugs (150)	1
inorganic compound kit, student set	includes: 2.5 cm balls of black alkane carbon (6), black alkene carbon (4), black alkyne carbon (2) green halogens and monovalient non-metals (5), yellow sulfur/selenium hexavalent (4), orange sodium/potassium monovalent metals (4); 2 cm balls or red oxygen (6), blue nitrogen/phosphorus trivalent and pentavalent elements (6), yellow aluminum/chromium trivalent metals(6), orange calcium/magnesium bivalent metals (6); 1 cm balls of white hydrogen with integral bonding lugs (25), bonding lugs (30)	6

Item	Description	Quantity per School
interface box, 500, Science Workshop	Pasco	3
jug, dispensing	19 L (5 gallon)	2
lab jack	aluminum and stainless steel construction, vertical height of 10 1/4", removable 8" square platform, support rod 17 3/4"	1
labelling kit		
marble chips	(chemiclals) neutral, calcium carbonate chips	
Microchemistry Kit	Kits available include: Basic for experiments related to mole ratios, catalysts, rates of reaction, equilibrium, and tritrations; Advanced for experiments in acids and bases, production of hydrogen, eletrochemical cell, and decomposition of water; Basic Current Indicator Display to measure high and low conductivity; LED Bar Graph Conductivity Plate indicates relative conductivity using bar graph display; Microstand, adjustable, used in titration experimetns as a microburette holder; Microburner, scaled-down version of standard burner; Microcap with Holes fit onto Combo plate, used in experiments where the equivalent of a multi-hole rubber stopper is required; Solid Microcaps ideal for long term storage of liquids and dry chemicals; Microspatulas used for dry chemicals; Microplate Strips for long term storage of liquids and dry chemicals; Microplate Electrodes used for electrochemistry experiments.	
model, atoms and molecules		1
mortar and pestle	porcelain, oversize pestle, glazed except for grinding surface, 3.5" diameter x 2" height	2
multimeters	digital, LCD display, requires one 9 V battery, 5" x 2 3/4" (shared with Physics)	8
organic molecular manipulative		
Petri dish	100 mm x 15 mm, sterile	3
pH paper	hydrion pH test pkg range: 0-13; 1.0-2.5; 3.0-5.5; 6.0,8.0; 8.0-9.5; 10.0-12.0; 12.5-14.0	10
pH paper	colorphast, 0-14	10
pH probe		2

Item	**Description**	**Quantity per School**
pipets	disposable, thin stem, non-sterile, 6 mL capacity, 500/box	1 box
pipets, replacement for dropping bottles		12/pkg
plate, clear acrylic	10 cm x 10	6
rack, glassware draining	neoprene-coated, steel wire rack, holds all types of beakers and test tubes, 26-place	1
rack, test tube	polyethylene, holds up to 6 25 mm test tubes	16/lab
reaction plate	24 wells, 5/pkg	3
reagent bottles, 500 mL	24/pkg	21
ring stand		1
rubber transport bucket		
safety goggles	scratch resistant, clear lenses with one-piece moulded frame and side shields	40/lab
safety shield	3/16" polycarbonate barrier with heavy steel perimeter to provide stability and protection against flying debris and splashes. 19.5" x 30"	1/Chem lab
scoop, laboratory	stainless steel, 6 1/2" L, 12/pkg	2 pkg
spectrum tube, air		1
spectrum tube, argon gas		1
spectrum tube, carbon dioxide		1
spectrum tube, chlorine gas		1
spectrum tube, helium gas		1
spectrum tube, hydrogen gas		1
spectrum tube, iodine vapour		1
spectrum tube, krypton gas		1
spectrum tube, mercury vapour		1
spectrum tube, neon gas		1
spectrum tube, nitrogren gas		1
spectrum tube, oxygen gas		1
spectrum tube, water vapour		1
spectrum tube, xenon gas		1
spoon	deflagrating, /38 cm	2

Item	**Description**	**Quantity per School**
spot plates	white porcelain, glazed surface, 12 cavities	16/lab
stirring rods, glass	solid fint glass, fire-polished rounded ends, 3/16" diameter, 10" length	100
stopper, rubber	solid one-, two- and three-hole stoppers in an assortment of sizes, 3 lbs	1
support rings	support separatory or standard funnels or can be used with triangles to support flat-bottomed glassware; clamps attach to rods up to 1/2" in diameter; cast iron, corrosion-resistant plate finish 4"	16/lab
test tube tongs	wire, self-closing, holds up to 1" diameter, 5" long, 6/pkg	24/lab
test tube, Pyrex	heatable, chemical-, corrosion-, and shock-resistent, 25 mm x 150 mm, 72/pkg	1 pkg
test tube, Pyrex	heatable, chemical-, corrosion-, and shock-resistent, 18 mm x 150 mm, 72/pkg	2 pkg
test tube, Pyrex	heatable, chemical-, corrosion-, and shock-resistent, 13 mm x 100 mm, 72/pkg	1 pkg
thermometer	indoor/outdoor, digital	4
thermometer, -20°-110°C	red alcohol, Teflon-coated, partial immersion, 12"	16/lab
tin snips	cut metal	
tongs, crucible	rustproof, 1/4" nickel-plated steel wire with riveted joints and accurately aligned corrugated tips, long handles	16
tongs, utility	nickel-plated, designed for handling cylindrical apparatus such as test tubes, flasks, and small beakers up to 2" in diameter, flattened serrated jaws	16
tray and bottle	semi-micro reagent	
tray, tote, laboratory, 48 cm x 23		4
tube, ignition, Pyrex	25 mm x 200	24
tubing	clear, vinyl, 10 ft length, 3/8"	1
Velcro, industrial strength		1/lab
vermiculite or diatomaceous earth or clay kitty litter		1 bag/lab
vial	flint glass w/screw cap	1
wall chart	laminated periodic	1

Item	**Description**	**Quantity per School**
wash bottles	removable jet tip, 250 mL	
watch glass	flint glass, fire-polished edges, 65 mm, 12/pkg	2
wet cell and porous cups, student	transparent, unbreakable plastic, screw-on plastic ring, two brass electrode holders, 1 1/8" x 5" porous ceramic cup, electrodes includes one each of aluminum, nickel, graphite, and iron, two each of copper, lead, and zinc	3

Appendix B: Reference Information

Significant Figure Rules and Rounding

There are special rules for counting significant figures.

