

Chemistry 3202

Curriculum Guide 2019



Education and Early Childhood Development

***Department of Education and Early
Childhood Development
Mission Statement***

The Department of Education and Early Childhood Development will improve provincial early childhood learning and the K-12 education system to further opportunities for the people of Newfoundland and Labrador.

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Section One: Newfoundland and Labrador Curriculum

Introduction

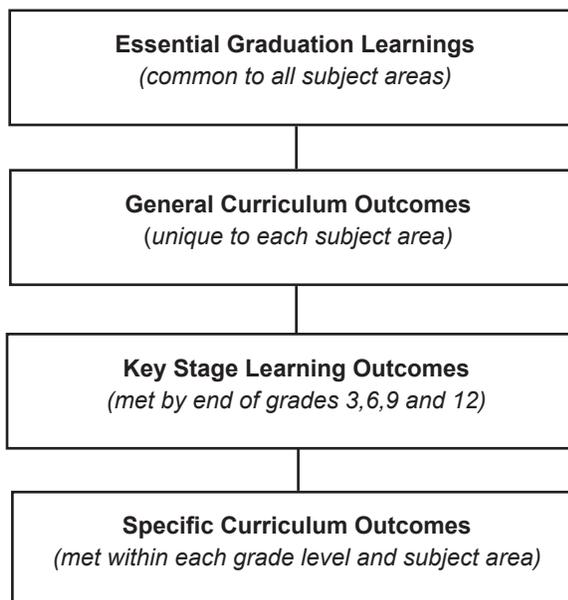
There are multiple factors that impact education: technological developments, increased emphasis on accountability, and globalization. These factors point to the need to consider carefully the education students receive.

The Newfoundland and Labrador Department of Education and Early Childhood Development believes that curriculum design with the following characteristics will help teachers address the needs of students served by the provincially prescribed curriculum:

- Curriculum guides must clearly articulate what students are expected to know and be able to do by the time they graduate from high school.
- There must be purposeful assessment of students' performance in relation to the curriculum outcomes.

Outcomes Based Education

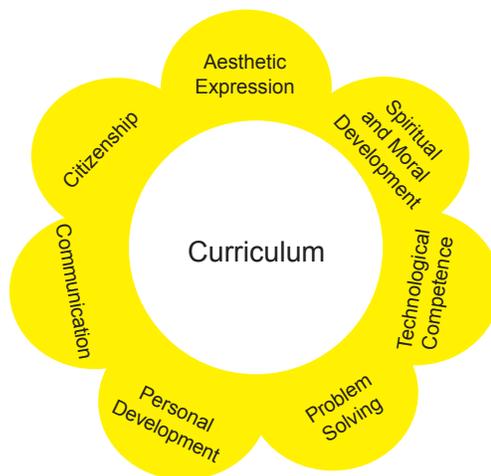
The K-12 curriculum in Newfoundland and Labrador is organized by outcomes and is based on *The Atlantic Canada Framework for Essential Graduation Learning in Schools* (1997). This framework consists of Essential Graduation Learnings (EGLs), General Curriculum Outcomes (GCOs), Key Stage Curriculum Outcomes (KSCOs) and Specific Curriculum Outcomes (SCOs).



Essential Graduation Learnings

EGLs provide vision for the development of a coherent and relevant curriculum. They are statements that offer students clear goals and a powerful rationale for education. The EGLs are delineated by general, key stage, and specific curriculum outcomes.

EGLs describe the knowledge, skills, and attitudes expected of all students who graduate from high school. Achievement of the EGLs will prepare students to continue to learn throughout their lives. EGLs describe expectations, not in terms of individual subject areas, but in terms of knowledge, skills, and attitudes developed throughout the K-12 curriculum. They confirm that students need to make connections and develop abilities across subject areas if they are to be ready to meet the shifting and ongoing demands of life, work, and study.



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), and mathematical and scientific concepts and symbols, to think, learn and communicate effectively.

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

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

Spiritual and Moral Development – Graduates will demonstrate understanding and appreciation for the place of belief systems in shaping the development of moral values and ethical conduct.

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.

Curriculum Outcomes

Curriculum outcomes are statements that articulate what students are expected to know and be able to do in each program area in terms of knowledge, skills, and attitudes.

Curriculum outcomes may be subdivided into General Curriculum Outcomes, Key Stage Curriculum Outcomes, and Specific Curriculum Outcomes.

General Curriculum Outcomes (GCOs)

Each program has a set of GCOs which describe what knowledge, skills, and attitudes students are expected to demonstrate as a result of their cumulative learning experiences within a subject area. GCOs serve as conceptual organizers or frameworks which guide study within a program area. Often, GCOs are further delineated into KSCOs.

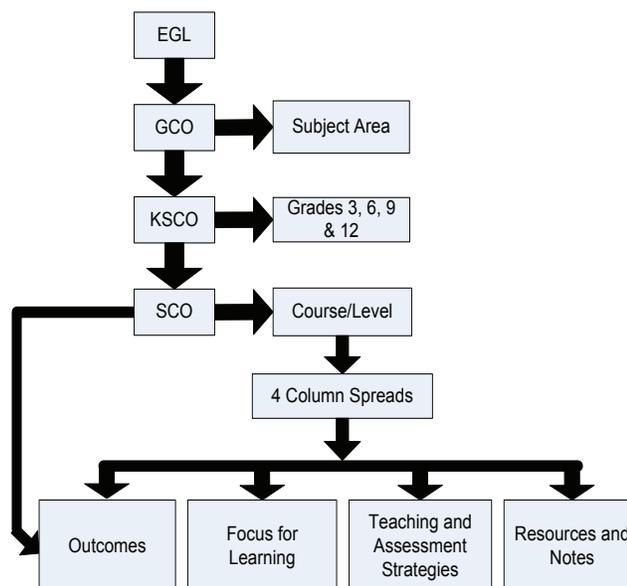
Key Stage Curriculum Outcomes (KSCOs)

Key Stage Curriculum Outcomes (KSCOs) summarize what is expected of students at each of the four key stages of grades three, six, nine, and twelve.

Specific Curriculum Outcomes (SCOs)

SCOs set out what students are expected to know and be able to do as a result of their learning experiences in a course, at a specific grade level. In some program areas, SCOs are further articulated into delineations. *It is expected that all SCOs will be addressed during the course of study covered by the curriculum guide.*

EGLs to Curriculum Guides



Context for Teaching and Learning

Teachers are responsible to help students achieve outcomes. This responsibility is a constant in a changing world. As programs change over time so does educational context. Several factors make up the educational context in Newfoundland and Labrador today: inclusive education, support for gradual release of responsibility teaching model, focus on literacy and learning skills in all programs, and support for education for sustainable development.

Inclusive Education

Valuing Equity and Diversity

Effective inclusive schools have the following characteristics: supportive environment, positive relationships, feelings of competence, and opportunities to participate. (The Centre for Inclusive Education, 2009)

All students need to see their lives and experiences reflected in their school community. It is important that the curriculum reflect the experiences and values of all genders and that learning resources include and reflect the interests, achievements, and perspectives of all students. An inclusive classroom values the varied experiences and abilities as well as social and ethno-cultural backgrounds of all students while creating opportunities for community building. Inclusive policies and practices promote mutual respect, positive interdependencies, and diverse perspectives. Learning resources should include a range of materials that allow students to consider many viewpoints and to celebrate the diverse aspects of the school community.



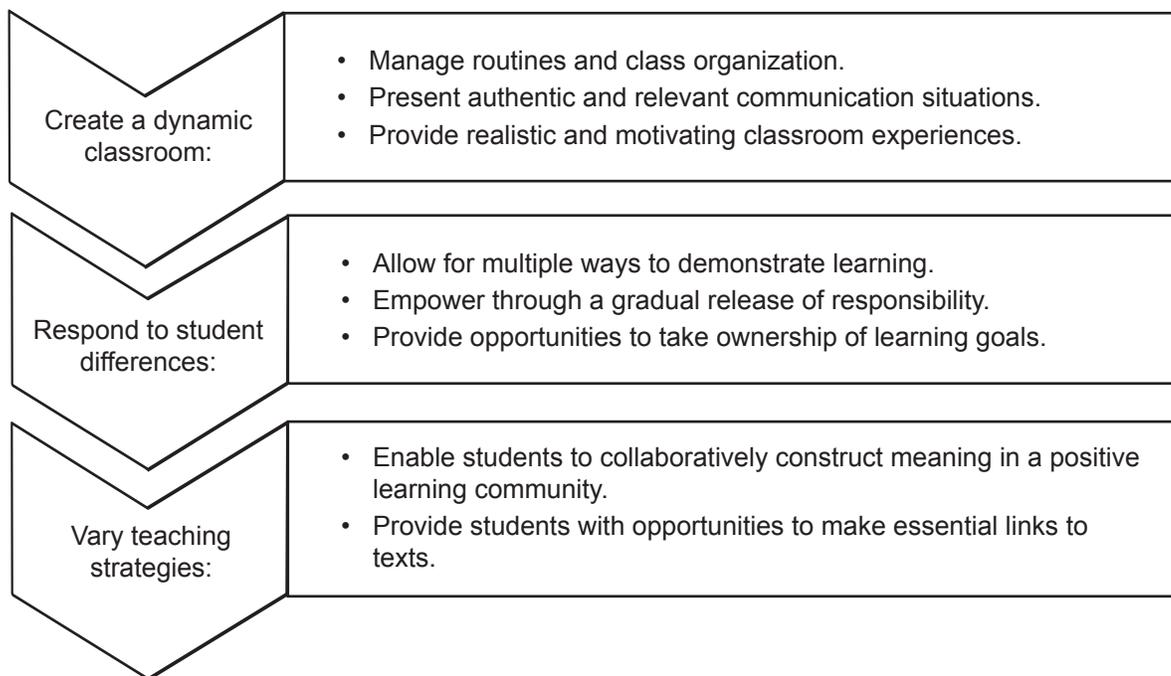
Differentiated Instruction

Differentiated instruction is a teaching philosophy based on the premise that teachers should adapt instruction to student differences. Rather than marching students through the curriculum lockstep, teachers should modify their instruction to meet students' varying readiness levels, learning preferences, and interests. Therefore, the teacher proactively plans a variety of ways to 'get it' and express learning. (Carol Ann Tomlinson, 2008)

Curriculum is designed and implemented to provide learning opportunities for all students according to abilities, needs, and interests. Teachers must be aware of and responsive to the diverse range of learners in their classes. Differentiated instruction is a useful tool in addressing this diversity.

Differentiated instruction responds to different readiness levels, abilities, and learning profiles of students. It involves actively planning so that the process by which content is delivered, the way the resource is used, and the products students create are in response to the teacher's knowledge of whom he or she is interacting with. Learning environments should be flexible to accommodate various learning preferences of the students. Teachers continually make decisions about selecting teaching strategies and structuring learning activities that provide all students with a safe and supportive place to learn and succeed.

Planning for Differentiation



Differentiating the Content

Differentiating content requires teachers to pre-assess students to identify those who require prerequisite instruction, as well as those who have already mastered the concept and may therefore apply strategies learned to new situations. Another way to differentiate content is to permit students to adjust the pace at which they progress through the material. Some students may require additional time while others will move through at an increased pace and thus create opportunities for enrichment or more indepth consideration of a topic of particular interest.

Teachers should consider the following examples of differentiating content:

- Meet with small groups to reteach an idea or skill or to extend the thinking or skills.
- Present ideas through auditory, visual, and tactile means.
- Use reading materials such as novels, websites, and other reference materials at varying reading levels.

Differentiating the Process

Differentiating the process involves varying learning activities or strategies to provide appropriate methods for students to explore and make sense of concepts. A teacher might assign all students the same product (e.g., presenting to peers) but the process students use to create the presentation may differ. Some students could work in groups while others meet with the teacher individually. The same assessment criteria can be used for all students.

Teachers should consider flexible grouping of students such as whole class, small group, or individual instruction. Students can be grouped according to their learning styles, readiness levels, interest areas, and/or the requirements of the content or activity presented. Groups should be formed for specific purposes and be flexible in composition and short-term in duration.

Teachers should consider the following examples of differentiating the process:

- Offer hands-on activities for students.
- Provide activities and resources that encourage students to further explore a topic of particular interest.
- Use activities in which all learners work with the same learning outcomes but proceed with different levels of support, challenge, or complexity.

Differentiating the Product

Differentiating the product involves varying the complexity and type of product that students create to demonstrate learning outcomes. Teachers provide a variety of opportunities for students to demonstrate and show evidence of what they have learned.

Teachers should give students options to demonstrate their learning (e.g., create an online presentation, write a letter, or develop a mural). This will lead to an increase in student engagement.

Differentiating the Learning Environment

The learning environment includes the physical and the affective tone or atmosphere in which teaching and learning take place, and can include the noise level in the room, whether student activities are static or mobile, or how the room is furnished and arranged. Classrooms may include tables of different shapes and sizes, space for quiet individual work, and areas for collaboration.

Teachers can divide the classroom into sections, create learning centres, or have students work both independently and in groups. The structure should allow students to move from whole group, to small group, pairs, and individual learning experiences and support a variety of ways to engage in learning. Teachers should be sensitive and alert to ways in which the classroom environment supports their ability to interact with students.

Teachers should consider the following examples of differentiating the learning environment:

- Develop routines that allow students to seek help when teachers are with other students and cannot provide immediate attention.
- Ensure there are places in the room for students to work quietly and without distraction, as well as places that invite student collaboration.
- Establish clear guidelines for independent work that match individual needs.
- Provide materials that reflect diversity of student background, interests, and abilities.

The physical learning environment must be structured in such a way that all students can gain access to information and develop confidence and competence.

Meeting the Needs of Students with Exceptionalities

All students have individual learning needs. Some students, however, have exceptionalities (defined by the Department of Education and Early Childhood Development) which impact their learning. The majority of students with exceptionalities access the prescribed curriculum. For details of these exceptionalities see www.gov.nl.ca/edu/k12/studentsupportservices/exceptionalities.html

Supports for these students may include

1. Accommodations
2. Modified Prescribed Courses
3. Alternate Courses
4. Alternate Programs
5. Alternate Curriculum

For further information, see Service Delivery Model for Students with Exceptionalities at www.cdli.ca/sdm/

Classroom teachers should collaborate with instructional resource teachers to select and develop strategies which target specific learning needs.

*Meeting the Needs
of Students who are
Highly Able
(includes gifted and
talented)*

Some students begin a course or topic with a vast amount of prior experience and knowledge. They may know a large portion of the material before it is presented to the class or be capable of processing it at a rate much faster than their classmates. All students are expected to move forward from their starting point. Many elements of differentiated instruction are useful in addressing the needs of students who are highly able.

Teachers may

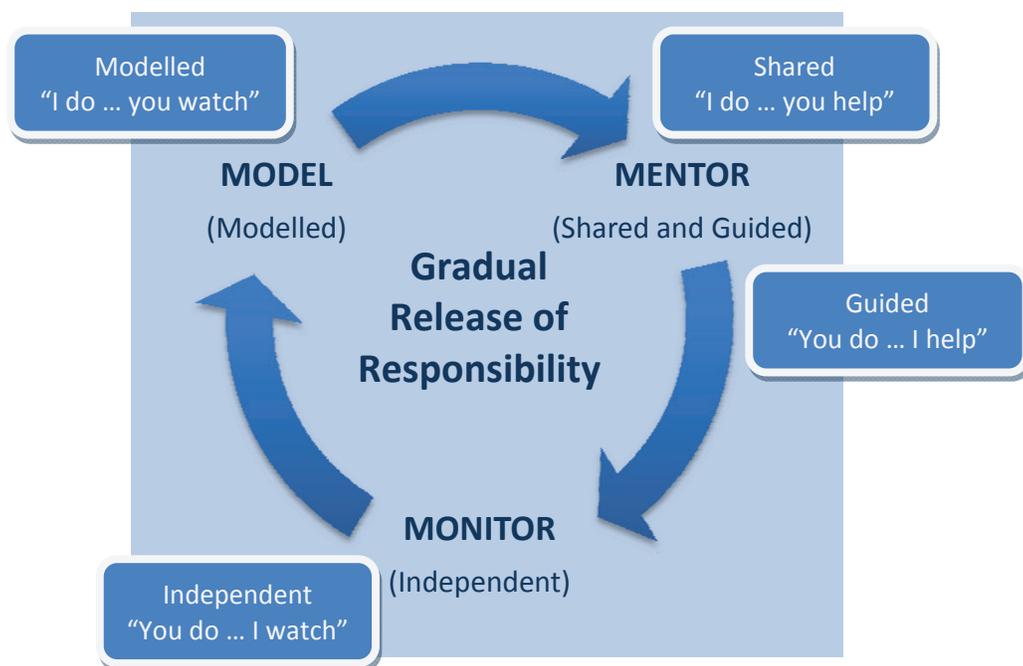
- assign independent study to increase depth of exploration in an area of particular interest;
- compact curriculum to allow for an increased rate of content coverage commensurate with a student's ability or degree of prior knowledge;
- group students with similar abilities to provide the opportunity for students to work with their intellectual peers and elevate discussion and thinking, or delve deeper into a particular topic; and
- tier instruction to pursue a topic to a greater depth or to make connections between various spheres of knowledge.

Highly able students require the opportunity for authentic investigation to become familiar with the tools and practices of the field of study. Authentic audiences and tasks are vital for these learners. Some highly able learners may be identified as gifted and talented in a particular domain. These students may also require supports through the Service Delivery Model for Students with Exceptionalities.

Gradual Release of Responsibility

Teachers must determine when students can work independently and when they require assistance. In an effective learning environment, teachers choose their instructional activities to model and scaffold composition, comprehension, and metacognition that is just beyond the students' independence level. In the gradual release of responsibility approach, students move from a high level of teacher support to independent work. If necessary, the teacher increases the level of support when students need assistance. The goal is to empower students with their own learning strategies, and to know how, when, and why to apply them to support their individual growth. Guided practice supports student independence. As a student demonstrates success, the teacher should gradually decrease his or her support.

Gradual Release of Responsibility Model



Literacy

“Literacy is the ability to identify, understand, interpret, create, communicate and compute, using printed and written materials associated with varying contexts. Literacy involves a continuum of learning in enabling individuals to achieve their goals, to develop their knowledge and potential, and to participate fully in their community and wider society”. To be successful, students require a set of interrelated skills, strategies and knowledge in multiple literacies that facilitate their ability to participate fully in a variety of roles and contexts in their lives, in order to explore and interpret the world and communicate meaning. (The Plurality of Literacy and its Implications for Policies and Programmes, 2004, p.13)

Literacy is

- a process of receiving information and making meaning from it; and
- the ability to identify, understand, interpret, communicate, compute, and create text, images, and sounds.

Literacy development is a lifelong learning enterprise beginning at birth that involves many complex concepts and understandings. It is not limited to the ability to read and write; no longer are we exposed only to printed text. It includes the capacity to learn to communicate, read, write, think, explore, and solve problems. Individuals use literacy skills in paper, digital, and live interactions to engage in a variety of activities:

- Analyze critically and solve problems.
- Comprehend and communicate meaning.
- Create a variety of texts.
- Make connections both personally and inter-textually.
- Participate in the socio-cultural world of the community.
- Read and view for enjoyment.
- Respond personally.

These expectations are identified in curriculum documents for specific subject areas as well as in supporting documents, such as *Cross-Curricular Reading Tools (CAMET)*.

With modelling, support, and practice, students' thinking and understandings are deepened as they work with engaging content and participate in focused conversations.

Reading in the Content Areas

The focus for reading in the content areas is on teaching strategies for understanding content. Teaching strategies for reading comprehension benefits all students as they develop transferable skills that apply across curriculum areas.

When interacting with different texts, students must read words, view and interpret text features, and navigate through information presented in a variety of ways including, but not limited to

Advertisements	Movies	Poems
Blogs	Music videos	Songs
Books	Online databases	Speeches
Documentaries	Plays	Video games
Magazine articles	Podcasts	Websites

Students should be able to interact with and comprehend different texts at different levels.