- All non-zero numbers are significant. Example: 143.257 has six significant figures.
- All zeros between non-zero numbers are significant. Example: 3408 and 1.205 both have four significant figures.
- All leading zeros following the decimal point are *not* significant. These zeros do nothing but set the decimal place. Example: 0.0012 has two significant figures.
- All trailing zeros after the decimal are significant. Example: 4.20 has three significant figures.
- All trailing zeros before a decimal are significant only if the decimal is present. Example: 100. has three significant figures; $1,000,000 has one.

There are two rules for calculations involving measured values.

- **Addition and Subtraction:** When adding and subtracting, round the answer to the least number of decimal places in any of the measurements. Example: 125.2 cm + 0.635 cm = 125.8 cm
- **Multiplication and Division:** When multiplying and dividing, round the answer to the least number of significant figures in any of the measurements. Example: 125.2 cm × 0.63 cm = 79 cm^2

Problems

Complete each of the following questions.

1. Determine the location of the last significant place value by placing a line under the digit. (Example: 1.70$\underline{0}$)

a) 8040
b) 0.0300
c) 699.5
d) 2.000×10^2
e) 0.90100
f) 90100
g) 4.7×10^{-8}
h) 10800000
i) 3.01×10^{21}
j) 0.000410

2. Determine the number of significant digits in the following numbers.

a) 0.02
b) 0.020
c) 501
d) 501.0
e) 5000
f) 5000.
g) 6051.00
h) 0.0005
i) 0.1020
j) 10001

3. Perform the following operations. Express the answer with the correct number of significant figures and include units.
   a) $1.65\ \text{m} \times 2.468\ \text{m}$ = ____________________
   b) $12.01\ \text{cm} + 36.2\ \text{cm} + 4\ \text{cm}$ = ___________
   c) $650\ \text{kg} - 12.2\ \text{kg}$ = ____________________
   d) $1.278 \times 10^3\ \text{m}^2 \div 0.27\ \text{m}$ = ________________
   e) $15.2\ \text{g} \div 9.6\ \text{mL}$ = _______________

Nomenclature (Ionic versus Molecular)

Before we begin, we should remember the differences between ionic and molecular compounds. Look at the table below to see some of the properties of ionic compounds.

Ionic Compounds	**Molecular Compounds**
• form between metals and non-metals	• form between two non-metals
• involve electron transfer	• involve electron sharing

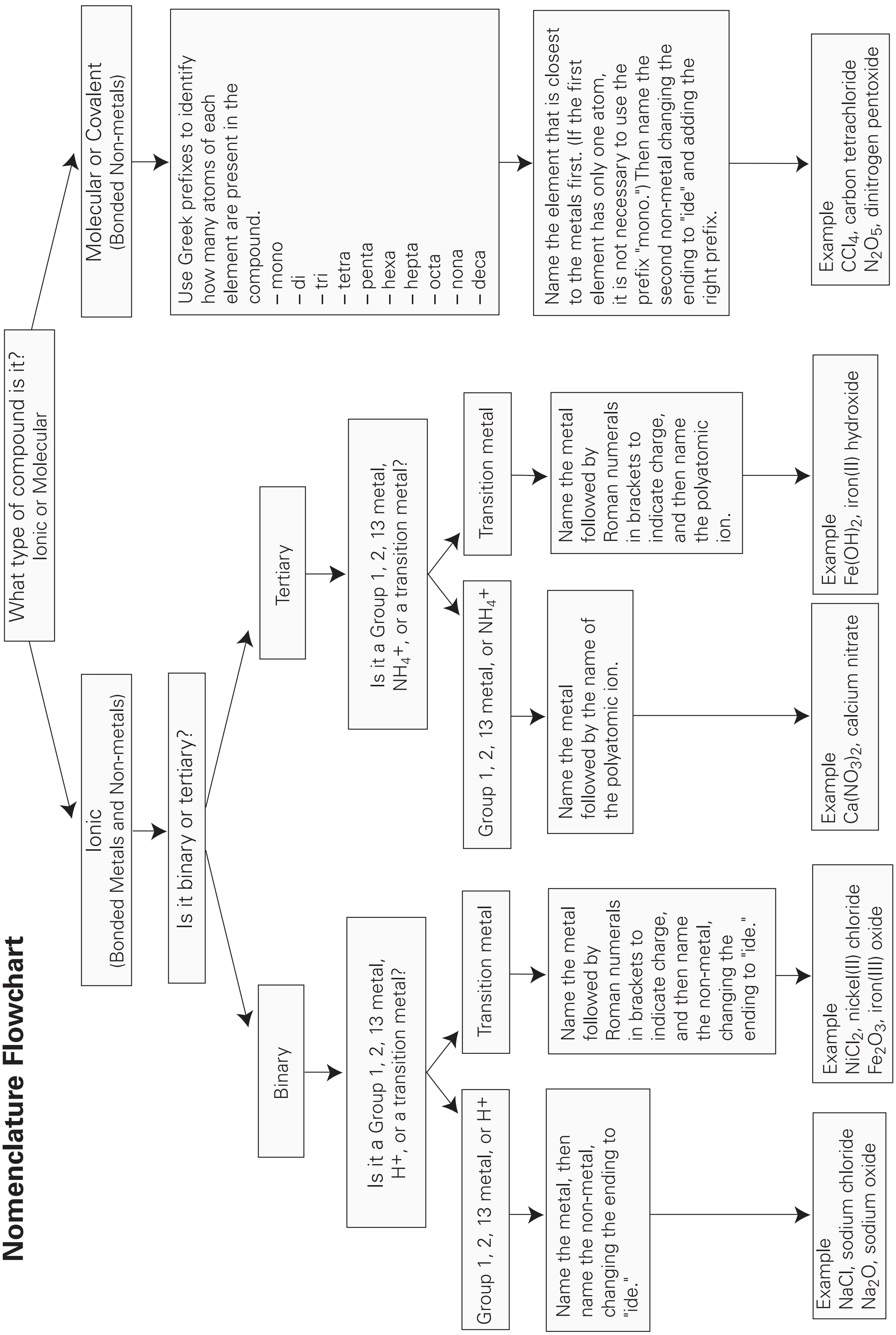
Since ionic and molecular compounds are different, they have different rules for naming. There are a lot of rules for naming compounds. To help with the naming process, go to the end of Appendix B for the nomenclature flowchart (p. 191). Another chart that will be helpful is the polyatomic ion reference sheet, also found at end of Appendix B, (p. 199).