There are three levels of text comprehension:

- Independent level – Students are able to read, view, and understand texts without assistance.
- Instructional level – Students are able to read, view, and understand most texts but need assistance to fully comprehend some texts.
- Frustration level – Students are not able to read or view with understanding (i.e., texts may be beyond their current reading level).

Teachers will encounter students working at all reading levels in their classrooms and will need to differentiate instruction to meet their needs. For example, print texts may be presented in audio form, physical movement may be associated with synthesizing new information with prior knowledge, or graphic organizers may be created to present large amounts of print text in a visual manner.

When interacting with information that is unfamiliar to students, it is important for teachers to monitor how effectively students are using strategies to read and view texts:

- Analyze and think critically about information.
- Determine importance to prioritize information.
- Engage in questioning before, during, and after an activity related to a task, text, or problem.
- Make inferences about what is meant but not said.
- Make predictions.
- Synthesize information to create new meaning.
- Visualize ideas and concepts.

Learning Skills for Generation Next

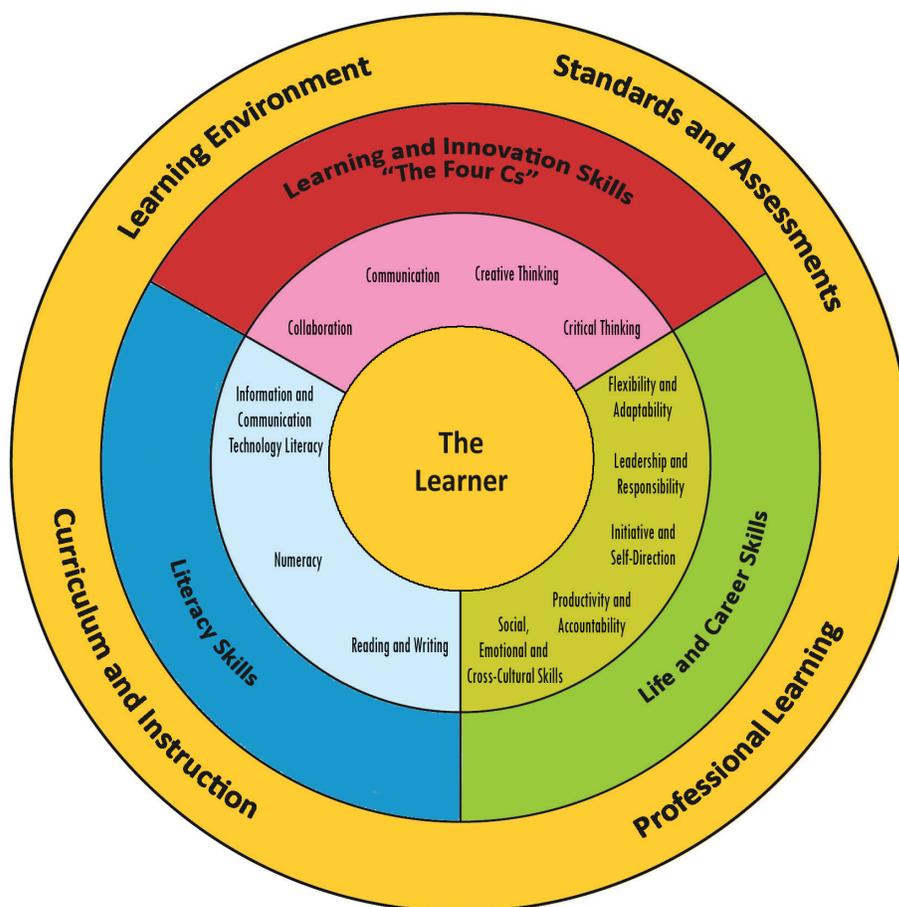
Generation Next is the group of students who have not known a world without personal computers, cell phones, and the Internet. They were born into this technology. They are digital natives.

Students need content and skills to be successful. Education helps students learn content and develop skills needed to be successful in school and in all learning contexts and situations. Effective learning environments and curricula challenge learners to develop and apply key skills within the content areas and across interdisciplinary themes.

Learning Skills for Generation Next encompasses three broad areas:

- Learning and Innovation Skills enhance a person's ability to learn, create new ideas, problem solve, and collaborate.
- Life and Career Skills address leadership, and interpersonal and affective domains.
- Literacy Skills develop reading, writing, and numeracy, and enhance the use of information and communication technology.

The diagram below illustrates the relationship between these areas. A 21st century curriculum employs methods that integrate innovative and research-driven teaching strategies, modern learning technologies, and relevant resources and contexts.



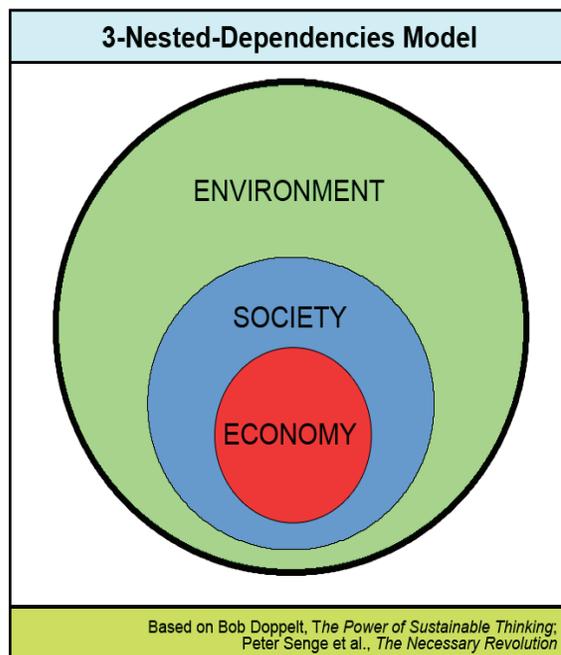
Support for students to develop these abilities and skills is important across curriculum areas and should be integrated into teaching, learning, and assessment strategies. Opportunities for integration of these skills and abilities should be planned with engaging and experiential activities that support the gradual release of responsibility model. For example, lessons in a variety of content areas can be infused with learning skills for Generation Next by using open-ended questioning, role plays, inquiry approaches, self-directed learning, student role rotation, and Internet-based technologies.

All programs have a shared responsibility in developing students' capabilities within all three skill areas.

Education for Sustainable Development

Sustainable development is defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. (Our Common Future, 43)

Sustainable development is comprised of three integrally connected areas: economy, society, and environment.



As conceived by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) the overall goal of Education for Sustainable Development (ESD) is to integrate the knowledge, skills, values, and perspectives of sustainable development into all aspects of education and learning. Changes in human behaviour should create a more sustainable future that supports environmental integrity and economic viability, resulting in a just society for all generations.

ESD involves teaching *for* rather than teaching *about* sustainable development. In this way students develop the skills, attitudes, and perspectives to meet their present needs without compromising the ability of future generations to meet their needs.

Within ESD, the knowledge component spans an understanding of the interconnectedness of our political, economic, environmental, and social worlds, to the role of science and technology in the development of societies and their impact on the environment. The skills necessary include being able to assess bias, analyze consequences of choices, ask questions, and solve problems. ESD values and perspectives include an appreciation for the interdependence of all life forms, the importance of individual responsibility and action, an understanding of global issues as well as local issues in a global context. Students need to be aware that every issue has a history, and that many global issues are linked.

Assessment and Evaluation

Assessment

Assessment is the process of gathering information on student learning.

How learning is assessed and evaluated and how results are communicated send clear messages to students and others about what is valued.

Assessment instruments are used to gather information for evaluation. Information gathered through assessment helps teachers determine students' strengths and needs, and guides future instruction.

Teachers are encouraged to be flexible in assessing student learning and to seek diverse ways students might demonstrate what they know and are able to do.

Evaluation involves the weighing of the assessment information against a standard in order to make a judgement about student achievement.

Assessment can be used for different purposes:

1. Assessment *for* learning guides and informs instruction.
2. Assessment *as* learning focuses on what students are doing well, what they are struggling with, where the areas of challenge are, and what to do next.
3. Assessment *of* learning makes judgements about student performance in relation to curriculum outcomes.

1. Assessment for Learning

Assessment *for* learning involves frequent, interactive assessments designed to make student learning visible. This enables teachers to identify learning needs and adjust teaching accordingly.

Assessment *for* learning is not about a score or mark; it is an ongoing process of teaching and learning:

- Pre-assessments provide teachers with information about what students already know and can do.
- Self-assessments allow students to set goals for their own learning.
- Assessment *for* learning provides descriptive and specific feedback to students and parents regarding the next stage of learning.
- Data collected during the learning process from a range of tools enables teachers to learn as much as possible about what a student knows and is able to do.

2. *Assessment as Learning*

Assessment as learning involves students' reflecting on their learning and monitoring their own progress. It focuses on the role of the student in developing metacognition and enhances engagement in their own learning. Students can

- analyze their learning in relation to learning outcomes,
- assess themselves and understand how to improve performance,
- consider how they can continue to improve their learning, and
- use information gathered to make adaptations to their learning processes and to develop new understandings.

3. *Assessment of Learning*

Assessment of learning involves strategies designed to confirm what students know in terms of curriculum outcomes. It also assists teachers in determining student proficiency and future learning needs. *Assessment of learning* occurs at the end of a learning experience and contributes directly to reported results. Traditionally, teachers relied on this type of assessment to make judgements about student performance by measuring learning after the fact and then reporting it to others. Used in conjunction with the other assessment processes previously outlined, *assessment of learning* is strengthened. Teachers can

- confirm what students know and can do;
- report evidence to parents/guardians, and other stakeholders, of student achievement in relation to learning outcomes; and
- report on student learning accurately and fairly using evidence obtained from a variety of contexts and sources.

Involving Students in the Assessment Process

Students should know what they are expected to learn as outlined in the specific curriculum outcomes of a course as well as the criteria that will be used to determine the quality of their achievement. This information allows students to make informed choices about the most effective ways to demonstrate what they know and are able to do.

It is important that students participate actively in assessment by co-creating criteria and standards which can be used to make judgements about their own learning. Students may benefit from examining various scoring criteria, rubrics, and student exemplars.

Students are more likely to perceive learning as its own reward when they have opportunities to assess their own progress. Rather than asking teachers, "What do you want?", students should be asking themselves questions:

- What have I learned?
- What can I do now that I couldn't do before?
- What do I need to learn next?

Assessment must provide opportunities for students to reflect on their own progress, evaluate their learning, and set goals for future learning.

Assessment Tools

In planning assessment, teachers should use a broad range of tools to give students multiple opportunities to demonstrate their knowledge, skills, and attitudes. The different levels of achievement or performance may be expressed as written or oral comments, ratings, categorizations, letters, numbers, or as some combination of these forms.

The grade level and the activity being assessed will inform the types of assessment tools teachers will choose:

Anecdotal Records	Photographic Documentation
Audio/Video Clips	Podcasts
Case Studies	Portfolios
Checklists	Presentations
Conferences	Projects
Debates	Questions
Demonstrations	Quizzes
Exemplars	Role Plays
Graphic Organizers	Rubrics
Journals	Self-assessments
Literacy Profiles	Tests
Observations	Wikis

Assessment Guidelines

Assessments should measure what they intend to measure. It is important that students know the purpose, type, and potential marking scheme of an assessment. The following guidelines should be considered:

- Collect evidence of student learning through a variety of methods; do not rely solely on tests and paper and pencil activities.
- Develop a rationale for using a particular assessment of learning at a specific point in time.
- Provide descriptive and individualized feedback to students.
- Provide students with the opportunity to demonstrate the extent and depth of their learning.
- Set clear targets for student success using learning outcomes and assessment criteria.
- Share assessment criteria with students so that they know the expectations.

Evaluation

Evaluation is the process of analyzing, reflecting upon, and summarizing assessment information, and making judgements or decisions based on the information gathered. Evaluation is conducted within the context of the outcomes, which should be clearly understood by learners before teaching and evaluation take place. Students must understand the basis on which they will be evaluated and what teachers expect of them.

During evaluation, the teacher interprets the assessment information, makes judgements about student progress, and makes decisions about student learning programs.

Section Two: Curriculum Design

Rationale

The vision of science education in Newfoundland and Labrador 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 which provide opportunity to explore, analyze, evaluate, synthesize, appreciate, and understand the interrelationships among science, technology, society, and the environment that will affect their personal lives, careers, and futures.

Science education which strives for scientific literacy must engage students in science inquiry, problem solving, and decision making.

Science Inquiry

Science 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, analyzing data, and interpreting data are fundamental to engaging in science. These skills are often represented as a cycle which involves the posing of questions, the generation of possible explanations, and the collection of evidence to determine which of these explanations is most useful in accounting for the phenomenon under investigation. Teachers should engage students in science inquiry activities to develop these skills.

Problem Solving

Problem solving involves seeking solutions to human problems. It may be represented as a cycle consisting of the proposing, creating, and testing of prototypes, products, and techniques in an attempt to reach an optimum solution to a given problem. The skills involved in this cycle facilitate a process which has different aims and procedures from science inquiry. Students should be given opportunities to propose, perform, and evaluate solutions to problem solving or technological tasks.

Decision Making

Decision making involves determining what we should do in a particular context or in response to a given situation. Increasingly, the types of problems that we deal with, both individually and collectively, require an understanding of the processes and products of science and technology. The process of decision making involves identification of the problem or situation, generation of possible solutions or courses of action, evaluation of the alternatives, and a thoughtful decision based on the information available. Students should be actively involved in decision making situations. While important in their own right, decision making situations also provide a relevant context for engaging in science inquiry and/or problem solving.

Curriculum Outcomes Framework

The basis of the curriculum outcomes framework are the general curriculum outcomes (GCOs). Four general curriculum outcomes have been identified to delineate the four critical aspects of students' scientific literacy: science, technology, society, and the environment (STSE); skills; knowledge; and attitudes. These four GCOs are common to all science courses.

General Curriculum Outcomes

GCO 1: Science, Technology, Society, and the Environment

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.

GCO 2: 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.

GCO 3: 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.

GCO 4: 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 (KSCOs) align with the GCOs and summarize what students are expected to know and be able to do by the end of Grade 12.

GCO 1: STSE

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

- describe and explain disciplinary and interdisciplinary processes used to enable us to understand natural phenomena and develop technological solutions
- distinguish between science and technology in terms of their respective goals, products, and values, and describe the development of scientific theories and technologies over time
- analyze and explain how science and technology interact with and advance one another
- analyze how individuals, society, and the environment are interdependent with scientific and technological endeavours
- evaluate social issues related to the applications and limitations of science and technology, and explain decisions in terms of advantages and disadvantages for sustainability, considering a variety of perspectives

GCO 2: Skills

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

- ask questions about observed relationships and plan investigations of questions, ideas, problems, and issues
- conduct investigations into relationships between and among observable variables, and use a broad range of tools and techniques to gather and record data and information
- analyze data and apply mathematical and conceptual models to develop and assess possible explanations
- work as a member of a team in addressing problems, and apply the skills and conventions of science in communicating information and ideas and in assessing results

GCO 3: Knowledge

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

- identify and explain the diversity of organic compounds and their impact on the environment
- demonstrate an understanding of the characteristics and interactions of acids and bases
- illustrate and explain the various forces that hold structures together at the molecular level, and relate the properties of matter to its structure
- use the redox theory in a variety of contexts related to electrochemistry
- demonstrate an understanding of solutions and stoichiometry
- predict and explain energy transfers in chemical reactions

GCO 4: Attitudes

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

- value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not
- appreciate that the applications of science and technology can raise ethical dilemmas
- value the contributions to scientific and technological development made by women and men from many societies and cultural backgrounds
- show a continuing and more informed curiosity and interest in science and science-related issues
- acquire, with interest and confidence, additional science knowledge and skills, using a variety of resources and methods, including formal research
- consider further studies and careers in science and technology-related fields
- confidently evaluate evidence and consider alternative perspectives, ideas, and explanations
- use factual information and rational explanations when analyzing and evaluating
- value the processes for drawing conclusions
- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas
- have a sense of personal and shared responsibility for maintaining a sustainable environment
- project the personal, social, and environmental consequences of proposed action
- want to take action for maintaining a sustainable environment
- show concern for safety and accept the need for rules and regulations
- be aware of the direct and indirect consequences of their actions

Specific Curriculum Outcomes

Specific curriculum outcomes (SCOs) align with the KSCOs and describe what students should know and be able to do at the end of each course. They are intended to serve as the focus for the design of learning experiences and assessment tasks. SCOs are organized into units for each course.

Course Overview

The vision of scientific literacy sets out the need for students to acquire science-related skills, knowledge, and attitudes, and emphasizes that this is best done through the study and analysis of the interrelationships among science, technology, society, and the environment.

Chemistry 3202 SCOs are organized into four units:

- Unit i: Integrated Skills
- Unit 1: From Kinetics to Equilibrium
- Unit 2: Acids and Bases
- Unit 3: Thermochemistry
- Unit 4: Electrochemistry

September	October	November	December	January	February	March	April	May	June
Unit 1 From Kinetics to Equilibrium		Unit 2 Acids and Bases			Unit 3 Thermochemistry		Unit 4 Electrochemistry		
Skills Integrated Throughout									

How to Use the Four Column Curriculum Layout

Outcomes

Column one contains specific curriculum outcomes (SCO) and accompanying delineations where appropriate. The delineations provide specificity in relation to key ideas.

Outcomes are numbered in ascending order.

Delineations are indented and numbered as a subset of the originating SCO.

All outcomes are related to general curriculum outcomes.

Focus for Learning

Column two is intended to assist teachers with instructional planning. It also provides context and elaboration of the ideas identified in the first column.

This may include:

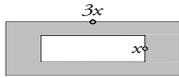
- cautionary notes
- clarity in terms of scope
- common misconceptions
- depth of treatment
- knowledge required to scaffold and challenge student learning
- references to prior knowledge

Sample Performance Indicator(s)

This provides a summative, higher order activity, where the response serves as a data source to help teachers assess the degree to which the student has achieved the outcome.

Performance indicators are typically presented as a task, which may include an introduction to establish a context. They are assigned at the end of the teaching period allocated for the outcome.

Performance indicators are assigned when students have attained a level of competence, with suggestions for teaching and assessment identified in column three.

SPECIFIC CURRICULUM OUTCOMES	
<i>GCO 1: Represent algebraic expressions in multiple ways</i>	
<p>Outcomes</p> <p><i>Students will be expected to</i></p> <p>1.0 model, record and explain the operations of multiplication and division of polynomial expressions (limited to polynomials of degree less than or equal to 2) by monomials, concretely, pictorially and symbolically. [GCO 1]</p> <p>1.2 model division of a given polynomial expression by a given monomial concretely or pictorially and record the process symbolically.</p> <p>1.3 apply a personal strategy for multiplication and division of a given polynomial expression</p>	<p>Focus for Learning</p> <p>From previous work with number operations, students should be aware that division is the inverse of multiplication. This can be extended to divide polynomials by monomials. The study of division should begin with division of a monomial by a monomial, progress to a polynomial by a scalar, and then to division of a polynomial by any monomial.</p> <p>Division of a polynomial by a monomial can be visualized using area models with algebra tiles. The most commonly used symbolic method of dividing a polynomial by a monomial at this level is to divide each term of the polynomial by the monomial, and then use the exponent laws to simplify. This method can also be easily modelled using tiles, where students use the sharing model for division.</p> <p>Because there are a variety of methods available to multiply or divide a polynomial by a monomial, students should be given the opportunity to apply their own personal strategies. They should be encouraged to use algebra tiles, area models, rules of exponents, the distributive property and repeated addition, or a combination of any of these methods, to multiply or divide polynomials. Regardless of the method used, students should be encouraged to record their work symbolically. Understanding the different approaches helps students develop flexible thinking.</p> <p>Sample Performance Indicator</p> <p>Write an expression for the missing dimensions of each rectangle and determine the area of the walkway in the following problem:</p> <ul style="list-style-type: none"> • The inside rectangle in the diagram below is a flower garden. The shaded area is a concrete walkway around it. The area of the flower garden is given by the expression $2x^2 + 4x$ and the area of the large rectangle, including the walkway and the flower garden, is $3x^2 + 6x$. 

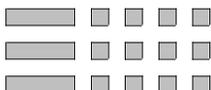
SPECIFIC CURRICULUM OUTCOMES

GCO 1: Represent algebraic expressions in multiple ways

Sample Teaching and Assessment Strategies

Teachers may use the following activities and/or strategies aligned with the corresponding assessment tasks:

Modeling division using the sharing model provides a good transition to the symbolic representation. For example, $\frac{3x+12}{3} = \frac{3x}{3} + \frac{12}{3}$. To model this, students start with a collection of three x -tiles and 12 unit tiles and divide them into three groups.



For this example, $x + 4$ tiles will be a part of each group, so the quotient is $x + 4$.

Activation

Students may

- Model division of a polynomial by a monomial by creating a rectangle using four x^2 -tiles and eight x -tiles, where $4x$ is one of the dimensions.

Teachers may

- Ask students what the other dimension is and connect this to the symbolic representation.

Connection

Students may

- Model division of polynomials and determine the quotient
 - (i) $(6x^2 + 12x - 3) \div 3$
 - (ii) $(4x^2 - 12x) \div 4x$

Consolidation

Students may

- Draw a rectangle with an area of $36a^2 + 12a$ and determine as many different dimensions as possible.

Teachers may

- Discuss why there are so many different possible dimensions.

Extension

Students may

- Determine the area of one face of a cube whose surface area is represented by the polynomial $24s^2$.
- Determine the length of an edge of the cube.

Resources and Notes

Authorized

- *Math Makes Sense 9*
- Lesson 5.5: Multiplying and Dividing a Polynomial by a Constant
- Lesson 5.6: Multiplying and Dividing a Polynomial by a Monomial
- ProGuide: pp. 35-42, 43-51
- CD-ROM: Master 5.23, 5.24
- See It Videos and Animations:
 - Multiplying and Dividing a Polynomial by a Constant, Dividing
 - Multiplying and Dividing a Polynomial by a Monomial, Dividing
- SB: pp. 241-248, 249-257
- PB: pp. 206-213, 214-219

Resources and Notes

Column four references supplementary information and possible resources for use by teachers.

These references provide details of resources suggested in column two and column three.

Suggestions for Teaching and Assessment

This column contains specific sample tasks, activities, and strategies that enable students to meet the goals of the SCOs and be successful with performance indicators. Instructional activities are recognized as possible sources of data for assessment purposes. Frequently, appropriate techniques and instruments for assessment purposes are recommended.

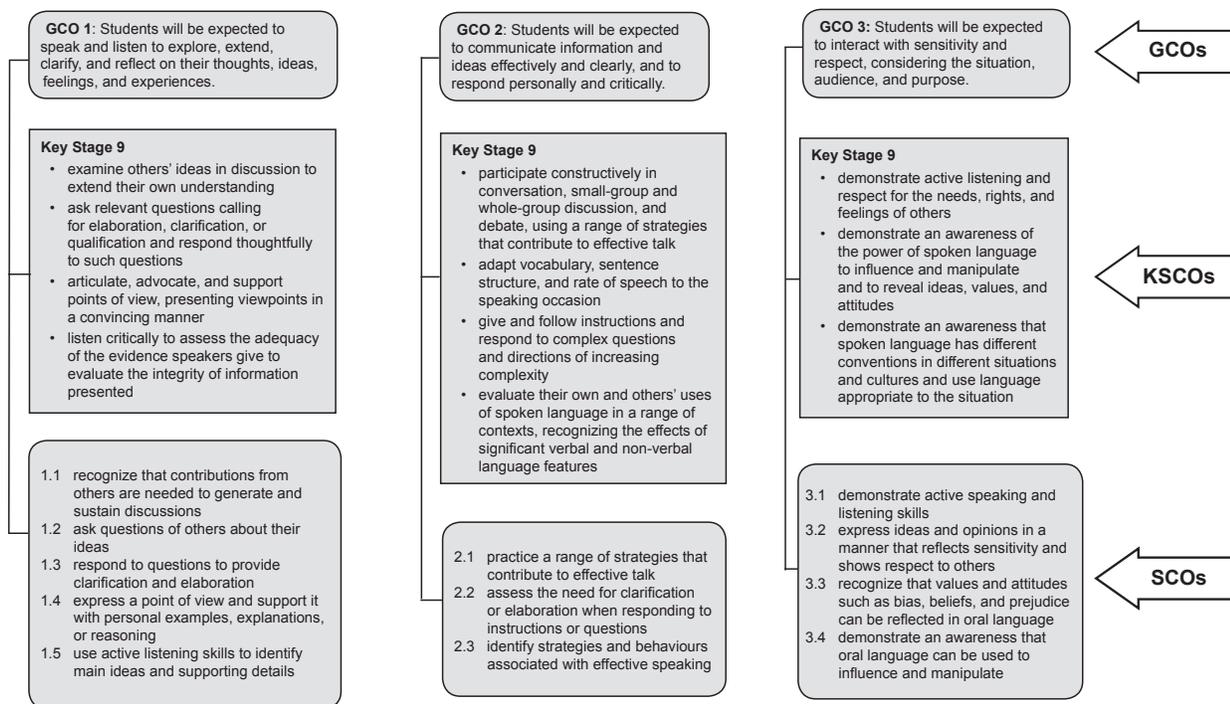
Suggestions for instruction and assessment are organized sequentially:

- Activation – suggestions that may be used to activate prior learning and establish a context for the instruction
- Connection – linking new information and experiences to existing knowledge inside or outside the curriculum area
- Consolidation – synthesizing and making new understandings
- Extension – suggestions that go beyond the scope of the outcome

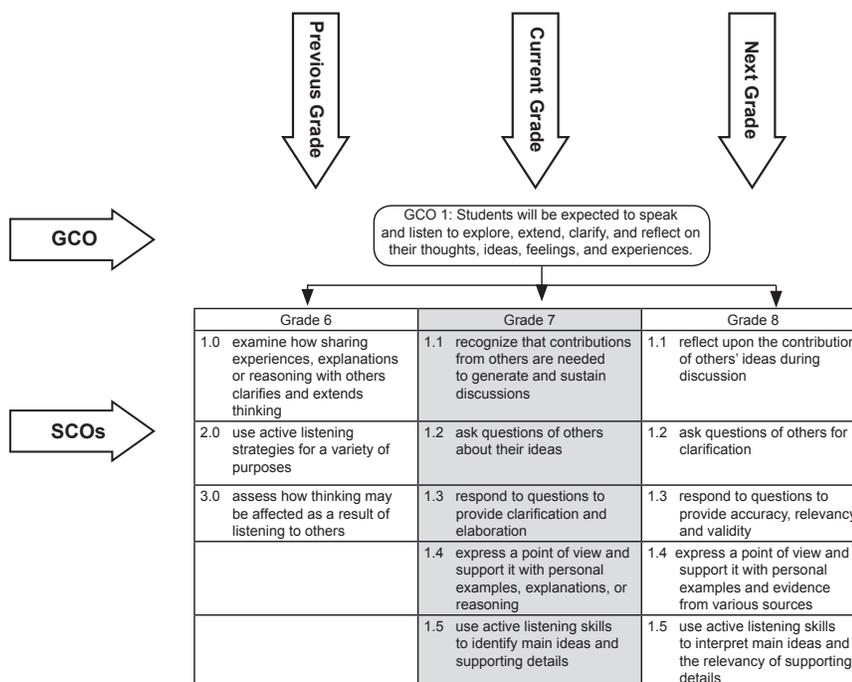
These suggestions provide opportunities for differentiated learning and assessment.

How to use a Strand overview

At the beginning of each strand grouping there is explanation of the focus for the strand and a flow chart identifying the relevant GCOs, KSCOs, and SCOs.



The SCOs Continuum follows the chart to provide context for teaching and assessment for the grade/course in question. The current grade is highlighted in the chart.



Section Three:
Specific Curriculum Outcomes

Unit i - Integrated Skills

Strand Overview

Focus

Students use a variety of skills in the process of answering questions, solving problems, and making decisions. While these skills are not unique to science, they play an important role in the development of scientific understandings and in the application of science and technology to new situations.

The listing of skills is not intended to imply a linear sequence or to identify a single set of skills required in each science investigation. Every investigation and application of science has unique features that determine the particular mix and sequence of skills involved.

Four broad areas of skills are outlined and developed:

- Initiating and Planning – These include questioning, identifying problems, and developing initial ideas and plans.
- Performing and Recording – These include carrying out action plans, which involves gathering evidence by observation and, in most cases, manipulating materials and equipment.
- Analyzing and Interpreting – These include examining information and evidence, processing and presenting data so that it can be interpreted, and interpreting, evaluating, and applying the results.
- Communication and Teamwork – Communication is essential at every stage where ideas are being developed, tested, interpreted, debated, and agreed upon. Teamwork is important since the development and application of science ideas is a collaborative process both in society and in the classroom.

Students should be provided with opportunities to develop and apply their skills in a variety of contexts. These contexts connect to the STSE component of the curriculum by linking to three processes for skills application:

- Science inquiry – seeking answers to questions through experimentation and research
- Problem solving – seeking solutions to science-related problems by developing and testing prototypes, products, and techniques to meet a given need
- Decision making – providing information to assist the decision making process

Unit i: Integrated Skills

Unit i, The Integrated Skills Unit, appears at the beginning of this curriculum guide. A total of forty-three skills are addressed throughout science courses in grades 10-12; however, not all skills appear in every curriculum guide or course. In Chemistry 3202, there is a focus on thirty-two skills; these are listed on the following page.

Outcomes Framework

GCO 2 (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.

Initiating and Planning

- 1.0 identify questions to investigate that arise from practical problems and issues
- 2.0 define and delimit problems to facilitate investigation
- 3.0 design an experiment identifying and controlling major variables
- 4.0 propose alternative solutions to a given practical problem, identify the potential strengths and weaknesses of each, and select one as the basis for a plan
- 5.0 state a prediction and a hypothesis based on available evidence and background information
- 6.0 identify the theoretical basis of an investigation and develop a prediction and a hypothesis that are consistent with the theoretical basis
- 7.0 formulate operational definitions of major variables
- 8.0 evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making

Performing and Recording

- 9.0 implement appropriate sampling procedures
- 10.0 carry out procedures controlling the major variables and adapting or extending procedures where required
- 11.0 use instruments effectively and accurately for collecting data
- 12.0 compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data
- 13.0 use library and electronic research tools to collect information on a given topic
- 14.0 select and integrate information from various print and electronic sources or from several parts of the same source
- 15.0 select and use apparatus and materials safely
- 16.0 demonstrate a knowledge of WHMIS standards by selecting and applying proper techniques for handling and disposing of lab materials
- 17.0 describe and apply classification systems and nomenclatures used in the sciences

Analyzing and Interpreting

- 18.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots
- 19.0 identify a line of best fit on a scatter plot and interpolate or extrapolate based on the line of best fit
- 20.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables
- 21.0 apply and assess alternative theoretical models for interpreting knowledge in a given field
- 22.0 compare theoretical and empirical values and account for discrepancies
- 23.0 evaluate the relevance, reliability, and adequacy of data and data collection methods
- 24.0 identify and explain sources of error and uncertainty in measurement and express results in a form that acknowledges the degree of uncertainty
- 25.0 construct and test a prototype of a device or system and troubleshoot problems as they arise
- 26.0 evaluate a personally designed and constructed device on the basis of criteria they have developed themselves
- 27.0 identify new questions or problems that arise from what was learned
- 28.0 identify and evaluate potential applications of findings

Communication and Teamwork

- 29.0 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results
- 30.0 identify multiple perspectives that influence a science-related decision or issue
- 31.0 work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise
- 32.0 evaluate individual and group processes used in planning, problem solving, and decision making, and completing a task

SCO Skills Continuum

GCO 2 (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.

Science 7-9	Science 10-12
<ul style="list-style-type: none"> rephrase questions in a testable form and clearly define practical problems identify questions to investigate arising from practical problems and issues 	<ul style="list-style-type: none"> identify questions to investigate that arise from practical problems and issues
<ul style="list-style-type: none"> define and delimit questions and problems to facilitate investigation 	<ul style="list-style-type: none"> define and delimit problems to facilitate investigation
<ul style="list-style-type: none"> design an experiment and identify major variables 	<ul style="list-style-type: none"> design an experiment identifying and controlling major variables design an experiment and identify specific variables
<ul style="list-style-type: none"> state a prediction and a hypothesis based on background information or an observed pattern of events 	<ul style="list-style-type: none"> state a prediction and a hypothesis based on available evidence and background information identify the theoretical basis of an investigation and develop a prediction and a hypothesis that are consistent with the theoretical basis
<ul style="list-style-type: none"> formulate operational definitions of major variables and other aspects of their investigations 	<ul style="list-style-type: none"> formulate operational definitions of major variables
<ul style="list-style-type: none"> select appropriate methods and tools for collecting data and information and for solving problems 	<ul style="list-style-type: none"> evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making develop appropriate sampling procedures
	<ul style="list-style-type: none"> implement appropriate sampling procedures
<ul style="list-style-type: none"> carry out procedures controlling the major variables 	<ul style="list-style-type: none"> carry out procedures controlling the major variables and adapting or extending procedures where required
<ul style="list-style-type: none"> use instruments effectively and accurately for collecting data 	<ul style="list-style-type: none"> use instruments effectively and accurately for collecting data
<ul style="list-style-type: none"> estimate quantities 	<ul style="list-style-type: none"> estimate quantities
<ul style="list-style-type: none"> organize data using a format that is appropriate to the task or experiment 	<ul style="list-style-type: none"> compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data
<ul style="list-style-type: none"> select and integrate information from various print and electronic sources or from several parts of the same source 	<ul style="list-style-type: none"> use library and electronic research tools to collect information on a given topic select and integrate information from various print and electronic sources or from several parts of the same source
<ul style="list-style-type: none"> use tools and apparatus safely 	<ul style="list-style-type: none"> select and use apparatus and materials safely
<ul style="list-style-type: none"> demonstrate a knowledge of WHMIS standards by selecting and applying proper techniques for handling and disposing of lab materials 	<ul style="list-style-type: none"> demonstrate a knowledge of WHMIS standards by selecting and applying proper techniques for handling and disposing of lab materials

SCO Skills Continuum

Science 7-9	Science 10-12
<ul style="list-style-type: none"> use or construct a classification key 	<ul style="list-style-type: none"> describe and apply classification systems and nomenclatures used in the sciences identify limitations of a given classification system and identify alternative ways of classifying to accommodate anomalies
<ul style="list-style-type: none"> compile and display data, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, bar graphs, line graphs, and scatter plots 	<ul style="list-style-type: none"> compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots
<ul style="list-style-type: none"> identify strengths and weaknesses of different methods of collecting and displaying data 	
<ul style="list-style-type: none"> predict the value of a variable by interpolating or extrapolating from graphical data 	
<ul style="list-style-type: none"> identify a line of best fit on a scatter plot and interpolate or extrapolate based on the line of best fit 	<ul style="list-style-type: none"> identify a line of best fit on a scatter plot and interpolate or extrapolate based on the line of best fit
<ul style="list-style-type: none"> interpret patterns and trends in data, and infer and explain relationships among the variables 	<ul style="list-style-type: none"> interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables
	<ul style="list-style-type: none"> apply and assess alternative theoretical models for interpreting knowledge in a given field
<ul style="list-style-type: none"> identify, and suggest explanations for discrepancies in data 	
<ul style="list-style-type: none"> apply given criteria for evaluating evidence and sources of information 	
<ul style="list-style-type: none"> calculate theoretical values of a variable 	<ul style="list-style-type: none"> compare theoretical and empirical values and account for discrepancies
	<ul style="list-style-type: none"> evaluate the relevance, reliability, and adequacy of data and data collection methods
	<ul style="list-style-type: none"> identify and apply criteria, including the presence of bias, for evaluating evidence and sources of information
<ul style="list-style-type: none"> identify potential sources of and determine the amount of error in measurement 	<ul style="list-style-type: none"> identify and explain sources of error and uncertainty in measurement and express results in a form that acknowledges the degree of uncertainty
<ul style="list-style-type: none"> state a conclusion, based on experimental data, and explain how evidence gathered supports or refutes an initial idea 	<ul style="list-style-type: none"> provide a statement that addresses the problem or answers the question investigated in light of the link between data and the conclusion explain how data support or refute the hypothesis or prediction
<ul style="list-style-type: none"> identify and correct practical problems in the way a prototype or constructed device functions 	<ul style="list-style-type: none"> identify and correct practical problems in the way a technological device or system functions

SCO Skills Continuum

Science 7-9	Science 10-12
<ul style="list-style-type: none"> test the design of a constructed device or system 	<ul style="list-style-type: none"> construct and test a prototype of a device or system and troubleshoot problems as they arise
	<ul style="list-style-type: none"> propose alternative solutions to a given practical problem, identify the potential strengths and weaknesses of each, and select one as the basis for a plan
<ul style="list-style-type: none"> evaluate designs and prototypes in terms of function, reliability, safety, efficiency, use of materials, and impact on the environment 	<ul style="list-style-type: none"> evaluate a personally designed and constructed device on the basis of criteria they have developed themselves
<ul style="list-style-type: none"> identify new questions and problems that arise from what was learned 	<ul style="list-style-type: none"> identify new questions or problems that arise from what was learned
<ul style="list-style-type: none"> identify and evaluate potential applications of findings 	<ul style="list-style-type: none"> identify and evaluate potential applications of findings
<ul style="list-style-type: none"> receive, understand, and act on the ideas of others communicate questions, ideas, intentions, plans, and results, using lists, notes in point form, sentences, data tables, graphs, drawings, oral language, and other means 	<ul style="list-style-type: none"> communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results
	<ul style="list-style-type: none"> synthesize information from multiple sources or from complex and lengthy texts and make inferences based on this information
	<ul style="list-style-type: none"> identify multiple perspectives that influence a science-related decision or issue
<ul style="list-style-type: none"> defend a given position on an issue or problem, based on their findings 	<ul style="list-style-type: none"> develop, present, and defend a position or course of action, based on findings
<ul style="list-style-type: none"> work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise 	<ul style="list-style-type: none"> work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise
<ul style="list-style-type: none"> evaluate individual and group processes used in planning, problem solving, decision-making, and completing a task 	<ul style="list-style-type: none"> evaluate individual and group processes used in planning, problem solving, decision-making, and completing a task

Suggested Unit Plan

The Integrated Skills unit is not intended to be taught as a stand alone unit. Rather, it is intended to be used as a reference. When skill outcomes [GCO 2] are encountered in units 1- 4, teachers should refer to the focus for learning elaborations and teaching and assessment suggestions provided here.

Skill outcomes have been integrated within units 1- 4. Students should be provided with opportunities to develop and apply these skills in varied contexts:

- Science inquiry – seeking answers to questions through experimentation and research
- Problem solving – seeking solutions to science-related problems by developing and testing prototypes, products, and techniques to meet a given need
- Decision making – providing information to assist the decision making process

September	October	November	December	January	February	March	April	May	June
Unit 1 From Kinetics to Equilibrium		Unit 2 Acids and Bases			Unit 3 Thermochemistry			Unit 4 Electrochemistry	
Skills Integrated Throughout									

Initiating and Planning

Outcomes

Students will be expected to

- 1.0 identify questions to investigate that arise from practical problems and issues
[GCO 2]

- 2.0 define and delimit problems to facilitate investigation
[GCO 2]

Focus for Learning

The basis of scientific investigations is questioning and therefore the subsequent search for answers. Questioning and critical thinking are developed and refined through practice and use. It is important that students begin with practical problems or issues (e.g., methods to prevent corrosion using electrochemistry principles), have time and opportunities to study, discuss and pose questions, and create a testable hypothesis.