Using the flowchart, name the following compounds.

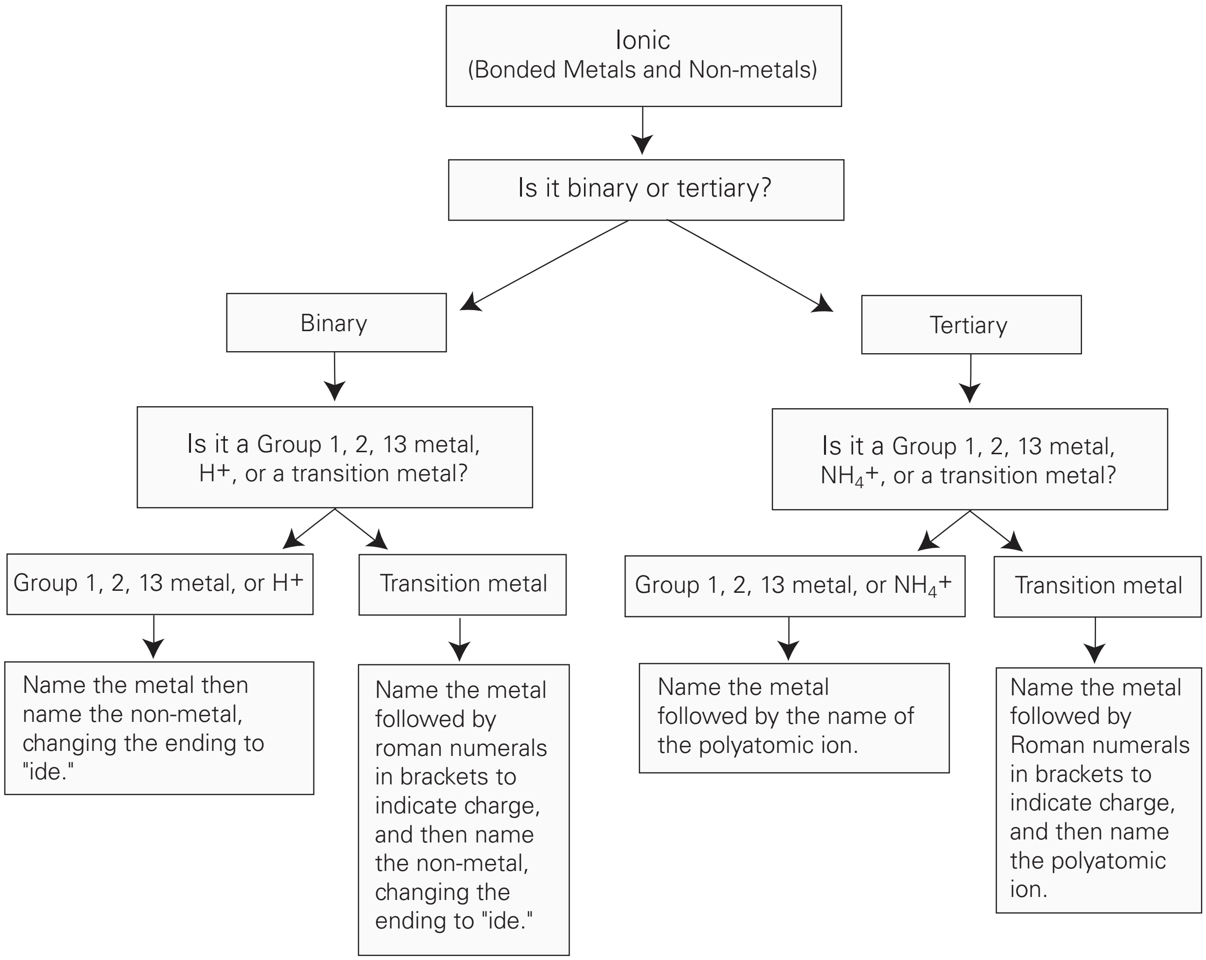
1. KCl
2. LiBr
3. $MgCl_2$
4. $NaNO_3$
5. $FeSO_4$
6. $CuCl_2$
7. CO_2
8. N_2O_4
9. SF_6
10. HCl
11. HNO_3
12. H_2SO_3

The compounds in the first column, numbers 1 through 6, are all metals plus non-metals. Using the flowchart then, we see that we are working with the ionic compounds and therefore only the left side of the chart.