Students will have prior knowledge of cause and effect relationships. For example, fruit turning brown as a result of oxidation is a cause and effect relationship. Other examples include using lemon juice on avocado or sliced apples to prevent oxidation.

Students should continue to have multiple opportunities to generate questions based on discussions, class work, issues, and practical problems.

An integral science skill involves identifying and defining topics or problems which require further investigation and determining limits or boundaries within.

The intent of this outcome is to evaluate questions identified and narrow the focus for investigation.

Students should have experience identifying problems and creating a purpose for an investigation (e.g., identifying factors that need to be controlled when determining spontaneity of redox reactions using various metals and metal ion combinations). They should be able to state the problem and identify specific criteria for an investigation, as well as identify constraints and limits to the investigation (e.g., defining a problem and not having sufficient equipment to investigate). Examples of how scientific investigations are limited by the evolution of technology and other constraints may be discussed at this point (e.g., how to study pH levels in soil and water).

Initiating and Planning

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Facilitate a brainstorming session to identify science related problems (e.g., how soil pH affects the colour of certain species of flower such as hydrangeas, issues of drinking water quality, aquaculture, mine tailings, carbon credits/taxing).
- Share a video clip, article, or case study that highlights a relevant problem (e.g., effect of fertilizer runoff on aquatic ecosystems).
- Provide statements, quotations, or questions. Ask students to discuss and share their thoughts (e.g., how acid precipitation has negative effects on different organisms in ecosystems).

Students may

- Use a graffiti wall to list impacts of acidic environments on organisms. Add ways to change pH as well as other questions.

Connection

Students may

- Brainstorm a list of acids and bases that could be added to soil to manipulate the colour of hydrangea flowers.
- Brainstorm factors that would impact soil pH.
- Create a set of criteria that can assess whether components of an investigation are testable.
- Discuss the Haber process (developed to maximize production of ammonia and is now used to maximize the production of fertilizers).
- Collect and compile a list of indicators to test the pH of a provided water sample. Design a step-by-step process that outlines how to use the indicators to determine an approximate value of the pH.
- Identify and define a problem, then list possible limitations or boundaries (e.g., How can corrosion of a pipeline be prevented?).

Consolidation

Students may

- Research the thermodynamics of popular heat pumps. Consider the science behind the heat pump and its efficiency and practical uses of heating and/or cooling our homes.
- Refer to questions that have been generated and apply criteria to determine if a question is testable within constraints and limits of school resources. Evaluate each question and select one to investigate further.
- Investigate how the natural corrosion of metals led to methods of slowing down these reactions. What questions must be answered to solve the problem and how has it led to technological advancements?

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (Teacher Resource [TR])

- pp. 231-232, 242, 245, 248-250, 252-254

Chemistry: Newfoundland and Labrador (Student Resource [SR])

- p. 657

Newfoundland and Labrador Teacher Resource and Solutions Manual (Digital)

Suggested

Resource Links: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202/resource-links.html> (Sign-in to the K-12 PL Site is necessary)

- Brilliant Labs
- CurioCity
- Eastern Newfoundland Science and Technology Fair
- Khan Academy
- Let's Talk Science
- Newfoundland and Labrador Public Libraries

Initiating and Planning

Outcomes

Students will be expected to

3.0 design an experiment identifying and controlling major variables
[GCO 2]

4.0 propose alternative solutions to a given practical problem, identify the potential strengths and weaknesses of each, and select one as the basis for a plan
[GCO 2]

Focus for Learning

To investigate problems, students should be able to critically analyze and design a controlled experiment. They should brainstorm a list of all specific variables they will need to consider when designing an investigation. From there, students should consider the requirements of their investigation. This includes

- control of variables,
- dependent variable,
- identification of materials required,
- independent variable, and
- sample size (replication).

Students should also have opportunities to address limitations on their experimental design (i.e., access to equipment and other possible constraints). In Science 1206 and in Chemistry 2202, students had opportunities to design their own investigations.

The first time this skill is introduced, only one factor or variable should be changed.

There may be misconceptions with the sequencing of the scientific method. It is important to note that science testing and investigations often follow a cyclical or repetitive process rather than a sequential one. Investigations do not always begin with stating a hypotheses. For example, an observation or an anomaly can result in an investigation, even though the 'why' may be a point of discussion.

Students should identify the problem to be evaluated, analyze the information provided, and use various problem solving techniques to develop a solution. During the process, both strengths and weaknesses of the problem should be identified to determine the best course of action.

Students should consider function, reliability, safety, efficiency, use of materials, and environmental impact.

Initiating and Planning

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Discuss the physical properties lab investigation from Science 1206. Based on observations of the chemical and physical properties, students may have developed operational definitions for ionic and molecular compounds.

Connection

Teachers may

- Discuss an investigation that focuses on one issue (identify independent variable) and brainstorm the possible variables that would need to be controlled. For example, ask students to identify the variables (independent, dependent, and control) required to measure the effect of surface area on a reaction rate.
- Review the process that a scientist may use in designing an investigation. Discuss how this process does not typically follow a set scientific method (an artificial process).

Students may

- Determine alternatives they could use when designing a calorimeter. Select based on strengths and weaknesses.
- Use calorimetry to determine molar heats of fusion, combustion, or neutralization.
- Discuss how current topics in Chemistry 3202 may or may not require further investigation.
- Predict which weak acid will have the lowest pH based on K_a values.

Consolidation

Students may

- Design an investigation related to an issue within one science unit. Identify variables and explain how they intend to control the variables. Once approved by the teacher, complete the investigation. For example, the teacher may provide a student with the chemical formula of an acid or base. Students then design a titration investigation to determine the concentration of that acid or base. They may also identify all materials needed and provide step-by-step instructions for the procedure.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 220-222

Chemistry: Newfoundland and Labrador (SR)

- pp. 589-594

Initiating and Planning

Outcomes

Students will be expected to

5.0 state a prediction and a hypothesis based on available evidence and background information [GCO 2]

6.0 identify the theoretical basis of an investigation and develop a prediction and a hypothesis that are consistent with the theoretical basis [GCO 2]

Focus for Learning

Students will have previous knowledge in questioning, defining problems, and determining how to investigate those problems. This skill now requires students to make predictions and hypotheses based on available evidence and background information. In Science 7-9, students made predictions and hypotheses based on background information or an observed pattern of events.

Predictions are made in relation to testable questions. In investigations, students predict how a change in the independent variable will affect the dependent variable. Experimental predictions may be written as “If..., then...” statements. A common misconception is to assume hypotheses and predictions are simple guesses as opposed to being based on background evidence. Evidence should provide the basis from which students will make predictions and hypotheses.

Predictions supported by detailed reasoning are referred to as hypotheses; they explain predictions. Hypotheses may be written as “If..., then..., because...” statements. A hypothesis includes a prediction (i.e., “If..., then...”) and an explanation (i.e., “because...”). Predictions and hypotheses are supported or rejected by the evidence collected. In reality, the vast majority of scientific hypotheses fail. If performed appropriately, investigations are considered successful, regardless of whether the evidence supports or rejects a hypothesis, because something has been learned. For example, a student may be asked to predict which substances (from a list) would display the properties of an acid or a base.

In Science 1206, students identified acids and bases from their formulas. Given an amphoteric species such as NaHCO_3 , their hypothesis and prediction would be incorrect.

To develop this skill, students should have opportunities to practice (with and without guidance). They should have a working knowledge of prediction or hypothesis writing. Project-based learning may help with the processes of predicting, hypothesizing, and connecting.

Theories are used for developing scientific investigations. It is important that students examine relevant theoretical information and then apply their knowledge to new situations. Based on the theoretical information involved, students should develop a prediction and a hypothesis.

Students should understand the difference between a prediction and a hypothesis. For example, to understand Le Châtelier’s principle, students should be able to predict shifts in equilibrium based on changes made to the system.

Practical labs used to develop student understanding of scientific theory are the primary method for acquiring this skill. Teachers may guide at first; however, full student-based discovery is the goal.

Where appropriate, when conducting investigations, students should make a prediction and a hypothesis.

Initiating and Planning

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Demonstrate an inquiry activity. Ask students to make and explain a prediction (e.g., demonstrate the effect of adding an acid to a given equilibrium in which there is a colour change, predict the colour change that would occur if a base were added).
- Discuss the types of predictions that occur every day (e.g., weather, precipitation levels, temperatures).
- Discuss (from Science 9) the theoretical basis of Mendeleev's arrangement of the periodic table (i.e., not all elements were discovered, therefore spaces were needed in the table). A video outlining the development of the periodic table may be helpful.

Students may

- Complete an admit slip to predict and make a hypothesis based on given theoretical information.
- Use prior knowledge to develop hypotheses and predictions regarding how changing concentrations would impact pH values.

Connection

Teachers may

- Share background information on a current topic or share data from a previous investigation. Discuss prediction and hypothesis.
- Set up stations with differing data sets and background. Have students circulate and write predictions based on available data. Share as a group, then compare predictions.

Students may

- Identify areas in chemistry where a theory is used to predict outcomes (e.g., collision theory, acid-base theory).
- Predict which combination of metals and corresponding electrolytic solutions will produce the highest cell potential.
- Predict what will happen to an acid pH when its concentration is changed (diluted).
- Predict the relative acidity of different citrus fruits.

Consolidation

Students may

- Use data and background information to state a prediction and hypothesis. List other pieces of evidence and information needed to determine if their prediction would be more accurate.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- p. 196

Chemistry: Newfoundland and Labrador (SR)

- p. 497

Suggested

Resource Links: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202/resource-links.html>

- Admit Slip Sample
- CurioCity: Periodic Table

Initiating and Planning

Outcomes

Students will be expected to

- 7.0 formulate operational definitions of major variables
[GCO 2]
- 8.0 evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making
[GCO 2]

Focus for Learning

This skill is important in the growth of scientific thought. Operational definitions describe how an object or phenomenon behaves. It makes connections between theory and the real world. They are not definitions in the literal sense; rather, they are unique to an individual investigation. An operational definition may help set parameters for investigation and will usually involve observable properties. It is a clarification or set of guidelines for the variable. For example, the operational definition for an acid would include observations such as taste (sour), conductivity, reaction with metals, etc. Likewise, electrochemical cells can be operationally defined based on the cell potential that is produced in the cell.

Investigations require the selection of appropriate tools and instruments for the collection of data. Students often perform investigations with predetermined or assigned scientific instruments. It is important for students to learn to evaluate which instrument is best to use based on the desired data to be collected.

Development of this skill will require opportunities for students to choose from a selection of tools to complete an investigation or data collection. Students should be able to articulate the reasons for their choice and defend the tool as the most appropriate. Students may be given a choice as to which instrument would be the most appropriate for a given experimental design (e.g., to use a graduated cylinder vs. a test tube for the collection of a gas).

Choices for the selection can be based on the amount of accuracy needed but will also need a clear identification of what is needed to be measured. The method of data collection is also important, whether it is trial and error or repetition. For example, students may determine the energy calculations of a substance by performing a calorimetry investigation.

Initiating and Planning

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Review the difference between qualitative and quantitative instruments (e.g., if the pH of a solution must be 6.3, a digital pH meter may be needed; however, if a solution needs to be basic, pH paper would be sufficient).
- Demonstrate and discuss capabilities of different instruments. For example, discuss the precision of a pipette or a burette in measuring a given volume of solution.
- Remind students of the lab investigation they designed in Chemistry 2202: Percentage Yield of a Precipitation Reaction, and in Science 1206: Factors Affecting Reaction Rates. Discuss variables, what has to be controlled, and other factors involved.

Connection

Students may

- Provide an operational definition for anode and cathode.
- Complete an activity-based project, such as testing the pH of household acids and bases. Gather evidence and describe the results for a particular issue.
- Identify sources of error associated with calorimetry investigations that are performed in the laboratory involving simple (coffee-cup) calorimeters.
- Test the effectiveness of various porous boundaries in galvanic cell design.
- Design a lab investigation to prove that manganese dioxide is a catalyst for the decomposition of hydrogen peroxide.
- Identify appropriate equipment for a titration lab. Compare the accuracy and precision of burettes and pipettes versus graduated cylinders. Consider the effect of using too much indicator during a titration investigation.

Consolidation

Students may

- Develop the procedure for an investigation. Before carrying out the investigation, justify instrument choices. For example, identify whether the enthalpy change for a given chemical reaction (or physical change) could be determined using a simple (coffee cup) calorimeter.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 245-250

Chemistry: Newfoundland and Labrador (SR)

- pp. 663-669, 677-684

Suggested

Resource Links: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202/resource-links.html>

- Discovery of Gravitational Waves

Performing and Recording

Outcomes

Students will be expected to

9.0 implement appropriate sampling procedures [GCO 2]

10.0 carry out procedures controlling the major variables and adapting or extending procedures where required [GCO 2]

Focus for Learning

In the application of this skill, the context will determine the appropriate procedures (e.g., use of a graduated cylinder vs. a beaker or test tube for the collection of a gas to measure reaction rates).

Experiential reinforcement is necessary for this skill to be properly developed.

When conducting sampling procedures, it is important to adhere to standardized procedures that allow for repeatability. Depending on the nature of the investigation, students should ensure proper selection of equipment in order to meet specific sampling requirements.

Given samples of acids and/or bases, students may use their choice of pH paper or pH sensors to take samples. Knowledge of which instrument is more appropriate under certain conditions can be developed through experimentation.

When conducting any lab investigation, teachers must review the safety considerations appropriate to the activity. These should include post-lab clean up and the appropriate disposal of products formed. Teachers may refer to and direct students to use Safety Data Sheets (SDS) to identify all risks associated with the chemicals in use.

Students should be able to identify the major variables within the hypothesis to be tested. They should have prior understanding of experimental variables. Teachers should ensure that independent, dependent, and other variables are controlled in any investigation (e.g., controlling temperature for any activity, or concentration of chemical species). Students should carry out procedures knowing that failure to isolate and control variables will compromise the validity of an investigation, resulting in improper conclusions. Procedures may need to be modified to ensure that the data collected addresses the problem and the hypothesis being tested.

Performing and Recording

Sample Teaching and Assessment Strategies

Activation

Students may

- Discuss limitations of sampling procedures (e.g., more than one trial in a titration investigation is needed to improve accuracy).

Connection

Teachers may

- Ask students to identify the variables of an experimental activity (e.g., reaction rates, equilibrium, titration labs).
- Discuss (within an experiential activity) why a particular sampling procedure was used and why it was appropriate in the situation.

Students may

- Improve accuracy of an investigation through repeated trials.
- Identify problems with an experimental design in which variables require manipulation (e.g., explain why temperature and concentration must be independently controlled to determine their impacts on reaction rates).
- Outline the variables that must be controlled when determining cell voltages of various galvanic cells made from various metal and metal ion combinations.

Consolidation

Teachers may

- Demonstrate and discuss capabilities of different instruments. For example, discuss why a pipette, rather than a graduated cylinder, is used when collecting the sample for a titration procedure.
- Review random and non-probability sampling. Discuss how subjective judgement of a researcher is used to select a sample.

Students may

- Develop the procedure for an investigation. Before carrying out the investigation, justify their instrument choices.
- List the variables of an investigation.
- Consider a dam failure of an acidic mine tailings pond. In groups,
 - determine the environmental effects of acid drainage (measuring pH downstream from site);
 - develop and implement a plan for the collection, display, and analysis of data; and
 - describe effects of the following on data collection: bias, language, ethics, cost, time and timing, cultural sensitivity, and privacy.
- Consider factors such as the collection method used, data reliability and usefulness, and the ability to make generalizations, from a sample, about the population.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 172-174, 254-258

Chemistry: Newfoundland and Labrador (SR)

- pp. 434-435, 704-705

Performing and Recording

Outcomes

Students will be expected to

11.0 use instruments effectively and accurately for collecting data
[GCO 2]

12.0 compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data
[GCO 2]

Focus for Learning

It is important that teachers demonstrate the proper techniques necessary for effective use of any instrument or piece of equipment. Students should identify potential sources of error caused by improper use of instruments and be able to discuss how the accuracy of data collection may vary depending on instruments used. After data collection is complete, a review of discrepancies between student results should be discussed and related back to the importance of using instruments effectively and accurately.

Frequent use of laboratory instruments is necessary for students to properly develop important skills. Students should have numerous opportunities to practice use of appropriate instruments during class routines (e.g., appropriate use of pipettes).

Students should be able to apply appropriate weighing techniques such as taring a balance and weighing by difference. They should be able to use both methods and choose the most appropriate method for a particular situation.

Students have prior knowledge and experience compiling and organizing data. They have used a variety of formats in science and other courses. Data can be collected using a variety of technologies and organized as charts, graphs, tables, notes, log books, or digital files. Mobile wireless devices allow for image collection, spreadsheet creation, data analysis, and peer collaboration.

Performing and Recording

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Demonstrate the use of any device used to collect data or make observations (e.g., describe and demonstrate how to properly read the meniscus of a burette).
- Differentiate between accuracy and precision of an investigation.

Students may

- Discuss prior use of line graphs, circle graphs, and scatter plots to organize and display data. Discuss when it is appropriate to use each of these formats.

Connection

Students may

- Demonstrate how to properly use a device for data collection. For example, demonstrate how to weigh a sample mass accurately using an electronic balance.
- Collect data using chosen instruments. Comment on instrument use within the procedure and propose recommendations that will make such use more effective.
- Compile and organize data from an analysis of community water supplies; this will assist in determining dissolved solid levels.
- Collect data and plot the graph from The Water Exchange mini investigation (*Chemistry: Newfoundland and Labrador* student text).
- Practice instrument use through implementation of consistent reflection and feedback.

Consolidation

Students may

- Create an appropriately labelled titration curve using the results of a titration investigation.
- Create a titration curve from data collected (to allow calculation of K_a values).
- Create a scatter plot from reaction rate and concentration data. Interpret the relationship between the two.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 172-173, 206-207

Chemistry: Newfoundland and Labrador (SR)

- pp. 413, 414-415, 434, 551-562
- p. 448 (The Water Exchange - mini investigation)

Performing and Recording

Outcomes

Students will be expected to

13.0 use library and electronic research tools to collect information on a given topic
[GCO 2]

14.0 select and integrate information from various print and electronic sources or from several parts of the same source
[GCO 2]

Focus for Learning

The intent of this outcome is to use appropriate research and inquiry techniques to collect information. Students will have also developed these skills in other curriculum areas.

Teachers should review relevant, acceptable use of library and electronic research tools, practices, and policies. Students will continue to develop practical skills necessary to evaluate the degree of validity, reliability, and bias of a source. They should be able to determine origin of material and check sources for appropriateness, organized links, and accessible information. They should also be able to use advanced search techniques and keywords.

It may be necessary for teachers to review rules and guidelines associated with

- acceptable information and sources,
- citations and references, and
- plagiarism.

Students should continue to develop strategies related to selecting, organizing, and integrating information that is gathered through research.

Performing and Recording

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Discuss the most efficient ways to organize data (that includes significant digits and units).
- Review research and citing protocol.
- Invite a representative from NLPL (Newfoundland and Labrador Public Libraries) to provide an overview of NLPL services and databases. Request library cards for students.

Students may

- Discuss topics from previous science courses on which they or their classmates conducted research.
- Discuss the importance of having reliable and valid sources when conducting research (a reliable source may not be valid).

Connection

Teachers may

- Initiate a classroom discussion on why certain online sites are not considered to be reliable sources. Discuss the importance of fact-checking for social media based information as well as the benefits of using peer reviewed sources for research.

Students may

- Organize the information collected while researching. For example, categorize the variety of energy sources (nuclear, chemical, and physical) as well as the pros and cons of each.
- Use inquiry to find how much heat can legally be released into a lake or river, and/or the best way to (economically) generate electricity in their own community or region.

Consolidation

Students may

- Choose one aspect of a lab investigation. Research one component that has generated questions.
- Complete research on a selected topic from the course. For example, research the International Space Station (ISS) as an isolated system.
- Create a presentation with each slide listing the title of a science, technology, society, and/or environment (STSE) topic. Individually or in groups, research information on one of the topics, then populate the corresponding slide. Present as a class.
- Research a health trend (e.g., alkaline water, Q-Ray bracelet) from an acid-base chemistry perspective. Use a minimum of three sources to evaluate the validity of health benefit claims.

Resources and Notes

Authorized

Appendices

- Appendix A: Scientific Conventions

Chemistry: Newfoundland and Labrador (SR)

- pp. 409, 493, 577, 639

Suggested

Resource Links: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202/resource-links.html>

- Newfoundland and Labrador Public Libraries

Performing and Recording

Outcomes

Students will be expected to

15.0 select and use apparatus and materials safely
[GCO 2]

16.0 demonstrate a knowledge of WHMIS standards by selecting and applying proper techniques for handling and disposing of lab materials
[GCO 2]

17.0 describe and apply classification systems and nomenclatures used in the sciences
[GCO 2]

Focus for Learning

When conducting any lab investigation, teachers should review applicable safety considerations as well as demonstrate proper handling techniques and use of equipment. Students should be able to select and use materials safely.

Students should be familiar with the safe and appropriate use of an electronic balance, a hotplate, glassware, a funnel or filter paper, and a thermometer. Students should also be able to properly clean and dry equipment.

Teachers should assess whether students are using apparatus and materials safely. Types of assessment include checklists, observations, peer evaluations, etc.

To be able to make appropriate choices, students will need practical experience. An overview of safety policies and correct procedures in laboratory environments is required before students participate in any activity or investigation. This should be part of the school safety plan and should be reviewed on an annual basis.

Students will have previous experience with Workplace Hazardous Materials Information System (WHMIS); however, due to its importance, an assessment will determine student level of proficiency. Teachers should demonstrate WHMIS standards and the proper techniques required when handling and disposing of materials.

An overview of specific WHMIS and safety procedures should be completed before any investigation takes place. For example, a review of acid safety or hotplate safety should be completed before students use either of these.

Students should be assessed on their ability to demonstrate WHMIS handling knowledge during lab investigations.

Classification systems are used throughout the course. Examples of classification systems in Chemistry 3202 include endothermic or exothermic reactions, redox reactions, strong acids and strong bases, or weak acids and weak bases.

Performing and Recording

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Demonstrate safe use of lab equipment and materials while abiding by current WHMIS (2015) standards. This may be completed on an as needed basis, or may include a designated set of equipment to be used throughout the year. Assessment of student understanding in this instance is also required.
- Create a T-chart study guide using course specific examples of classification systems (e.g., endothermic vs. exothermic).
- Discuss how the periodic table demonstrates that elements are organized based on their properties.

Students may

- Set up an investigation and demonstrate proper safety procedures, including proper disposal and storage.
- Create an acid-base spill solution and a broken glass station.

Connection

Students may

- Develop safety signs for the lab, emphasizing content specific to Chemistry 3202.
- Create fact sheets to list safe operating procedures regarding lab equipment and materials.
- Outline WHMIS guidelines on posters or infographics. Display in the lab.

Consolidation

Students may

- Perform a reaction rate investigation in which students gather the appropriate materials and handle all substances using proper WHMIS protocol.
- Handle and dispose of acids and bases in a safe and appropriate manner.
- Develop a mix and match activity using WHMIS symbols and their meaning.
- Present WHMIS guidelines to a group of younger science students.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 198-199

Chemistry: Newfoundland and Labrador (SR)

- p. 508

Analyzing and Interpreting

Outcomes

Students will be expected to

18.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots
[GCO 2]

19.0 identify a line of best fit on a scatter plot and interpolate or extrapolate based on the line of best fit
[GCO 2]

20.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables
[GCO 2]

Focus for Learning

Communication must reflect ideas, plans, and results accurately and without bias. Students have previously represented data in a variety of ways and should continue to develop skills associated with data representation. This may include using diagrams, models, charts, graphs, and various statistical figures.

Teachers should emphasize the use of clear and concise modes of representation that appropriately and accurately reflect results of a student oriented investigation. Use of numbers, symbols, graphs, and language is pervasive across the sciences; therefore, opportunities to demonstrate proficiency are necessary.

Tables are often used to compile data while graphs and charts are used to interpret and present this data. Tables should include both rows and columns with appropriate headings. A descriptive title that includes a number (e.g., Table 1: Title) should be located at the top.

Diagrams, charts, and graphs provide a means to present trends in collected data. These are considered to be figures and should be numbered with a descriptive title included at the bottom (e.g., Figure 1: Title/description). Additionally, the x and y axis of a graph should be clearly labelled with the appropriate units and with the x-axis containing the independent variable.

Students worked with scatter plots, line of best fit, interpolating, and extrapolating in Science 9. They should continue to work with data plotted from activities or investigations and then construct a line of best fit. Examining data within the line (interpolate) and predicting data from beyond the plotted data range (extrapolate) are essential skills. Teachers should clarify when a curve of best fit is more appropriate, such as the case with pH curves.

Interpretation and inference are two important subsets of critical thinking. Students should be able to make the connection about the importance of a line or curve of best fit when interpreting data.

Students should also recognize patterns and determine relationships between variables (e.g., linear relationships include data sets that increase or decrease by constant intervals according to changes in the independent variable; nonlinear relationships include increases or decreases by varying, quantifiable amounts).

Students should be able to examine data in an investigation to determine relationships (linear and nonlinear), correlations, trends, predicted values, and line equations. Appropriate inferences can be made based on data collected during investigations.

Teachers should caution the interpretation of patterns based on small sample sizes (especially when dealing with living systems). In many investigations, a large sample is required to properly assess and determine appropriate relationships.

Analyzing and Interpreting

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Present students with graphs that include plotted data. Ask them to use extrapolation and interpolation to obtain information.
- Provide sample data sets that demonstrate linear and nonlinear relationships (e.g., reaction rates, temperature concentration).
- Discuss prior use of line graphs, circle graphs, and scatter plots to organize and display data.

Students may

- Create their own line or curve of best fit from data sets. Consider using graph paper before using technological devices to plot data.
- Brainstorm when it is appropriate to use line graphs, circle graphs, and scatter plots (from Mathematics 9).

Connection

Teachers may

- Guide students as they graph data from early investigations.

Students may

- Predict, from a titration curve, the pH of an equivalence point.
- Justify use of a particular data format and display in an experiential activity. Indicate why it was appropriate and how it helped in the interpretation of the data.
- Use reaction rate and concentration data to create a line or curve of best fit. Utilize this for interpolation and extrapolation of data.
- Create a graph to determine the rate of a chemical reaction.

Consolidation

Students may

- Interpret patterns and trends in data and infer relationships within, by using a visual representation such as a line graph.
- Use titration curves to determine an end point and an equivalence point.
- Use a scatter plot to graph data from a reaction rate lab (for instance, rate of $\text{CO}_2(\text{g})$ production over time). Use the resulting graph to determine reaction rate and extrapolate to determine the volume of $\text{CO}_2(\text{g})$ produced at a particular time (not previously measured).
- Use either a pH probe or pH paper to collect pH data throughout a titration. Graph the data using a scatter plot. Use the resulting graph to identify the equivalence point, the pH at the equivalence point, the type of titrant (strong acid or weak acid, strong base or weak base) and the type of unknown (strong acid or weak acid, strong base or weak base).

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (SR)

- pp. 413-415, 434, 551-562, 566

Analyzing and Interpreting

Outcomes

Students will be expected to

21.0 apply and assess alternative theoretical models for interpreting knowledge in a given field [GCO 2]

22.0 compare theoretical and empirical values and account for discrepancies [GCO 2]

Focus for Learning

Alternative theoretical models are needed since scientific knowledge is based on the available evidence at a specific time and therefore must be constantly reassessed. Scientific knowledge can change over time as a result of new and emerging evidence from the development of new technologies. Scientific knowledge is often subject to different interpretations based on the knowledge provided. As a result, different theoretical models are possible.

Students will have experience (from intermediate science) analyzing the different theoretical models of the atom as proposed by Dalton, Thomson, Rutherford, and Bohr. The need for revisions and changes to the models, based on emerging evidence, was also discussed.

The process of accounting for discrepancies will allow students to be critically reflective of their own abilities.

Empirical values are measures collected from investigations and observation. Theoretical values are the accepted values that have been determined by thorough, repeated experimentation (for example, the accepted value for the molar enthalpy of combustion of paraffin, $C_{25}H_{52}(s)$, is 18 000 kJ/mol). When students investigate a problem, they may develop trends, make predictions, or calculate values. Students should compare their results to known theoretical values through percent discrepancy or percent error. This provides a pathway through which students can determine the validity of their investigation and reflect on the process used. Students should identify why such discrepancies exist and suggest how experimentation can be modified to limit them. For example, they may experimentally determine the molar enthalpy of combustion of paraffin, $C_{25}H_{52}(s)$, calculate the percent discrepancy or error, then suggest reasons for differences. Similarly, students may experimentally determine the voltage of a variety of half-cell combinations and compare to the accepted tabulated values found in the Table of Standard Reduction Potentials (SRP Table).

Investigations should focus on inquiry, problem solving, or testing hypotheses. Having a large discrepancy does not mean failure; it provides a learning opportunity that allows reflection on practices and skills used throughout experimentation.

Students have prior experience (from intermediate mathematics) discussing theoretical versus experimental probabilities. A connection should be made to help compare values and to account for discrepancies.

Analyzing and Interpreting

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Discuss a variety of theoretical models which have evolved through time. New technologies that emerge produce new data collection tools. This new data may result in the production of alternative theories and models. For example, in Science 9, students studied historical changes to the models of the atom.

Students may

- Reflect on and discuss the differences between theory and practice. Within the discussion, begin a commentary on the accuracy of instruments and assumptions in theory.

Connection

Teachers may

- Discuss the development of acid-base theories including Arrhenius, modified (modern) Arrhenius, and Brønsted-Lowry.

Students may

- Observe or complete an activity that focuses on heat capacity of a metal. Consider the direction of error caused by the limitations of the procedure (e.g., the measured heat capacity should never be higher than the generally accepted value).
- Measure known quantities in sample activities (e.g., measure the voltage of batteries and compare these values to the theoretical value of the voltage: What is the voltage output of a 9 V battery? Is it actually 9 V?).
- Identify other known quantities that have theoretical equivalents in daily life. List reasons why observed data may be different from known quantities (e.g., the speed of a car).
- Compare data (when measuring voltages of half-cell reactions) with the accepted theoretical values.
- Discuss the assumptions of calorimetry and then compare the experimental and accepted values of enthalpy.

Consolidation

Students may

- Propose alternative theories to the theories stated within an activity. Justify theories based on observations and other data.
- Compare the cell voltages in a galvanic cell investigation to those calculated using the SRP Table.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 254-258

Chemistry: Newfoundland and Labrador (SR)

- pp. 704-705

Analyzing and Interpreting

Outcomes

Students will be expected to

23.0 evaluate the relevance, reliability, and adequacy of data and data collection methods
[GCO 2]

24.0 identify and explain sources of error and uncertainty in measurement and express results in a form that acknowledges the degree of uncertainty
[GCO 2]

Focus for Learning

Students should be able to review research methodologies and advances that occur during investigative processes; scientific investigations require constant change and modifications. They should examine the data collected and evaluate the quality in terms of

- accuracy,
- relevance to the study in question,
- sample size, and
- sampling techniques.

Students should also discuss that investigations can be set up incorrectly and can therefore produce results that will not properly address a research question or hypothesis (e.g., when collecting data to observe strengths of oxidizing and reducing agents, consistent molar concentrations of nitrates should be used; metals are to be sanded). Similarly, to ensure reliability of data, tools used in collecting data should be free of all types of bias.

The concepts of accuracy and precision may be introduced here. This may also be related to the use of significant digits. What implications does the estimation in measurement have for the results in an investigation?

Significant digits should be an important part of this discussion, as well as different types of error (e.g., random or systematic error).

One of the most difficult parts of designing an investigation is to control or account for all possible factors except the one independent variable that is being studied.

Teachers should demonstrate variability in the measuring process due to errors from instrumentation and procedures. Instrument failure and human error (e.g., technique) are common examples.

After activities have been completed, teachers should hold a debriefing session (either in small groups or as a whole class) to address discrepancies in results from different groups of students. Brainstorming possible reasons for the discrepancies, sources of error, and uncertainty in measurement can help students critically reflect on their practices and make notes for improvement during subsequent activities.

Analyzing and Interpreting

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Discuss types of timing devices (e.g., stopwatches, wristwatches, cell phone apps) used to collect data in labs such as those that involve the measurement of reaction rates. Ask different students to record the time of various trials. Discuss why there are discrepancies in the times and how these differences can be minimized.
- Demonstrate how using a lab thermometer can produce sources of error. For example, the temperature of a liquid can be measured simultaneously with multiple thermometers and the results can be compared. After heating or cooling, the temperatures can be measured again. Students can compare the changes in temperatures recorded by each thermometer and develop a list of potential errors that result from improper usage. Other apparatus-based activities that may be suitable include use of microscope, scales, meter stick, and graduated cylinders.

Connection

Teachers may

- Reference population biology investigations to reflect on the quality of data and to evaluate data collection methods. How many fish should be sampled to produce a model of the whole population? Where should the sampling occur and when? Is the sample representative of the population? Were the methods used standardized and accepted? Other examples include studying reaction rates or dating with radioisotopes.
- Discuss the rationale for the rule of 500 for approximations of equilibrium calculations. It is appropriate because K_a and K_b are usually not known beyond two significant digits.

Students may

- Identify and explain ways that error can be reduced in experimentation. Apply appropriate methods to increase the reliability of their own data collection methods.
- Photograph their measuring instruments (riders on a triple-beam balance, meniscus in burette, or volumetric flask, etc.). Share results and discuss how the readings can and should be interpreted.
- Measure the mass of a volume of solution using a graduated cylinder, delivery pipette, or small beaker. Compare the results. Discuss the precision and reliability of measurement.

Resources and Notes

Authorized

Appendices

- Appendix A: Scientific Conventions

Chemistry: Newfoundland and Labrador (TR)

- pp. 243-244

Chemistry: Newfoundland and Labrador (SR)

- p. 657

Analyzing and Interpreting

Outcomes

Students will be expected to

25.0 construct and test a prototype of a device or system and troubleshoot problems as they arise [GCO 2]

26.0 evaluate a personally designed and constructed device on the basis of criteria they have developed themselves [GCO 2]

Focus for Learning

Problem solving is an important part of the scientific method. Documenting improvements and modifications from start to finish will help demonstrate the importance of problem solving in science. During prototype development, there should be ongoing evaluation, modification, and changes. For example, students may test several different designs for a galvanic cell, observing the use of specific electrolyte solutions or the effect of using a salt bridge versus not using a salt bridge.

Developing criteria to evaluate a constructed device requires critical thinking. Students may use appropriate technology, tests, or measurements to evaluate their design. Once evaluated, the criteria may need to be modified as part of the problem solving process. For example, using their knowledge of the required components, students may design their own calorimeter or attempt to construct an electrochemical cell. They may account for problems as they arise and make adjustments as necessary.

Analyzing and Interpreting

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Review prior student experience (Science 7, Heat unit) with
 - selection of appropriate methods and tools to construct and test a thermometer, and
 - collection of data during design testing.
- Review the design process with students. They have experienced this process in previous science courses as well as in intermediate technology courses.
- Develop a group design challenge related to a current Chemistry 3202 topic. Facilitate the challenge with another group.

Consolidation

Students may

- Develop and examine a technological device used in science activities. Evaluate this device, suggest possible design changes, implement the changes, and evaluate the results. For example, students can design their own simple calorimeter.
- Build an electrochemical cell intended to deliver a particular voltage. Use provided materials (e.g., choice of electrodes, electrolytes, conductors).
- Troubleshoot or optimize another student's constructed electrochemical cell.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 254-258

Chemistry: Newfoundland and Labrador (SR)

- pp. 704-705

Suggested

Resource Links: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202/resource-links.html>

- Let's Talk Science: Classroom Activities

Analyzing and Interpreting

Outcomes

Students will be expected to

27.0 identify new questions or problems that arise from what was learned
[GCO 2]

28.0 identify and evaluate potential applications of findings
[GCO 2]

Focus for Learning

Students should analyze current knowledge to identify problems. They should develop, through the processes of critical thinking, relevant and applicable questions. Good questions will demonstrate an appreciation of the topic and foster creative thinking required to address the problem. Although original thoughts are deemed to be the focus of scientific discovery, building on the work of others is also important. Creative thinking is necessary to identify questions while critical thinking is important when discovering problems.

To develop important science skills, students should have opportunities to continuously question their surroundings and all things to which they are exposed. They should also have opportunities to examine how scientists use the results of investigations or research to develop new applications (e.g., the development and modification of acid-base theories).

Many innovation and skilled-based programs have possible applications as one of their outcomes. Students should be aware that an idea is just an idea until someone develops a useful way for it to be used; this development will involve creative thinking skills. The evaluation of these applications will help develop each student's critical thinking skills.

Teachers may consider a Dragon's Den™ approach to this skill development. It is important to not limit students to commercial ventures; rather, social, global, ecological, and environmental ventures should be the focus. This will allow students to develop their social conscience along with their skills.

Analyzing and Interpreting

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Use a timeline or web to demonstrate how a scientific theory was developed from other theories. For example, use a timeline to trace the development of theories dealing with acids and bases.
- Outline unintended consequences of some scientific discoveries; these have been both positive and negative; therefore, examples should reflect this. For example, both nitrous oxide and ether were initially used as recreational drugs before their more accepted use was developed.

Connection

Students may

- Research the development of the lithium ion battery.
- Research the history of once common products such as DDT, PCBs, or leaded gasoline. Identify the applications these products once had and the ultimate reason they were discontinued. Present findings to the class.
- Identify possible practical implications of spontaneous redox reactions (e.g., selection of storage containers for solutions and methods used to prevent corrosion).

Consolidation

Students may

- Prepare a Dragon's Den™ presentation for one of the products researched above. Based on its potential benefits, pitch the product to the class.

Extension

Students may

- Participate in a science fair. In the development of the project, consider the applications of the concept researched. Incorporate the applications in the project report.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 197-199

Chemistry: Newfoundland and Labrador (SR)

- pp. 498-509

Communication and Teamwork

Outcomes

Students will be expected to

29.0 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results
[GCO 2]

Focus for Learning

Students should have opportunities to record data in a variety of ways. Students will further develop skills associated with this by determining the appropriate form to represent data, as well as using diagrams, models, charts, graphs, and various statistical figures. Teachers should emphasize the use of clear and concise modes of representation that accurately reflect results of a student oriented investigation.

This has significant applicability in high school science as accuracy in significant figures, units, nomenclature, and terminology is important for the understanding of many concepts.

Students should be able to explain how use of numbers, symbols, graphs, and language allows scientists to communicate using a standardized system of organization, grouping, and naming. Teachers may use examples of how common language aids in collaboration and understanding. For example, chemists use common nomenclature to identify and name chemical compounds.

Teachers should ensure that students have opportunities to use such classification systems and nomenclature, specifically in an investigation. Knowledge and development of such skills will be further refined through activity. For example, students may discuss how to operationally identify an unknown acid or base.

Communication and Teamwork

Sample Teaching and Assessment Strategies**Activation**

Teachers may

- Discuss why, for the results of a titration, a graph of pH values is a better representation than a table of pH values.
- Discuss why and how people use different names for the same things (e.g., acetic acid vs. ethanoic acid and conventional current vs. electron flow).

Connection

Students may

- Collect (or be provided with) data from a previous lab investigation. In groups, decide how to present results. In each instance, justify the use of numeric, symbolic, graphical, and linguistic modes of communication. Take the presented results and use a completely different set of numbers, symbols, graphs, and language to describe the data. Compare the two methods to determine which is most effective and why.
- Collect, analyze, and present results made by each lab group. For example, discuss how to represent and explain the variability observed when different groups attempt to measure the same materials or elements.