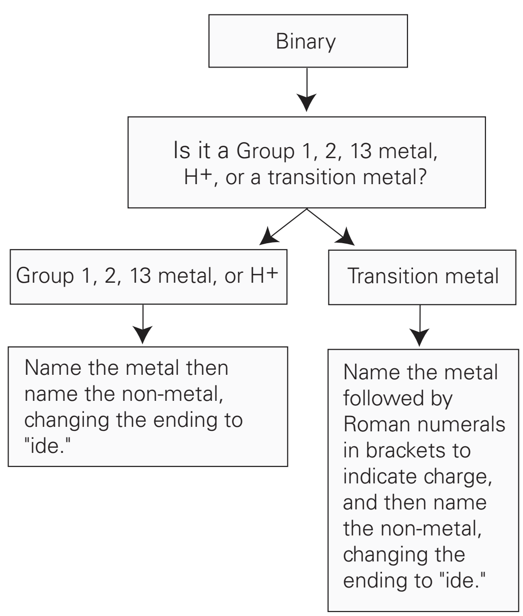
Nomenclature Flowchart



Nomenclature Flowchart: Ionic (left) Side Only



- **KCl:** We see that KCl is a binary compound (it has only two types of elements—potassium, K, and chlorine, Cl. Now we only need the far left of the flowchart.



K is a group 1 metal; thus we "name the metal then name the non-metal, changing the ending to 'ide'." So KCl is potassium chloride.

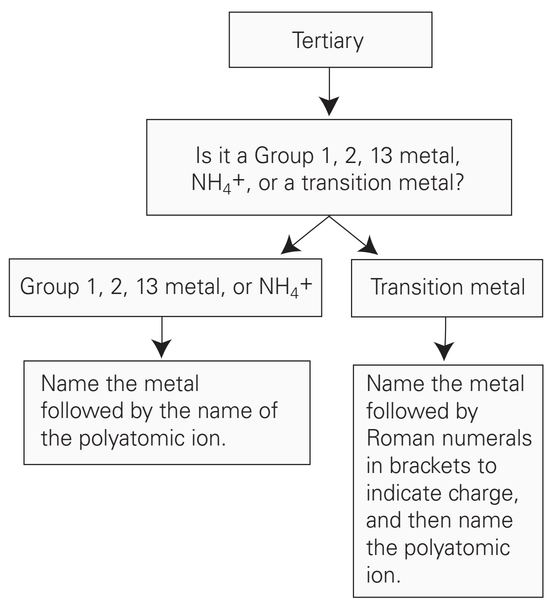
- **LiBr:** We see that LiBr is another binary compound (it has only two elements—lithium, Li, and bromine, Br. We again only need the far left of the flowchart and can name this compound the same way we named KCl.

  LiBr = lithium bromide

- **$MgCl_2$:** We see that $MgCl_2$ is yet another binary compound (it has only two types of elements—magnesium, Mg, and chlorine, Cl. The subscript 2 means that we need 2 Cl^{-1} ions to combine with one Mg^{2+} ion to form the compound (that has a zero charge). We again only need the far left of the flowchart and we can name this compound the same way we named KCl.

  $MgCl_2$ = magnesium chloride

- **$NaNO_3$:** We can see that this compound is not binary but tertiary (three different elements make up its formula). Therefore, we are using the second part of the ionic compound nomenclature chart.



$NaNO_3$ contains Na^+ (a group 1 metal ion) and the polyatomic ion NO_3^{1-}. In the polyatomic ion chart we see that NO_3^{1-} is nitrate. Since we are working with a group 1 metal ion, we need to look at the left side of the tertiary flowchart above. We see that the rule to name $NaNO_3$ is "Name the metal followed by the name of the polyatomic ion."

$NaNO_3$ = sodium nitrate

- **$FeSO_4$** is also a tertiary compound. It also contains a polyatomic ion (SO_4^{2-} = sulphate). Fe, iron, is a transition metal, so we need to look at the right side of the tertiary chart above, but iron has more than one charge. Iron can be Fe^{2+} or Fe^{3+}. We have to know which one it is to follow the rule for naming these types of compounds. The rule states "Name the metal followed by Roman numerals in brackets to indicate charge, and then name the polyatomic ion." Since the sulfate ion has a charge of -2, iron has to have a charge of +2 to add to zero. All compounds have a charge of zero.

  +2 –2
  ↓ ↓
  $FeSO_4$

  $FeSO_4$ = iron(II) sulphate

- **$CuCl_2$** is a binary ionic compound, so we are back to the far left of the ionic compound-naming flowchart. This time we are talking about a transition metal because Cu, copper, is element number 29 and is in the transition metal group. Like Fe, Cu has two charges, Cu^+ and Cu^{2+}. We know that Cl has a charge of –1 and there are two of them, so the total negative charge is –2. Therefore, the total positive charge on Cu is +2 to add to zero. The rule states, Name the metal followed by Roman numerals in brackets to indicate charge, and then name the non-metal, changing the ending to 'ide.'

  +2 –2
  ↓ –1×2
  $CuCl_2$

  $CuCl_2$ = copper(II) chloride

- **CO_2** is a covalent compound, also called a molecular compound. Remember that molecular compounds share electrons and because of that do not have distinct charges (+1, +2, –3, etc.). They share their electrons with each other much like you would share your things with your friends. What this means for us when we name the compounds is that we have to tell how many friends are present (sharing) in the compound by using prefixes. If you look to the farthest right of the flowchart you see the following part of the chart.

Molecular or Covalent
(Bonded Non-metals)

↓

Use Greek prefixes to identify how many atoms of each element are present in the compound.
– mono
– di
– tri
– tetra
– penta
– hexa
– hepta
– octa
– nona
– deca

↓

Name the element that is closest to the metals first. (If the first element has only one atom, it is not necessary to use the prefix "mono.") Then name the second non-metal, changing the ending to "ide," and adding the right prefix.

We have one carbon atom and two oxygen atoms. So the rule states "Name the element that is closest to the metals first. (If the first element has only one atom, it is not necessary to use the prefix 'mono'.) Then name the second non-metal, changing the ending to 'ide' and adding the right prefix."

CO_2 = carbon dioxide

- **N_2O_4** is named in the same way as CO_2. Here we have six friends, two nitrogen atoms sharing with four oxygen atoms. The prefix for 2 is "di," the prefix for 4 is "tetra."