Resources and Notes**Authorized**

Appendices

- Appendix A: Scientific Conventions

Chemistry: Newfoundland and Labrador (SR)

- pp. 551-562, 566

Communication and Teamwork

Outcomes

Students will be expected to

30.0 identify multiple perspectives that influence a science-related decision or issue
[GCO 2]

31.0 work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise
[GCO 2]

32.0 evaluate individual and group processes used in planning, problem solving and decision making, and completing a task
[GCO 2]

Focus for Learning

Students should understand that, depending on their world view, gender, socioeconomic status, religion, education level, access to resources, rights provided under laws, etc., people may hold different views on a situation or topic. Acceptance and respect for differing perspectives is required if meaningful communication is to occur.

Students should also discuss how careful planning with consideration of multiple perspectives is necessary in order to make sound science-related decisions. They should have opportunities to identify potential stakeholders and investigate the position of each on specific issues. Students should also have opportunities to investigate how science may have changed as a result of differences in perspectives from historical periods to modern times. Teachers may find it helpful to introduce and discuss the story of Galileo; the unwillingness of leaders of the time to accept multiple perspectives led to Galileo's house imprisonment and consequently the reduction of the impact his work may have had on science.

Students should focus on collaboration as an important skill in science. Contrary to popular opinion, scientists do not work in isolation and do not know everything about a particular discipline. For example, chemistry includes many different branches such as organic, inorganic, physical, medical, biochemistry. This makes it very difficult for one person to know everything about all branches. Within a branch of chemistry, scientists specialize in a specific topic and are not experts in all areas.

Students should have a range of opportunities, through teamwork and cooperative learning, to develop collaboration skills. It is expected that students will develop key attributes of collaboration and teamwork such as following directions, negotiating, listening, allowing others' an opportunity to speak, agreeing to disagree, working towards common goals, constructively criticizing, accepting feedback, and incorporating feedback appropriately. Working in pairs and small groups during lab investigations and other activities will help students build skills necessary for all life experiences.

Students should understand that science communication is an integral part of a scientist's life. Scientists must work with numerous people to complete any task. To be effective, communication between team members is vital. Self and peer evaluation is important when planning, problem solving, decision making, and completing a task. Problems must be viewed from as many perspectives as possible.

Students should participate in self and peer evaluations during and after group projects and other applicable activities. They should be able to critically reflect on the entire processes of planning, decision making, and implementing. Determining strengths and weaknesses are crucial to refining and repeating the process.

Communication and Teamwork

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Introduce the topic of electrochemical cells by discussing the different perspectives of Galvani and Volta.
- Discuss the issue of methylmercury and the reservoirs required for hydroelectric dams. Weigh the benefits of renewable energy generation against the harms of environmental change and effects on food gathering.

Connection

Teachers may

- Introduce a titration lab investigation where half the class are first taught how to pipette while the rest are taught how to use a burette. During the investigation, pair students with complementary skills who can then teach each other.
- Develop, with students, a set of guidelines for group work. Ask students to share past experiences: What worked? What didn't? What improvements could be made?
- Suggest a topic (e.g., construction of a resource road to access a remote mine site). Students may choose a perspective (e.g., science, social, technological, environmental, economic, legal, ethical) and present pros and cons to the class.

Students may

- Participate in an investigation that includes data collection. In groups, analyze data from other groups. Discuss the importance of accurately recording and clearly communicating observations.
- Examine perspectives on pipeline development in Canada. List arguments of the detractors and supporters. Consider how different perspectives have led to some of the decisions made.

Consolidation

Students may

- Redesign or critique a previously completed lab investigation. Identify procedures that can be streamlined or improved. Create a short video to highlight difficulties encountered in the lab.
- Create, in a group, a study guide for a topic or unit.
- Evaluate peers on the collaboration which takes place in the science classroom. Use an agreed upon framework.
- Complete an indicator challenge using three solutions, each with a different pH (e.g., 3.5, 7.2, 9.8). Test each with multiple acid-base indicators (>6). In groups, interpret the colours of each solution in each indicator. Compile and display the data so that the group is able to estimate the pH of each solution.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (SR)

- pp. 582, 605, 622-629

Section Three:
Specific Curriculum Outcomes

Unit 1: From Kinetics to Equilibrium

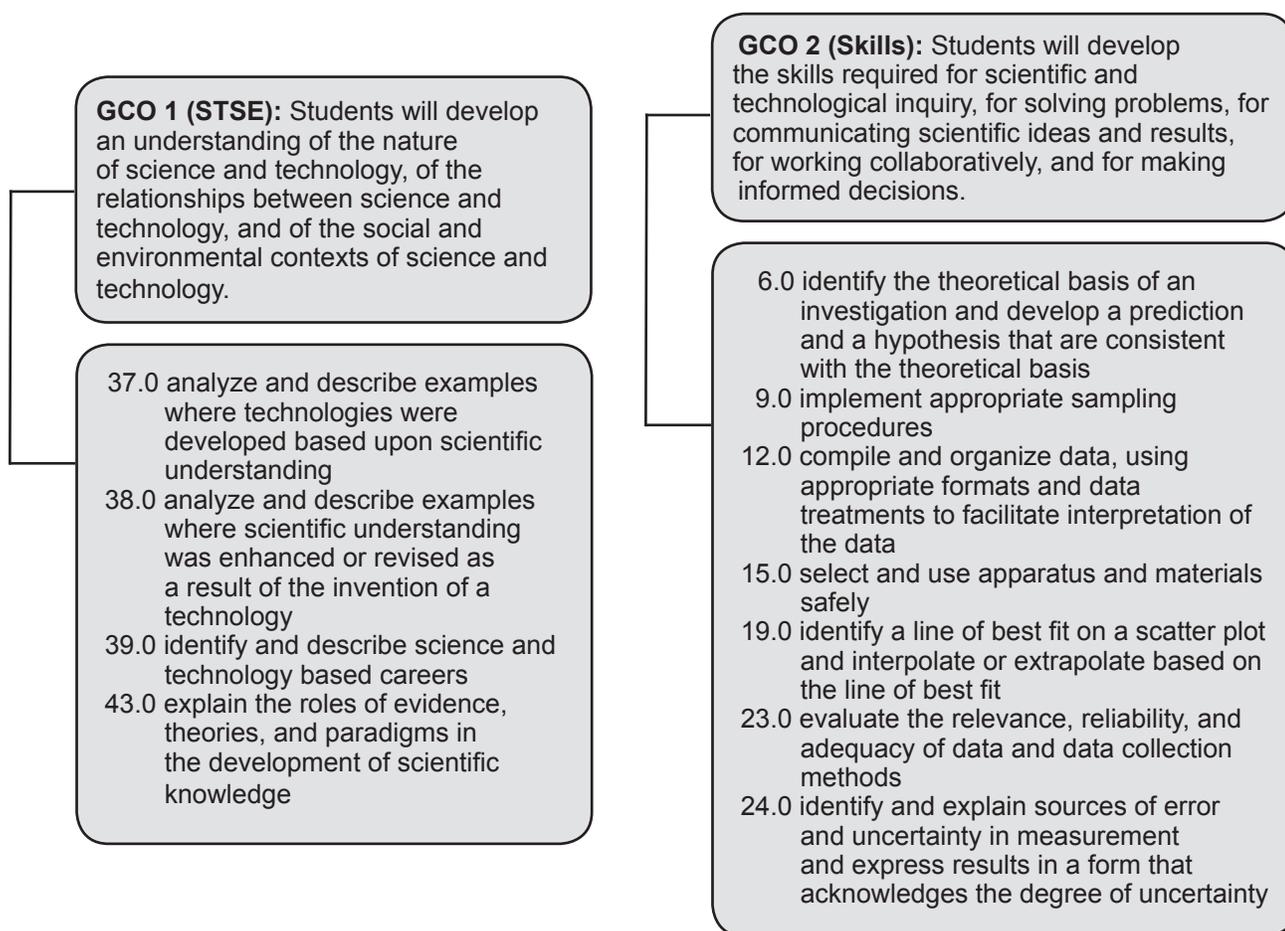
Focus

Many factors affect the rate of chemical reactions. Students will study collision theory, investigation of factors that affect reaction rates, interpretation of potential energy diagrams, and a catalyst's role in chemical reactions.

Understanding that reactions can be described as dynamic equilibrium systems by criteria, equations, calculations, concentrations, and experiments within the context of everyday phenomena is the focus of this unit. The concept of equilibrium, and the role of evidence in Le Châtelier's principle will also be addressed.

Problem-solving, critical thinking, and skill-building activities are integrated throughout this unit. Lab investigations to test reaction rates and to use Le Châtelier's principle are valuable to understanding this unit. As well, STSE connections include technologies that were developed and revised based on scientific understanding. In Science 1206, students interpreted and balanced chemical equations. Chemistry 2202 included introducing ions, ionic compounds, and molecular structure, as well as measuring amounts in moles.

Outcomes Framework



GCO 3 (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.

33.0 describe collision theory and its connection to factors involved in altering reaction rates
34.0 identify and discuss the properties and factors which affect reaction rate
35.0 sketch and interpret potential energy diagrams for chemical reactions
36.0 describe a reaction mechanism and a catalyst's role in a chemical reaction
40.0 define the concept of dynamic equilibrium as it pertains to reversible chemical reactions
41.0 define the concept of equilibrium constant expression as it pertains to chemical systems
42.0 explain how different factors affect chemical equilibrium

GCO 4 (Attitude): 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.

Students are encouraged to

- confidently evaluate evidence and consider alternative perspectives, ideas, and explanations
- have a sense of personal and shared responsibility for maintaining a sustainable environment
- show a continuing and more informed curiosity and interest in science and science-related issues

SCO Continuum

GCO 3: Knowledge		
Science 1206	Chemistry 2202	Chemistry 3202
<ul style="list-style-type: none"> • name and write formulas for some common ionic and molecular compounds, using the periodic table and a list of ions • represent chemical reactions and the conservation of mass using molecular models and balanced symbolic equations • illustrate how factors affect chemical reactions 	<ul style="list-style-type: none"> • write and name the formulas of ionic and molecular compounds, following simple IUPAC rules • define molar mass and perform mole-mass interconversions for pure substances • explain solubility, using the concept of equilibrium • define the concept of equilibrium as it pertains to solutions • use the solubility generalizations to predict the formation of precipitates • identify mole ratios of reactants and products from balanced chemical equations • predict how the yield of a particular chemical process can be maximized • identify and describe the properties of molecular substances • identify and describe the properties of ionic substances 	<ul style="list-style-type: none"> • describe collision theory and its connection to factors involved in altering reaction rates • identify and discuss the properties and factors which affect reaction rate • sketch and interpret potential energy diagrams for chemical reactions • describe a reaction mechanism and a catalyst's role in a chemical reaction • define the concept of dynamic equilibrium as it pertains to reversible chemical reactions • define the concept of equilibrium constant expression as it pertains to chemical systems • explain how different factors affect chemical equilibrium

Suggested Unit Plan It is recommended that Unit 1: From Kinetics to Equilibrium, be completed as the first unit of Chemistry 3202.

September	October	November	December	January	February	March	April	May	June
Unit 1 From Kinetics to Equilibrium		Unit 2 Acids and Bases			Unit 3 Thermochemistry		Unit 4 Electrochemistry		
Skills Integrated Throughout									

Factors That Affect Reaction Rates

Outcomes

Students will be expected to

- 9.0 implement appropriate sampling procedures [GCO 2]
- 12.0 compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data [GCO 2]
- 15.0 select and use apparatus and materials safely [GCO 2]
- 19.0 identify a line of best fit on a scatter plot and interpolate or extrapolate based on the line of best fit [GCO 2]
- 23.0 evaluate the relevance, reliability, and adequacy of data and data collection methods [GCO 2]
- 24.0 identify and explain sources of error and uncertainty in measurement and express results in a form that acknowledges the degree of uncertainty [GCO 2]

Focus for Learning

In Science 1206, students designed a lab investigation on reaction rates. In Chemistry 3202, students should participate in a lab investigation on reaction rates. This investigation will provide the basis for discussions on kinetic molecular theory and collision theory. Students should incorporate both quantitative and qualitative analysis, including identifying and explaining sources of error. They should also display evidence using a variety of formats.



The lab investigation should also include the following:

Surface Area

- For example, compare calcium carbonate powder versus calcium carbonate chips (TUMS™) in acid. Here, the temperature, mass of calcium carbonate, volume of acid, concentration of acid and mass of powder or chip will be kept constant, and the two values for the rates will be compared.

Temperature

- For example, conduct a variety of trials at different temperatures of the reaction of sodium carbonate and acid. The surface area/mass of calcium carbonate and acid concentration/volume of acid will be kept constant. Rate data versus temperature should be collected, graphed, and analyzed, including the use of a line or curve of best fit.

Concentration

- For example, conduct a variety of trials using different concentrations of acid (by dilution) with sodium carbonate. The surface area, temperature, and volume of acid will be kept constant. Rate data versus concentration should be collected, compared, and graphed, including the use of a line or curve of best fit.

Continued

Factors That Affect Reaction Rates

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Discuss the importance of lab safety. Ask students to provide examples of things they should and should not do in a lab setting.

Students may

- Brainstorm the requirements of a lab investigation and the importance of control variables.

Connection

Students may

- Write balanced chemical equations for the chemicals provided during a lab activity that investigates reaction rates.
- Graph average reaction rates from their investigation.
- Identify and assess the presence of outliers in quantified data.
- Investigate the impact of increasing the temperature of a reaction by 10 °C.

Consolidation

Students may

- Determine the effect each factor has on the rate of a chemical reaction.
- Compare individual and class lab results to analyze error and uncertainty.
- Propose alternate methods of measuring reaction rates for the individual labs.
- Design and carry out an investigation to collect data on the rate of a simple reaction (e.g., metal with an acid, antacid with water). Use a graph to record data.
- Examine pieces of laboratory equipment and determine how each could be used to measure reaction rate (e.g., pH sensor, digital scale, thermometer, Vernier™ equipment).

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 172-173

Chemistry: Newfoundland and Labrador (SR)

- pp. 413, 414-415, 434

Newfoundland and Labrador teacher Resource and Solutions Manual (Digital)

Teaching and Learning Strategies: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202.html>

- Factors That Affect Reaction Rates

Note

The magnifying glass icon is used to denote required investigations of questions, ideas, problems, and issues.



Factors That Affect Reaction Rates

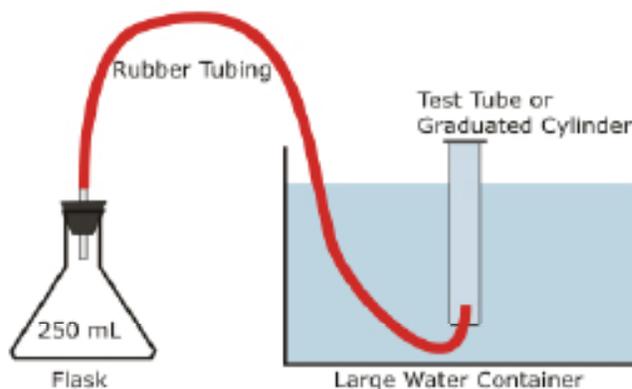
Outcomes

Students will be expected to

- 9.0 *implement appropriate sampling procedures*
[GCO 2]
- 12.0 *compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data*
[GCO 2]
- 15.0 *select and use apparatus and materials safely*
[GCO 2]
- 19.0 *identify a line of best fit on a scatter plot and interpolate or extrapolate based on the line of best fit*
[GCO 2]
- 23.0 *evaluate the relevance, reliability, and adequacy of data and data collection methods*
[GCO 2]
- 24.0 *identify and explain sources of error and uncertainty in measurement and express results in a form that acknowledges the degree of uncertainty*
[GCO 2]

Focus for Learning

The rate of reaction (mL/s) can be measured by the timed collection of $\text{CO}_2(\text{g})$ using an inverted graduated cylinder in water bath (pneumatic trough). Some chemical suppliers also offer gas collection tubes which may be used without requiring pneumatic troughs (e.g., a large water container or storage tub may be used). If both pieces of apparatus are available, students may select which of the two they consider to be most appropriate.



Refer to the Integrated Skills unit for further elaboration on SCOs in column 1. This investigation also provides an opportunity to address additional inquiry-related skills (e.g., 3.0, 5.0, 16.0, 32.0).

Attitude

Encourage students to confidently evaluate evidence and consider alternative perspectives, ideas, and explanations. [GCO 4]

Factors That Affect Reaction Rates

Sample Teaching and Assessment Strategies**Extension**

Students may

- Propose alternate methods of measuring reaction rates for the individual labs.
- Propose alternate chemicals to carry out a similar experiment.

Resources and Notes**Authorized**

Chemistry: Newfoundland and Labrador (TR)

- pp. 172-173

Chemistry: Newfoundland and Labrador (SR)

- pp. 413, 414-415, 434

Collision Theory

Outcomes

Students will be expected to

33.0 describe collision theory and its connection to factors involved in altering reaction rates

[GCO 3]

Focus for Learning

In Science 7, students were introduced to particle theory (i.e., the fundamentals of the kinetic molecular theory, or KMT) as well as simple gas properties including relationships between volume, temperature, and pressure.

In Chemistry 3202, students should be able to describe the KMT of matter which states that particles of matter; atoms, ions, or molecules, are in a state of constant, random motion. This tends to result in many collisions. The kinetic energy associated with each collision is conserved.

Students should also be able to describe two pieces of evidence that support the KMT:

1. Pressure – The collision of gas molecules apply force against the sides of a container, thus creating pressure.
2. Diffusion – The gas particles are in constant motion and move as far apart as possible, completely filling the space they occupy.

Students should be able to explain that the collision theory is an extension of the KMT. They should also identify and be able to explain the following principles of the theory:

- Reactions are the result of successful collisions between reactant particles (not all collisions are successful).
- To be successful, reacting particles must collide with sufficient kinetic energy (E_k) and must collide in the correct orientation.

Teachers should establish that there is a direct relationship between the rate of reaction and the number of successful collisions amongst reacting particles: To increase the rate of a reaction, one must increase the frequency of successful collisions.

Students should be able to describe how, given a chemical reaction, reaction rates can be measured by monitoring a variety of changing macroscopic properties, including the following: mass, colour, pressure, concentration, volume, and pH.

Continued

Collision Theory

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Demonstrate (i.e., class demonstrations, videos, simulations)
 - correct orientation of reactant particles, using the analogy of puzzle pieces fitting together;
 - particle movement for KMT (e.g., use an inflated balloon or food colouring in water); and
 - rates with a variety of reactions (e.g., decomposition of hydrogen peroxide, Alka-seltzer™ in hot and cold water).

Students may

- Brainstorm prior knowledge of the kinetic molecular theory and properties of gases. Share their knowledge and ask questions when other students share.

Connection

Students may

- Provide examples of diffusion of gases (e.g., cooking aromas fill the house, perfume scents fill a room) and rates (e.g., milk spoils at room temperature).
- Role-play as moving molecules. A successful collision is a face-to-face one while an unsuccessful collision is any other combination where they would bounce off each other. Record the number of successful versus unsuccessful collisions.