  N_2O_4 = dinitrogen tetraoxide

- **SF_6** is also named in the same way as CO_2. Here we have seven friends, one sulphur atom sharing with six fluorine atoms. The prefix for 1 is "mono" but as with CO_2 it is ignored since it is the first non-metal that has the single atom; the prefix for six is "hexa."

  SF_6 = sulphur hexafluoride

- **HCl** brings us back to ionic compounds, but to a special way of naming them. According to the flowchart, we could name this compound just like number 1, a binary compound. Name the metal (hydrogen) and then name the non-metal, changing the ending to "ide": chloride. Therefore HCl is hydrogen chloride. But compounds like HCl are a special type known as acids. Acids usually begin with an H in their chemical formula. The alternate way of naming a binary acid is to use prefix hydro + element stem + ic then the word acid. Let's try. Since our element in this acid is chlorine, the element stem would be "chlor."

  HCl = hydrochloric acid

- **HNO_3** is a tertiary compound that contains hydrogen and a polyatomic ion, nitrate. The name of this compound, following the rule, would be hydrogen nitrate. But because the chemical formula begins with an H, it is an acid. When naming acids with polyatomic ions containing "ate," you have to change the ending to "ic," so nitrate changes to nitric. Thus the name of the acid is nitric acid.
- **H_2SO_3** is again a tertiary compound. SO_3^{2-} is sulphite, so the name of the compound is hydrogen sulphite. But notice that like the last compound, it begins with an H and therefore is an acid. With polyatomic ions that end with "ite," you have to change the ending to "ous," so sulphite changes to sulphurous. Thus the name of the acid is sulphurous acid.

Problems

1. Complete the following table.

Name	Formula
sodium hydroxide	NaOH
	LiCl
	H_3PO_4
	$FeCl_3$
	KOH
	HBr
	CCl_4
	$BaCO_3$
	NH_4Cl
	P_2O_5
	HF
	$PbSO_4$
	$HC_2H_3O_4$
	$CuNO_3$
	$MgCrO_4$
	LiF
	Al_2O_3
	SO_3
	CO_2
	$Sn(Cr_2O_7)_2$
	Ag_2SO_4

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

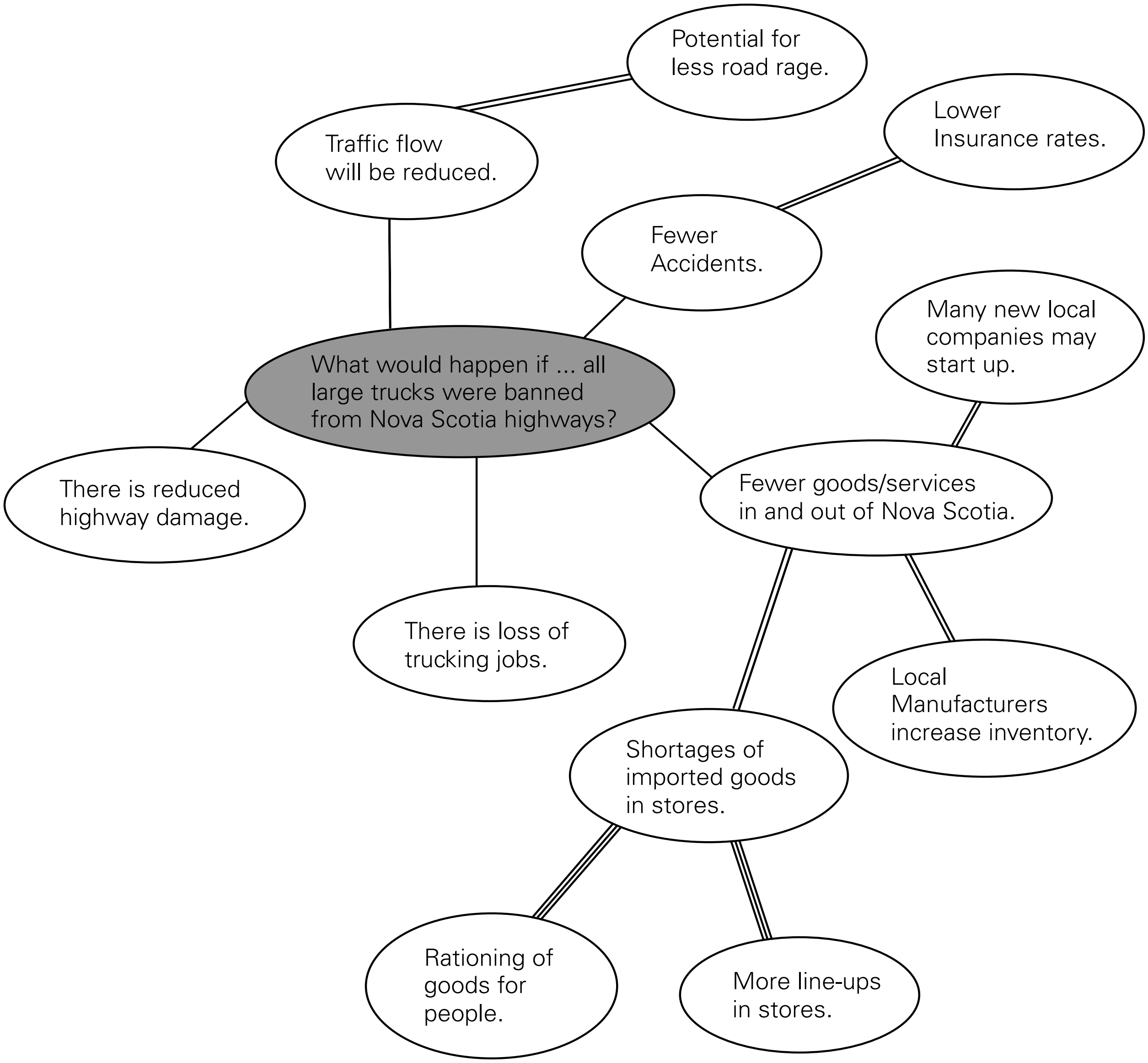
*average atomic mass values in parenthesis is the mass of the most stable isotope