Consolidation

Students may

- Explain how increasing pressure in a reaction involving gases can affect the rate of the reaction.
- Determine unit possibilities for reaction rate (e.g., g/s, mL/min).
- Explain the observation that best supports the KMT:
 - Acetic acid odour is detected from across the room.
 - Combustion of butane produces heat.
 - Liquid water freezes at 0 °C under standard conditions.
 - Nitrogen dioxide gas is dark brown in colour.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 166-168

Chemistry: Newfoundland and Labrador (SR)

- pp. 412, 420

Suggested

Resource Links: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202/resource-links.html> (Sign-in to the K-12 PL Site is necessary)

- Air Bag Inflation Rate (simulation)
- Collision Theory (video)
- Diffusion Activity (random motion and collisions of particles)
- KMT: Diffusion (simulation)
- Reaction Rate: Temperature (animation)
- Reaction Rates (simulation)
- Centre for Distance Learning and Innovation (chemistry videos)

Collision Theory

Outcomes

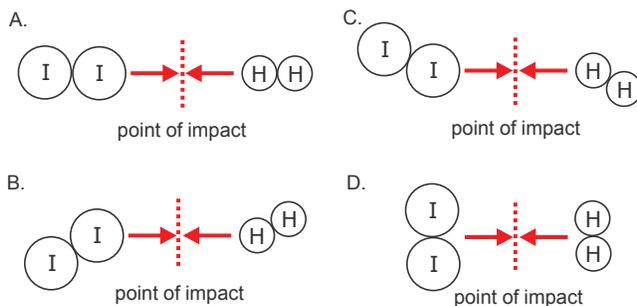
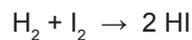
Students will be expected to

33.0 describe collision theory and its connection to factors involved in altering reaction rates
[GCO 3]

Focus for Learning

Sample Performance Indicators

1. Use kinetic molecular theory to explain why a basketball stays inflated.
2. Which two particle collisions will most likely result in a successful reaction?



Collision Theory

Sample Teaching and Assessment Strategies

Extension

Students may

- Make and share connections between Brownian motion and KMT.
- Demonstrate particle movement for KMT (e.g., use an inflated balloon placed in a refrigerator or food colouring in water).
- Demonstrate particle motion of different states. Completely fill a petri dish with beans or beads (to represent a solid) and shake from side-to-side (particles hardly move). Take out half of the beans or beads (to represent a liquid) and shake from side-to-side again (greater and more varied movement). Take out all except for four beans or beads and repeat to represent a gas.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 168-170

Chemistry: Newfoundland and Labrador (SR)

- pp. 420-421

Factors Affecting Reaction Rates

Outcomes

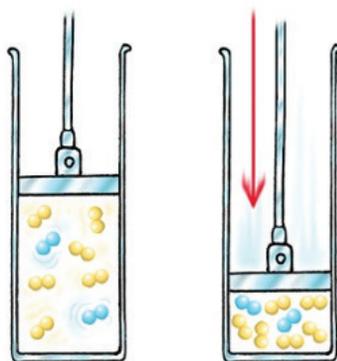
Students will be expected to

- 34.0 identify and discuss the properties and factors which affect reaction rate [GCO 3]

Focus for Learning

Using the appropriate theory (collision theory and/or kinetic molecular theory), students should identify and explain how changes in temperature, concentration, volume, pressure, surface area, and the presence of a catalyst, affect the rate of reaction.

1. Changes in temperature affect the kinetic energy of all particles within a substance. Temperature is defined as the average kinetic energy of all particles within a substance.
2. Changes in concentration affect the number of particles per unit volume.
3. Changes in the volume of a gas, as shown below, result in a change of pressure, which changes the number of particles per unit volume.



4. Changes in the surface area affect the exposed area (the number of exposed particles) of a solid substance.
5. A catalyst provides an alternative pathway for the reaction, one with a lower activation energy.

A more detailed discussion of the workings of a catalyst will be addressed with mechanisms.

Sample Performance Indicators

1. Based on factors that affect reaction rates and using collision theory, explain the following:
 - Coal dust reacts faster than a lump of coal.
 - It is advisable to rust-check your vehicle.
 - Milk spoils faster when left out of the fridge.
 - Zinc and aluminum dust are more flammable than sheets of the metals.
2. Consider the following reaction:

$$\text{Zn(s)} + 2 \text{HCl(aq)} \rightarrow \text{H}_2\text{(g)} + \text{ZnCl}_2\text{(aq)}$$
 - Describe four ways to increase the reaction rate.
 - List at least three ways the rate of the chemical reaction can be measured.

Factors Affecting Reaction Rates

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Use analogies to describe how collisions occur under varying conditions. For example, changing concentrations is like changing the number of people in a closed area.
- Share incidents of collision theory such as dust explosions (e.g., Westray Mine disaster or BC sawmill explosion, 2012). Discuss.

Students may

- Discuss when it is desirable to speed up or slow down a chemical reaction and why it is easier to ignite kindling than a log?
- Determine in which cup the sugar would dissolve more quickly: Two cups of coffee have identical volume, cup shape, and temperature. A sugar cube is placed in one cup. A second sugar cube is cut in half and both halves are placed in the second cup.

Connection

Students may

- Share examples of how different factors affect reaction rates. Predict reaction rates under varying circumstances.
- Discuss examples of collision theory (e.g., oxygen tanks for respiratory illnesses).
- Calculate the surface area of a solid object. Divide it in half and calculate the surface area of the two halves. Has the volume and surface area increased, decreased, or stayed the same? Once cut in half, was there an increase or a decrease in the number of exposed particles? How would this affect the rate of a reaction?

Consolidation

Teachers may

- Discuss slow and fast chemical reactions and why it is important to control the rates of reactions (e.g., the need for both fast and slow reactions such as an air bag reaction and rust prevention).

Students may

- Answer the questions: Why is it better to use a catalyst to speed up a reaction than to increase the temperature? Why do factories that produce chemicals want to be able to control reaction rates?

Extension

Students may

- Provide a reason for the differences in the following reaction rates: $\text{H}_2(\text{g})$ reacts more rapidly with $\text{F}_2(\text{g})$ than it does with $\text{Cl}_2(\text{g})$.
- Research use of inhibitors to decrease reaction rates (e.g., salt).

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 166-170

Chemistry: Newfoundland and Labrador (SR)

- pp. 416-418, 424-426

Suggested

Resource Links: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202/resource-links.html>

- University of Oregon Chemistry (demos)
- Catalysts (video)

Potential Energy

Outcomes

Students will be expected to

35.0 sketch and interpret potential energy diagrams for chemical reactions [GCO 3]

Focus for Learning

Students should be able to demonstrate that potential energy (stored energy) diagrams are used to illustrate changes in potential energy as a reaction proceeds. They should also explain the following:

- Overall, endothermic reactions absorb energy to form products. Endothermic reactions have the general form



- Overall, exothermic reactions release energy as they form products. Exothermic reactions have the general form

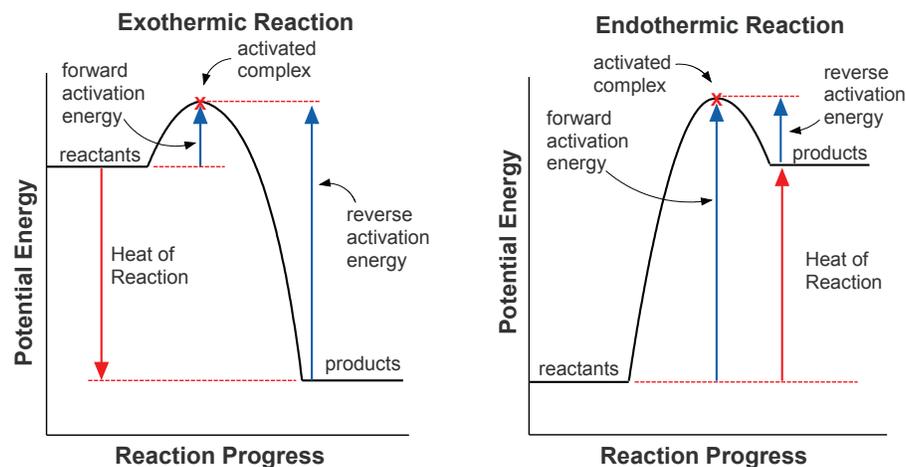


Endothermic and exothermic reactions, as well as enthalpy (ΔH) will be addressed in greater detail in Unit 3: Thermochemistry. Equilibrium and reverse reactions will be addressed in greater detail later in this unit.

Students are expected to draw, interpret, and label potential energy diagrams for exothermic and endothermic reactions. Diagrams should include

- activated complex site,
- activation energy (forward and reverse),
- heat of reaction/enthalpy (ΔH),
- labelled axes (x-axis: reaction progress and y-axis: potential energy or E_p), and
- specific reactants and products for the reaction used.

Two typical reaction and potential energy diagrams are shown below:



Continued

Potential Energy

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Share a video of a combustion reaction and ask whether the substance undergoing combustion or the resulting products contains more potential energy. Discuss as a class.

Students may

- Discuss common examples of exothermic and endothermic reactions such as coal combustion, metabolism of sugars in the body, lime production from limestone, and hot and cold packs.

Connection

Students may

- Use cellular respiration on potential energy diagrams to show the complementary energy gain through photosynthesis and energy loss.

Consolidation

Teachers may

- Provide students with an E_p diagram which shows the energy changes involved in an uncatalyzed and a catalyzed reversible reaction. Ask students to match the descriptions below to the values on the graph (some values do not have matching descriptions):
 - Activation energy of the first step of the forward catalyzed reaction
 - Activation energy of the forward uncatalyzed reaction
 - Activation energy of the reverse uncatalyzed reaction
 - Overall change in energy for the reaction
 - Transition state/site of activated complex

Students may

- Use the following reaction: $D + E \rightarrow F + G$, and that $\Delta H = -56 \text{ kJ/mol}$ and $E_{a(\text{rev})} = 120 \text{ kJ/mol}$. Complete the following:
 - Determine whether the reaction is endothermic or exothermic.
 - Draw a potential energy diagram.
 - Determine $E_{a(\text{fwd})}$ for the reaction (add to the diagram).
 - A catalyst speeds up this reaction by providing an alternative, three-step mechanism. On the diagram, sketch a curve to represent the effect of the catalyst on the reaction.
- Draw and label a potential energy diagram for the following exothermic reaction: $2 \text{ClO}(g) \rightarrow \text{Cl}_2(g) + \text{O}_2(g)$

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- p. 169

Chemistry: Newfoundland and Labrador (SR)

- pp. 421, 422, 425, 584-585

Potential Energy

Outcomes

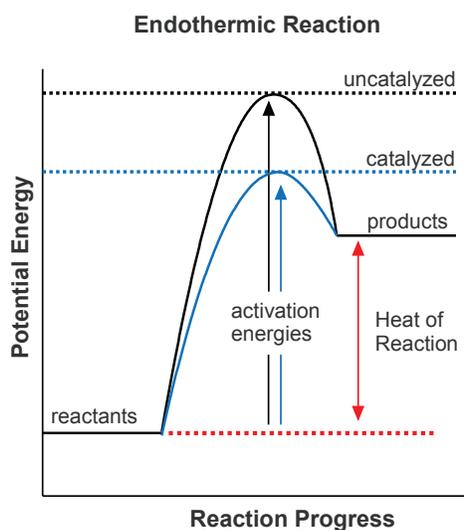
Students will be expected to

35.0 sketch and interpret potential energy diagrams for chemical reactions [GCO 3]

Focus for Learning

Teachers should note that the topic of activated complex should be limited to its definition, location on the graph, and energy. Its possible structure should not be addressed.

Students should be able to compare the activation energies of catalyzed and uncatalyzed reactions and relate them to reaction rates.



Sample Performance Indicator

A reaction has a heat of reaction of -45 kJ/mol and a forward activation energy of $+35 \text{ kJ/mol}$. Complete the steps below:

1. Sketch and label a potential energy diagram.
2. Determine the activation energy for the reverse reaction.

Potential Energy

Sample Teaching and Assessment Strategies

Extension

Students may

- Propose a structure for an activated complex of a chemical reaction.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- p. 169

Chemistry: Newfoundland and Labrador (SR)

- pp. 421, 422, 425, 584-585

Reaction Mechanisms

Outcomes

Students will be expected to

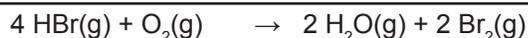
36.0 describe a reaction mechanism and a catalyst's role in a chemical reaction [GCO 3]

Focus for Learning

Teachers should explain that most chemical equations are a summary of all the processes that occur as reactants become products.

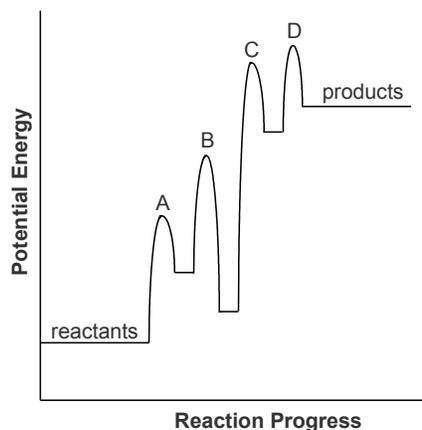
Students should state that in some cases, reactions involve more than one step, with each step representing the breaking and forming of bonds as successful collisions occur. Often, these changes are too complicated to happen at one simple stage. Instead, the reaction involves a series of small changes.

For example,



When presented with a reaction mechanism, students should be able to identify

- a reaction mechanism as a series of elementary reactions (steps) that add to give an overall balanced equation;
- an elementary process (i.e., elementary reaction or step) as a single-step reaction in a multi-step reaction mechanism;
- a reaction intermediate as a substance which is produced by one step, but consumed in a later step;
- a catalyst (reactant consumed in one step that is regenerated in a later step) as a species that speeds up the overall reaction rate by providing an alternate pathway of lower activation energy, and
- the rate-determining step (RDS) as the slowest step in the reaction mechanism (the RDS always has the greatest activation energy, but may not correspond to the activated complex with the greatest potential energy; the RDS will always be the curve that has the highest energy change from its reaction intermediate to the peak).



For the four-step mechanism shown, the RDS is C. Even though step D has an activated complex with the highest absolute potential energy, the activation energy for step C (starting at the beginning of its energy barrier to the top of its hill) is higher than that of step D.

Continued

Reaction Mechanisms

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Use an analogy to analyze elementary processes and rate-determining steps (e.g., washing a car, making bread, tying shoes).

Students may

- Brainstorm further examples of processes that require multiple steps. Provide examples where efforts have been made to speed up these multi-step processes.

Connection

Teachers may

- Demonstrate
 - the decomposition of hydrogen peroxide: catalyst – manganese(IV) oxide, and
 - the reaction of the oxalate ion with acidified potassium permanganate solution: catalyst – Mn^{2+} .

Students may

- Share examples of catalysts used in industry and medicine.
- Describe the effect of a catalyst on a number of reactions such as decomposition of bleach: catalysts – cobalt(II) chloride, raw liver, raw potato.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 170-171

Chemistry: Newfoundland and Labrador (SR)

- pp. 427-431

Suggested

Resource Links: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202/resource-links.html>

- Reaction Mechanisms (podcasts)
- Colourful Catalysts (investigation)

Reaction Mechanisms

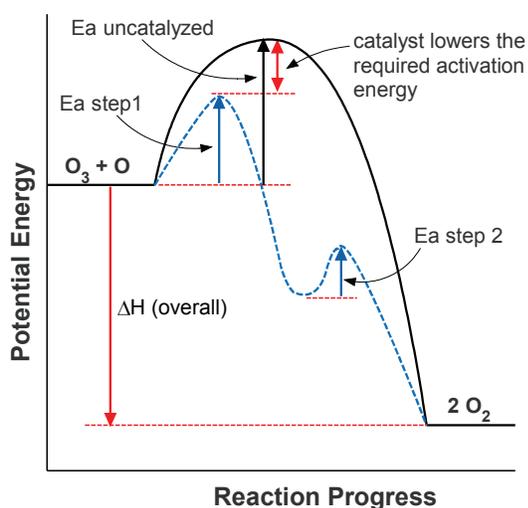
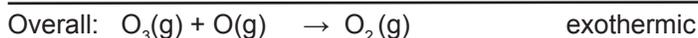
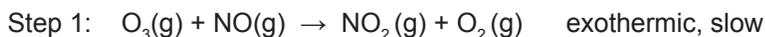
Outcomes

Students will be expected to

36.0 describe a reaction mechanism and a catalyst's role in a chemical reaction [GCO 3]

Focus for Learning

Given a reaction mechanism, students should be able to write the overall chemical reaction. Students should also be able to sketch and label a potential energy diagram for multi-step mechanisms (with or without a catalyst). For example,



Students should describe the impact of a catalyst on a reaction and be able to illustrate this on a potential energy diagram (one-step or multi-step, as illustrated in the diagram above). Teachers should inform students that the number of activated complexes depends on the number of steps in the catalyzed mechanism.

Students should be able to draw a possible mechanism for a given set of reaction steps. This should be done based on the relative speed of each step which would be provided. Teachers may indicate if each elementary step is endothermic or exothermic; the magnitude of ΔH for each step is not necessary. Only the overall magnitude of ΔH is necessary (see diagram on the following page - 88).

Continued

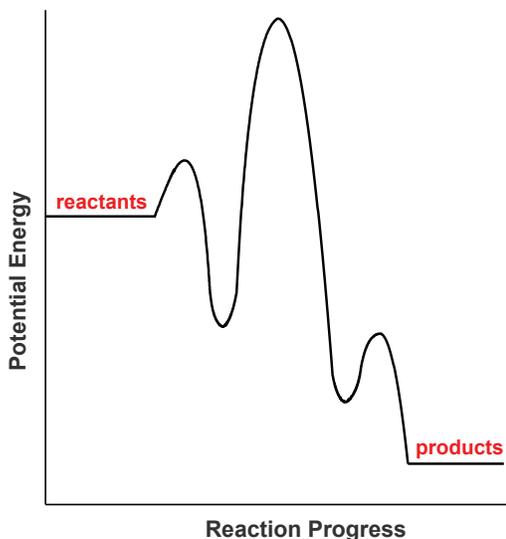
Reaction Mechanisms

Sample Teaching and Assessment Strategies

Consolidation

Students may

- Explain how they know if a species is a catalyst or a reaction intermediate.
- Show where an activated complex and where a reaction intermediate appear on an E_p diagram.
- Complete a lab investigation to determine factors affecting rates, monitoring rates (gas production), catalysts, and intermediates.
- Use the graph below to determine the rate-determining step:



Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 170-171

Chemistry: Newfoundland and Labrador (SR)

- pp. 428-429, 435-437

Suggested

Resource Links: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202/resource-links.html>

- University of Oregon Chemistry (demos)

Reaction Mechanisms

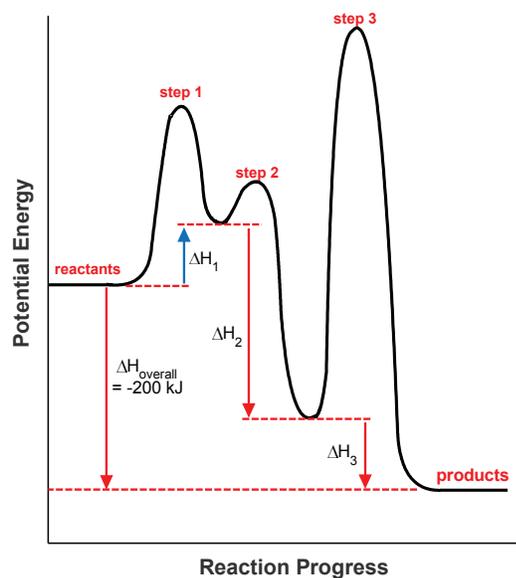
Outcomes

Students will be expected to

36.0 describe a reaction mechanism and a catalyst's role in a chemical reaction [GCO 3]

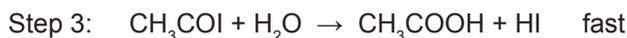
Focus for Learning

Step 1:	$A + B \rightarrow C$	endothermic, slow
Step 2:	$C + D \rightarrow E$	exothermic, fast
Step 3:	$E + A \rightarrow 2 F$	exothermic, very slow
Overall:	$2A + B + D \rightarrow 2 F$	$\Delta H = -200 \text{ kJ/mol}$



Sample Performance Indicator

Consider the three-step reaction mechanism:



- For the above mechanism, identify any reaction intermediate(s), catalyst(s), and the rate-determining step (RDS). Write the overall uncatalyzed reaction.
- For the above exothermic mechanism, sketch a potential energy diagram for (i) the overall uncatalyzed and (ii) the three-step catalyzed mechanism.
- What effect would increasing the concentration of CO have on the overall reaction rate?
- What effect would increasing the concentration of CH_3OH have on the overall reaction?