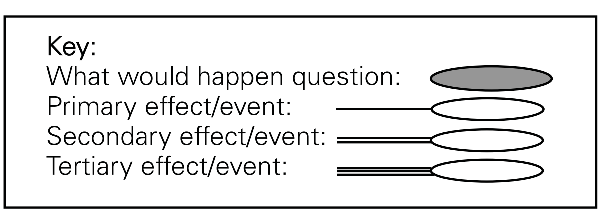
Names, Formulas and Charges of Some Common Polyatomic Ions

Positive Ions (Cations)		Negative Ions (Anions)	
		acetate	$C_2H_3O_2^-$
ammonium	NH_4^+	bromide	Br^-
		carbonate	CO_3^{2-}
		hydrogen carbonate or bicarbonate	HCO_3^-
		chlorate	ClO_3^-
		chloride	Cl^-
		chlorite	ClO_2^-
		chromate	CrO_4^{2-}
		cyanide	CN^-
		dichromate	$Cr_2O_7^{2-}$
		fluoride	F^-
		hydroxide	OH^-
		hypochlorite	ClO^-
		iodide	I^-
		nitrate	NO_3^-
		nitrite	NO_2^-
		oxide	O^{2-}
		oxalate	$C_2O_4^{2-}$
		hydrogen oxalate or binoxalate	$HC_2O_4^-$
		perchlorate	ClO_4^-
		permanganate	MnO_4^-
		peroxide	O_2^{2-}
		phosphate	PO_4^{3-}
		phosphite	PO_3^{3-}
		monohydrogen phosphate	HPO_4^{2-}
		dihydrogen phosphate	$H_2PO_4^-$
		sulphate	SO_4^{2-}
		hydrogen sulphate or bisulphate	HSO_4^-

Positive Ions (Cations)	Negative Ions (Anions)	
	sulphide	S^{2-}
	hydrogen sulphide or bisulphide	HS^{-}
	sulphite	SO_3^{2-}
	hydrogen sulphite	HSO_3^{-}
	thiocyanate	CNS^{-}
	thiosulphate	$S_2O_3^{2-}$

Appendix C: Futures Wheel Template





Appendix D: Memo Format

MEMORANDUM (2–3 spaces)

To: ______________ (double space)

Copies To: ____________ (double space)

From: _____________ (double space)

Date: _____________ (double space)

Subject: ______________ (3 spaces)

Dear _____________ (2 spaces)

Body of Text: Use single spacing with one blank line between paragraphs; paragraphs are either block or indented on the first line.

Signature Line (optional) or simply name

Notes: There are variations for confidential memos, interoffice memos, memos for multi-distribution, etc.

Appendix E: Video Resources

Education Media Library

The Education Media Library has over 5000 titles in its video collection. All programs have been evaluated for curriculum fit and are intended to support the Nova Scotia Public School Program. They may be used by teachers and others engaged in public education in Nova Scotia. Public performance rights have been purchased so that all videos can be shown in classroom settings to students and educators.

The Media Library offers video loans and video dubbing services. Loan videos have an assigned number that begins with the number 2 (e.g., 23456). These videos may be borrowed and returned. The videos that are available through dubbing begin with a V (e.g., V1123). The Media Library makes a copy of these videos, which is then retained by the client. Dubbing services are provided for the nominal recovery cost of the videocassette on which the programs are taped. Tape prices range from $1.44 for a 20-minute tape to $2.59 for a two-hour tape. Programs can be stacked onto one tape (e.g., four 30-minute programs on one tape) or be dubbed on separate tapes.

The Learning Resources and Technology website (http://lrt.EDnet.ns.ca) provides a rich variety of curriculum-related resources to help teachers in their classrooms. Teachers can search the video database, find out about educational software, search the database of curriculum-related websites, download curriculum catalogues, access workshops on web safety, and find tips on integrating technology into the classroom.

Title	Description
Acid-Base Indicators (V9071) 20 min., 1962	Proton-donor acceptor theory is used to interpret the experimental behaviour of acid-base indicators. Experiments and animation show the effects on indicators of changing acidity. Equilibrium constants of four indicators are determined and arranged in order of decreasing acid strength. The competition among bases for protons is shown by mixing the indicators and showing that each changes colour at different total acidity.
Acids and Alkalis (23229) 20 min., 1996	Everyday examples of acids and their uses are the starting point for an investigation of the chemical properties of acids and their industrial and economic importance. The pH scale is used to measure the acidity or alkalinity of a solution. Since acids and alkalis are opposites, they have a neutralizing affect on each other. For example, sulphur dioxide, an acid released when coal is burned for electricity, causes acid rain when it mixes with the rain in the air; however, this effect can be neutralized by adding an alkali.
Acids and Bases (20980) 15 min., 1989	The properties of acids and bases, including neutralization, are shown. The definition of pH is simplified to make it understandable for the average student. Real world examples are the neutralizing action of antacid tablets and the problem of acid rain.
Acids and Bases (23227) 14 min., 1993	Many common, everyday chemical processes are reactions of acids and bases. How do these processes occur, and what methods can be used to identify whether the chemical agents involved are acids or bases? In this program, laboratory experiments are used to demonstrate procedures for identifying substances as either acids or bases. In addition, the program uses animated particle models to illustrate graphically how ions are formed when acids and bases react with each other or with amphoteric substances such as water.
Atom Bond: The Atom with the Golden Electron (23193) 28 min., 1999	A parody of a James Bond movie, Gold Metallic Bond is sent off to investigate why Carbon, Nitrogen, and other atoms are training themselves in other types of bonds. He discovers their bond school and finds that they are all working toward “Project D.” Basic concepts include ionic bonding, covalent bonding, covalent network solids, metallic bonding, and intermolecular forces. Includes brief teacher’s guide.
Catalysts (20979) 15 min., 1989	The function of catalysts on the rates of chemical reactions is highlighted in this program via graphics, demonstrations, and the real world. Specific examples are the iron catalyst used in the production of ammonia, and zeolite and enzyme catalysts. The module is designed to help students understand how catalysts work and is closely tied to Chemical Kinetics (20978).

Title	Description
Catalytic Reactions (23230) 1991	This program defines the principles of a catalytic reaction and describes the effect of a catalyst on other substances. It also explains the occurrence of catalyst poisons and discusses the importance of catalysts in modern technology.
Chemical Kinetics (20978) 15 min., 1989	Laboratory demonstrations illustrate the effects of temperature, concentration, and catalysts on the rates of reaction. These effects are then examined through molecular motion and collision theory. Slowing down reactions is illustrated by a food chemist who discusses some of the problems of the food industry that are related to the effects of temperature, concentration, and catalysts.
Covalent Bonding (23195) 1995	Concepts from the program include molecular—how substances are held together by sharing electrons—and intramolecular—shapes and patterns explained with reference to water and polyethene.
Electrochemical Cells (V9062) 22 min., 1962	The construction and operation of an electrochemical cell are shown. Time lapse photography of the changes at the electrodes and animation of the cell processes show the nature of the electrode reactions, the motion of the electron and ion currents, and the relationship between concentrations and cell voltage.
Energy Choices (23305) 43 min., 1995	The conversion of fossil fuels and other primary forms of energy into electricity, heat, and mechanical power needed for transportation and industry accounts for a significant portion of all economic activity and an even larger share of all manmade pollution. The video, featuring the Canadian pop group, Moxy Fruvous, is divided into four parts: history of energy use and technology, energy and the environment, energy efficiency and renewable energy, and hydrogen.
Equilibrium (V9063) 23 min., 1962	What is chemical equilibrium? How do chemists recognize it? How do they explain it? In answering the questions, the program stresses the dynamic nature of equilibrium. Radioactive iodine tracers are used to demonstrate the dynamic molecular behaviour of the substances at equilibrium in a closed system. An analogy in terms of fish population in two connected bowls, and animation using molecular models, present the concepts with striking simplicity.

Title	Description
How to Create a Junk Food (21202) 57:30 min., 1988	New foods are not plucked from the trees anymore; nor are they whipped up in Grandma's kitchen. These days, a new food product is more likely to result from a collaboration among food engineers, biochemists, production specialists, and market researchers. The program follows a food development company as it demonstrates the development of an "integrated sandwich." Company executives meet to analyse market information and discuss the concept of the new food product. They agree that the ideal product is a snack food that's convenient, tasty, and healthful, crispy outside and moist inside. At this point, the biochemists and food engineers take over. Potential ingredients are analysed; meat ingredients are broken down and reformulated. The correct flavours are produced by blending chemicals—accomplished with the aid of mass spectometry. Then the activity of the cheek muscles of volunteer eaters is measured by electromyography to determine the product's chewability. The chosen product is mass-produced by a cooker-extruder, a high-tech version of a pastry tube. Finally it is marketed as a healthy sandwich snack under the carefully chosen name Crack-a-Snack.
Introduction to Reaction Kinetics (V9075) 14 min., 1962	This videotape illustrates the mechanism of some simple chemical reactions. It explains the effect of temperature, activation energy, geometry of collision, and catalysis upon the rate of reaction. The reactions between hydrogen and chlorine, and hydrogen and iodine, are illustrated. The speed of the action has been slowed down by a factor 10^{14}. Potential energy curves clarify the relationship between the energy available to drive the reaction or be produced by the reaction and the relative position of the reaction particles before, during, and after the collision.
Ionic and Covalent Bonding, Part 2 (21338) 16 min., 1992	This program examines three types of intermolecular forces of attraction between molecules: dipole-dipole interactions, hydrogen bonding, and Van der Waal's forces. These forces hold molecules together in varying degrees.
Lab Sense: Lab Safety for Science Students (V1714, 21793) 27:44 min., 1995	This video, conceived and performed by a team of high school students from Halifax County–Bedford District School Board, is designed to motivate students entering their first lab-based science course to the basics of safe procedure in the lab. Four student actors host this infotainment parody. *Lab Sense* directs viewers to such topics as protective clothing, safe experimental procedure, basic safety equipment, and safety attitudes. The tone is hip, flip, and humorous, but the program is an integrated part of a written lab safety curriculum that accompanies the video. The video is a co-production of EMS and Halifax County–Bedford District School Board through the locally initiated Curriculum Resource Development Program.

Title	Description
Matter: Form and Substance in the Universe (23380) 1996	This program introduces students to the basic characteristics of matter. Included are the concepts of mass, density, weight, and inertia; the differences between elements, compounds, substances, and solutions; the unique physical properties (boiling and freezing points, conductor or insulator, solubility, hardness); and chemical characteristics (reactivity, flammability, acid or base, combustibility) of different types of matter, and the four states of matter, solid, liquid, gas, and plasma.
Molecular Motion (23566) 1998	This program is designed to help students understand the key concepts about molecular motion. Topics include characteristic molecular properties of the states of matter; the kinetic theory of solids, liquid, and gases; the smoke cell and Brownian motion; diffusion in gases and liquids; and changes of state and the energy transfers that accompany them. Includes brief teacher's guide.
Organic Chemistry 2: Industrial Application (20970) 60 min., 1988	A sequel to *Organic Chemistry I*, this program uses sophisticated three-dimensional animation to show how the molecules and properties of compounds lend themselves to a wide variety of industrial applications. Since the number of synthetic compounds under development is steadily increasing, the program concludes with a program on the benefits and risks of these materials. Segments include "Fibres," "Soaps," "Glues," "ASA," "Cosmetics," and "Life After Chemistry." Closed-captioned.
Periodic Table: Reactions and Relationships (23382) 1996	The periodic table contains a wealth of information, and this program helps students learn how to access it. The program explains the periodic law and the significance of the rows and columns of the periodic table and also outlines the physical and chemical qualities of the members of each group of elements, from the alkaline metals to the noble gases. The importance of various groups of elements in industrial applications and in the environment is highlighted.
Reactions and their Driving Forces (20977) 15 min., 1989	A panoply of chemical reactions is shown while asking the question, What are the driving forces of these reactions? The first driving force, energy, is explained by showing a number of exothermic and endothermic processes in the real world, and by using graphics and demonstrations. The second driving force, entropy, is similarly illustrated.

Title	Description
Reactions: The Chemistry of Change (23383) 27 min., 1996	This program looks at various types of reactions—exothermic and endothermic, spontaneous and non-spontaneous—and how variables such as temperature, concentration, and the presence of catalyst affect the rate of chemical reactions. The concepts of chemical equilibrium and the reversibility of reactions are also introduced. The importance of chemical reactions in biological processes such as photosynthesis and industrial applications are also examined.
Synthesis of an Organic Compound (V9072) 21 min., 1962	This videotape shows the synthesis of 2-butanone, a ketone, from 2-butanol, an alcohol, as an example of a common type of organic synthesis. It discusses three basic steps: synthesis, purification, and identification. In the synthesis, butanol is oxidized by sodium dichromate and sulfuric acid to yield 2-butanone. Purification is accomplished by solvent extraction, followed by distillation of the 2-butanone. The identity of the product is established by forming a solid derivative of the 2-butanone and determining its melting point, and is confirmed by infrared spectroscopy.
The Atmosphere (20976) 15 min., 1989	Beginning with a common theory on the formation of the atmosphere, this program examines the composition of our present atmosphere, highlighting some of our environmental contaminants. The greenhouse effect, the hole in the ozone layer, and the commercial use of CFCs are discussed.
The Mole Concept (23523)	*The Mole Concept* clarifies the reasoning behind the historical development of the mole concept—the mole is the ultimate standard container for directly comparing large numbers of atoms—and opens the way to understanding chemical reactions at the molecular level. Each program uses animation of scientific concepts and analogies from daily life to simplify the material. Exercises in reasoning, using such theories as Gay-Lussac's law of combining gas volumes and Avogadro's hypothesis, encourage class discussion. Through a process of postulation and refutation, students will discover a practical working tool for comparing atoms in chemical reactions.
The Reactivity of Elements (23564) 1998	Reactions are among the most interesting aspects of chemistry. This program helps us appreciate the astonishing science of chemistry. The use of experiments, 3-D computer animation, graphics, and live photography clarify and provide context for the following concepts: highly reactive metals—group 1, periodic table; highly reactive halogens—group 17, periodic table; and the range of reactivity among metals. Includes brief teacher's sheet.

Appendix F: Print Resources

Authorized Learning Resources

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 parenthesis. For more details, visit the website (https://w3apps.EDnet.ns.ca/nssbb).

McGraw-Hill Ryerson Chemistry (23700)

Science Safety Guidelines, Grades Primary–12 (2005)

Other Print Resources

This appendix contains resources that are 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.

Atlantic Provinces Education Foundation. *Foundation for the Atlantic Canada Science Curriculum* (1998)

Budavari, Susan. *Merck Index on CD-ROM* (Loose Leaf), 12th Edition. Boca Raton, FL: CRC Press L/C, 1996. ISBN-10: 0412829207, ISBN-13: 978-0412829208

Budavari, Susan. *The Merck Index: An Encyclopedia of Chemicals, Drugs, and Biologicals*, Rahway, NJ: Merck & Co., Inc.; 11th Edition (1989). ISBN-10: 091191028X

Chem13 News (chem13news.uwaterloo.ca)

ChemMatters, search in acs.org

Council of Ministers of Education, Canada. *Common Framework of Science Learning Outcomes K to 12: Pan-Canadian Protocol for Collaboration on School Curriculum* (October 1997), www.cmec.ca/science/framework/pages/english/cmec%20Eng.html.

Department of Education and Culture. *Secondary Science: A Teaching Resource*. Halifax, 1999.

Education in Chemistry (rsc.org/Education/EiC)

Health Canada. *Food Additive Dictionary* (www.hc-sc.gc.ca/fn-an/securit/addit/diction/index-eng.php).

Journal of Chemical Education (jchemed.chem.wisc.edu)

Lide, David. *CRC Handbook of Chemistry and Physics, 87th Edition,* London, UK: Taylor & Francis, 2006. ISBN-10: 0849304873, ISBN-13: 978084930473

Merck. *ChemOffice: The Merck Index*; Drawing, Modeling and Information (CD-ROM). Rahway, NJ: Merck. ISBN-10: 047174400X, ISBN-13: 9780471744009

Nova Scotia Department of Education. *Nova Scotia Chemistry Data Booklet,* 2008

O'Neil et al [eds]. *The Merck Index: An Encyclopedia of Chemicals, Drugs, and Biologicals with CD–ROM,* 14th Edition, Whitehouse Station, NJ: Merck & Co., Inc.; 2006. ISBN-10: 091191000X, ISBN-13: 9780911910001

O'Neil, Maryadele J., Ann Smith, and Patricia E. Heckelman. *The Merck Index: An Encyclopedia of Chemicals, Drugs, and Biologicals*, 13th Edition. Whitehouse Station, NJ: Merck & Co., Inc., 2001. ISBN-10: 0911910131, ISBN-13: 978-091191013

Windholz, Martha.*Table of Molecular Weights: A Comparison Volume to The Merck Index*, 9th Edition, 1978, Rahway, NJ: Merck, 1978. ISBN 0911910735

Windholz, Martha. *The Merck Index: An Encyclopedia of Chemicals, Drugs, and Biologicals*, Merck; 10th Edition, Rahway, NJ: Merck, 1983. ISBN: 0911910271

Windholz, Martha.*The Merck Index [microform]: An Encyclopedia of Chemicals and Drugs,* 10 microfiches, Beauport, PQ: CMIC, (between 1976 and 1985). ISBN 0911910263