Reaction Mechanisms

Sample Teaching and Assessment Strategies**Extension**

Students may

- Discuss order of reactions in relation to reaction mechanisms.
- Research
 - an industrial process (identify its rate-determining step and what is done to increase the overall rate of reaction), and/or
 - various catalysts used in industry.

Resources and Notes**Authorized**

Chemistry: Newfoundland and Labrador (TR)

- pp. 170-171

Chemistry: Newfoundland and Labrador (SR)

- pp. 428-429, 435-437

Applications of Kinetics

Outcomes

Students will be expected to

37.0 analyze and describe examples where technologies were developed based upon scientific understanding [GCO 1]

38.0 analyze and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology [GCO 1]

39.0 identify and describe science and technology based careers [GCO 1]

Focus for Learning

Students should research how knowledge of reaction kinetics and mechanisms can be used in environmental, industrial, and biochemical applications. This should also involve investigating the role of chemistry professionals (e.g., chemical engineer, industrial chemist, baker) in solving these problems. Sample topics are included below.

Surface area and reaction rate

- Some medications need to be absorbed into the bloodstream quickly and others must be absorbed slowly. Solid capsules of medicine can be swallowed whole so that they are not released into the bloodstream too rapidly. Other medications are consumed as small granules within gel capsules that dissolve rapidly upon ingestion.
- Grain is a mixture of flammable organic powders. The high volume of powder has a large surface area. Any source of spark is prohibited around grain storage areas (grain elevators) since the high surface area grain may quickly combust.
- A car's catalytic converter changes environmentally toxic exhaust gases such as NO(g) and CO(g) to less harmful emissions. The catalytic converter reacts quickly with gases passing through the exhaust system. It uses a high surface area for the catalyst (e.g., beaded or honeycomb design) to allow for maximum collision with the exhaust gases and the fastest possible reaction rate (to convert them to less harmful gases).

Temperature and reaction rate

- Some products must be stored at cooler temperatures to ensure that they do not decompose faster. For example, hydrogen peroxide solutions decompose, and should be kept in a cool environment to avoid decomposing to water and oxygen gas.

Collisions and reaction rate

- A scratch in the paint of a car will expose the metal surface to air, allowing the metal to rust. If the scratch is repaired and painted, metal is not exposed and is no longer able to collide with the oxygen in the air as easily; therefore it will not rust.

Mechanisms and environmental chemistry

- Ground-level ozone is harmful to humans and results from NO(g) and CO(g) pollution. Removal of the NO(g) catalyst from the environment means that the mechanism of ozone, O₃(g), production from oxygen, O₂(g), cannot occur.

Catalysts and reaction rate

- Enzymes are biological catalysts which speed up certain natural processes, providing an efficient reaction pathway for the process. For example, people who are lactose intolerant have trouble digesting the milk sugar lactose; many have a serious deficiency in the enzyme lactase (an enzyme that splits the milk sugar lactose to produce the sugars glucose and galactose).

Continued

Applications of Kinetics

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Introduce the use of catalysts in everyday life (e.g., catalytic converters, water treatment, enzymes in laundry detergent).

Connection

Students may

- Discuss the link between smog and acid rain.
- Discuss why it is important for journalists to have a basic understanding of reaction rates when covering environmental topics.
- Consider the following: One possible mechanism for the production of ground level ozone from automobile engines exhaust is given below. Identify any catalyst and reaction intermediates and write the overall reaction.
 - Step 1: $2 \text{NO}(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2 \text{NO}_2(\text{g})$ fast
 - Step 2: $2 \text{NO}_2(\text{g}) \rightarrow 2 \text{NO}(\text{g}) + 2 \text{O}(\text{g})$ slow
 - Step 3: $2 \text{O}(\text{g}) + 2 \text{O}_2(\text{g}) \rightarrow 2 \text{O}_3(\text{g})$ fast
 - Overall:

Consolidation

Students may

- Prepare a multimedia presentation on research associated with the role of chemistry professionals in solving problems related to reaction mechanisms.
- Research various biological enzymes to study the enzyme(E)-substrate(S) relationship and their products(P) in context of catalyst and reaction intermediates:
 - Step 1: $\text{E} + \text{S} \rightarrow \text{ES}$
 - Step 2: $\text{ES} \rightarrow \text{EP}$
 - Step 3: $\text{EP} \rightarrow \text{E} + \text{P}$

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- p.176

Chemistry: Newfoundland and Labrador (SR)

- pp. 420-423

Applications of Kinetics

Outcomes

Students will be expected to

37.0 analyze and describe examples where technologies were developed based upon scientific understanding. [GCO 1]

38.0 analyze and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology [GCO 1]

39.0 identify and describe science and technology based careers [GCO 1]

Focus for Learning

Given a chemical mechanism and background information on how this mechanism is part of an environmental, industrial, or biochemical issue, students should be able to analyze the mechanism in terms of its catalyst(s), intermediate(s), and overall equation, and determine how the mechanism is used to explain the issue. For example, given the mechanism of smog formation from oxygen, students may be asked to evaluate a number of changes to the mechanism as well as possible environmental impacts.

Many reactions of great commercial importance can proceed by more than one reaction path. Knowledge of the reaction mechanisms involved may make it possible to choose reaction conditions favouring one path over another, thereby resulting in maximum amounts of desired products and minimum amounts of undesired products.

Through this, students should learn that there is great interest in these reactions because they are reactions by which valuable materials such as plastics, dyes, synthetic fibres, and medicinal agents are prepared as well as because most of the biochemical reactions of living systems are of this type.

Attitude

Encourage students to

- have a sense of personal and shared responsibility for maintaining a sustainable environment, and
- show a continuing and more informed curiosity and interest in science and science-related issues. [GCO 4]

Sample Performance Indicator

Discuss that one possible solution to the problem of ground level ozone production is to remove NO(g) and that scientists and engineers solved this problem by developing a catalytic converter which utilizes a metal catalyst through the suggested mechanism:

- Step 1: $\text{CO(g)} \rightarrow \text{CO(ad)}$ (repeated x 2)
- Step 2: $\text{NO(g)} \rightarrow \text{N(ad)} + \text{O(ad)}$
- Step 3: $\text{N(ad)} + \text{NO(g)} \rightarrow \text{N}_2\text{(g)} + \text{O(ad)}$
- Step 4: $\text{CO(ad)} + \text{O(ad)} \rightarrow \text{CO}_2\text{(g)}$ (repeated x 2)



Applications of Kinetics

Sample Teaching and Assessment Strategies**Extension**

Students may

- Complete research on
 - alternate forms of automobile technology that would further reduce smog production (e.g., electric, hydrogen, and hybrid vehicles);
 - the use of mechanisms to solve other problems encountered in science, technology, and society; and/or
 - the design of catalytic converters.

Resources and Notes**Authorized**

Chemistry: Newfoundland and Labrador (TR)

- p. 176

Chemistry: Newfoundland and Labrador (SR)

- pp. 420-423

Equilibrium

Outcomes

Students will be expected to
40.0 define the concept of dynamic equilibrium as it pertains to reversible chemical reactions [GCO 3]

Focus for Learning

Students should explain that a reversible reaction is one that has the general format: Reactants \rightleftharpoons Products, whereby the forward and reverse reactions are occurring simultaneously.

Students should be able to define the concept of dynamic equilibrium as it pertains to reversible reactions and explain that any dynamic equilibrium describes reversible processes. In the case of chemical equilibria, there are forward and reverse chemical reactions.

Students should state the criteria for an equilibrium be established as

- closed system with constant temperature and pressure,
- constant macroscopic properties,
- equal rates of forward and reverse processes, and
- reversible reaction.

Students should be able to describe the changes in reaction rates of the forward and reverse reactions as a chemical system attains dynamic equilibrium.

From reactants only:

1. The forward rate is initially very high and as concentration of reactants decreases, the forward rate decreases.
2. The reverse rate is initially zero and as concentration of products increases, the reverse reaction rate increases.
3. The system reaches equilibrium (the forward and reverse reaction rates become equal).

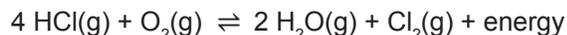
It is important to acknowledge that chemical equilibria do not have to start with reactants only, but may start with any combination of reactants and/or products.

Teachers should reinforce that, at equilibrium, it is the reaction rates which become equal, not the amounts of products and reactants.

Students should write and interpret chemical equations for chemical systems at equilibrium, when states of matter are provided. Students must indicate an equilibrium by writing a double arrow (\rightleftharpoons) in an equation, as opposed to using a single arrow (\rightarrow) for a reaction which goes to completion. Teachers should include states of matter when discussing chemical reactions.

Sample Performance Indicator

Chlorine gas, $\text{Cl}_2(\text{g})$; is a yellowish-green gas that can be produced by reacting hydrogen chloride, $\text{HCl}(\text{g})$; and oxygen, $\text{O}_2(\text{g})$; both of which are colourless.



The reactants are added to a clear, empty reaction vessel. Describe a piece of evidence that can be used to determine when equilibrium has been achieved.

Equilibrium

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Discuss various highly visual examples of equilibrium systems (e.g., saturated solution, closed flask versus open flask of carbonated water).
- Use analogies for establishing chemical equilibrium.

Students may

- Discuss how to infer that the amounts of reactants and products are remaining constant at equilibrium.

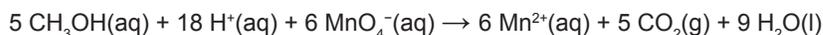
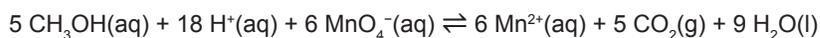
Connection

Teachers may

- Compare endothermic and exothermic reactions (e.g., if energy is absorbed in one direction, it is released in the opposite direction).

Students may

- Discuss the changing rates of reaction for forward and reverse in reference to collision theory.
- Examine what happens when carbonated water is made (e.g., open a bottle of soda pop and explain what they see).
- Determine which chemical equation is in an open container and which is in a closed container? Explain.



Consolidation

Students may

- Draw concentration versus time graphs to demonstrate the nature of how chemical equilibria are established.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- p. 178

Chemistry: Newfoundland and Labrador (SR)

- pp. 446-449

Suggested

Resource Links: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202/resource-links.html>

- Equilibrium (simulation)
- Equilibrium (demonstration video)
- Predicting Shifts in Equilibrium

Equilibrium Constant

Outcomes

Students will be expected to

41.0 define the concept of equilibrium constant expression as it pertains to chemical systems [GCO 3]

Focus for Learning

Students should be able to write equilibrium constant expressions, K , for chemical systems and recognize that solids and liquids are not included in the expression since their concentrations don't change.

Writing Equilibrium Constant Expressions

For $aA + bB \rightleftharpoons cC + dD$, the equilibrium constant expression is

$$K = \frac{[C]^c [D]^d}{[A]^a [B]^b}$$

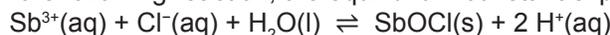
where the states of A, B, C, and D are (g) or (aq) and not (s) or (l)

For the reaction

$2 \text{N}_2\text{O}_5(\text{g}) \rightleftharpoons 4 \text{NO}_2(\text{g}) + \text{O}_2(\text{g})$,
the equilibrium constant expression is

$$K = \frac{[\text{NO}_2]^4 [\text{O}_2]}{[\text{N}_2\text{O}_5]^2}$$

For the following reaction, the equilibrium constant expression is



$$K = \frac{[\text{H}^+]^2}{[\text{Sb}^{3+}] [\text{Cl}^-]}$$

Teachers should inform students that K is temperature dependent.

Students should predict whether reactants or products result in a reversible reaction on the basis of the magnitude of the equilibrium constant, whereby the following will apply:

- If K is much greater than 1, it means that the numerator (products) is larger than the denominator (reactants). Thus, products are favoured.
- If K is much less than 1, the numerator (products) is less than the denominator (reactants). Thus, reactants are favoured.
- If $K = 1$, neither reactants nor products are favoured.

Students should be able to complete the following:

1. Calculate K
 - given equilibrium concentrations of all species;
 - given initial concentration(s) and one equilibrium concentration (Initial concentration, Change in concentration, Equilibrium concentration, ICE table); and
 - given initial concentration(s) and the percent reaction (ICE table).
2. Calculate an equilibrium concentration when K and all other equilibrium concentrations are given.
3. Calculate the percent reaction given initial and equilibrium concentration.

Continued

Equilibrium Constant

Sample Teaching and Assessment Strategies

Connection

Teachers may

- Share varying initial concentrations (e.g., all reactants to start, all products to start, some combination of reactants and products, and the resultant equilibrium concentrations). Discuss that the ratio of R and P, regardless of initial concentrations, remain the same once the system reaches equilibrium.

Students may

- Use Vernier™ colourimetry equipment to calculate concentrations of reversible reactions, both before and after equilibrium has been established. Calculate K with the data.

Consolidation

Students may

- Answer and discuss the following questions:
 - At 827 °C, 0.777 moles of $\text{SO}_3(\text{g})$ is introduced into a 1.00 L closed container and allowed to reach the equilibrium stated below. If the equilibrium concentration of $\text{SO}_3(\text{g})$ is 0.520 mol/L, calculate K .

$$2 \text{SO}_3(\text{g}) \rightleftharpoons 2 \text{SO}_2(\text{g}) + \text{O}_2(\text{g})$$
 - At 25 °C, $3 \text{X}(\text{g}) + \text{Y}(\text{g}) \rightleftharpoons 2 \text{W}(\text{g}) + \text{Z}(\text{g})$, the equilibrium concentrations X, Y, W, and Z were found to be 7.0 mol/L, 6.0 mol/L, 5.0 mol/L and 7.0 mol/L respectively. When the temperature was raised to 40 °C, the new equilibrium concentration of Z was found to be 6.0 mol/L. Calculate the new equilibrium concentrations, and the new K .
 - When 0.250 mol of $\text{NO}(\text{g})$ is placed in a sealed 1.00 L container at a particular temperature, 40.0% of it decomposes. Calculate the equilibrium constant at this temperature. $2 \text{NO}(\text{g}) \rightleftharpoons \text{N}_2(\text{g}) + \text{O}_2(\text{g})$
 - The equilibrium below occurs when 1.00 mol of $\text{NH}_3(\text{g})$ is placed in a 2.00 L sealed container. What is the percent reaction if the $[\text{NH}_3]$ is 0.20 mol/L at equilibrium?

$$\text{N}_2(\text{g}) + 3 \text{H}_2(\text{g}) \rightleftharpoons 2 \text{NH}_3(\text{g}) + \text{energy}$$

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 179-180

Chemistry: Newfoundland and Labrador (SR)

- pp. 450-464

Note

Calculating equilibrium concentration when K and initial concentrations are given is addressed in Unit 2 when calculating pH of a weak acid (base).

Equilibrium Constant

Outcomes

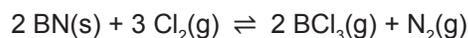
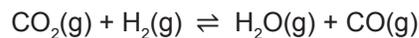
Students will be expected to

41.0 define the concept of equilibrium constant expression as it pertains to chemical systems
[GCO 3]

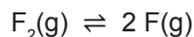
Focus for Learning

Sample Performance Indicators

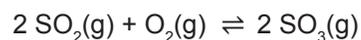
1. Write an equilibrium constant expression for the equations below:



2. If $[\text{F}_2] = 1.0 \times 10^{-2} \text{ mol/L}$ and $[\text{F}] = 3.0 \times 10^{-4} \text{ mol/L}$ in the equilibrium below, what is the value of the equilibrium constant?



3. At a particular temperature, 0.40 mol of $\text{SO}_2(\text{g})$ and 0.40 mol of $\text{O}_2(\text{g})$ are introduced into a sealed 2.0 L reaction vessel. If, at equilibrium, there are 0.25 mol of $\text{O}_2(\text{g})$ remaining, what is the equilibrium constant at this temperature?



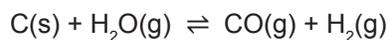
Equilibrium Constant

Sample Teaching and Assessment Strategies

Extension

Students may

- Determine (given initial concentrations and K) if the reaction is at equilibrium, and if not, in which direction it would need to shift to reach equilibrium.
- Complete the following:
 - Given concentrations of reactants and products, and the K value for an equilibrium, determine whether a system is at equilibrium.
 - Given solubility equilibrium constants, K_{sp} , calculate ion concentrations in aqueous solutions.
 - At 25 °C the value of K is 1.6×10^{-6} , while at 827 °C the value of K is 10.0. Explain whether the reaction is endothermic or exothermic.



Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 179-180

Chemistry: Newfoundland and Labrador (SR)

- pp. 450-464

Le Châtelier's Principle

Outcomes

Students will be expected to

42.0 explain how different factors affect chemical equilibrium
[GCO 3]

43.0 explain the roles of evidence, theories, and paradigms in the development of scientific knowledge
[GCO 1]

6.0 identify the theoretical basis of an investigation and develop a prediction and a hypothesis that are consistent with the theoretical basis
[GCO 2]

12.0 *compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data*
[GCO 2]

15.0 *select and use apparatus and materials safely*
[GCO 2]

Focus for Learning

Students should be able to apply Le Châtelier's principle (qualitatively and with concentration vs. time graphs):

1. Predict shifts in equilibrium position caused by changes in temperature, pressure, volume, or concentration.
2. Determine how the concentration of a reactant and/or product shifts after a change is imposed on an equilibrium.
3. Explain why adding a catalyst or changing the surface area of a solid species does not cause an equilibrium shift, but does have an effect on the time it takes for a system to reach equilibrium.
4. Explain why changing the amount of a solid or liquid species does not cause disturbances to the equilibrium.

The effect of the addition of inert gases is not an expectation of this course.

Students should complete a lab investigation on Le Châtelier's principle to predict and observe how each stress affects equilibrium. Students should apply Le Châtelier's principle to various changes made to a system at equilibrium (qualitative).



Skills should include

- following detailed and specific instructions,
- handling chemicals safely,
- selecting appropriate glassware,
- making appropriate qualitative observations, and
- displaying observations in appropriate tables.

The lab investigation should include the following:

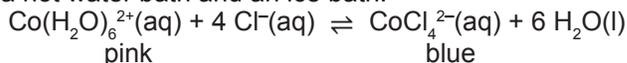
Pressure/Volume

- For example, a small sample of club soda is added to a large syringe sealed with a rubber stopper. Given the equilibrium below, students may predict and explain observations using Le Châtelier's principle when volume is changed by moving the syringe in and then moving the syringe out.



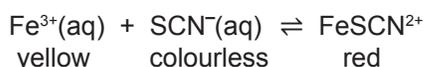
Temperature

- For example, predict whether the reaction is endothermic or exothermic and explain observations using Le Châtelier's principle when a solution of cobalt(II) chloride in alcohol is added to a hot water bath and an ice bath.



Concentration

- For example, prepare a solution of acidified $\text{Fe}(\text{NO}_3)_3$ and KSCN. Predict and explain observations using Le Châtelier's principle when a single drop of NaOH is added and when five drops of KSCN are added.



Continued

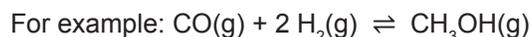
Le Châtelier's Principle

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Introduce the topic of Le Châtelier's principle with a concentration versus time graph and show what happens when a disturbance to the system occurs.

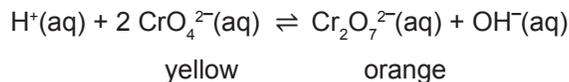


- The above system is at equilibrium when CO is added at time t. Ask students to draw and explain a concentration-time graph for all three chemical species showing before, at, and after time t.

Connection

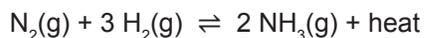
Teachers may

- Share a video of changes in concentration and its effect on equilibrium. For example, prepare a solution of potassium chromate, $\text{K}_2\text{CrO}_4\text{(aq)}$. Predict and explain observations using Le Châtelier's principle when $\text{H}^+\text{(aq)}$ is added and when $\text{OH}^-\text{(aq)}$ is added.



Students may

- Use Le Châtelier's principle to predict how the value of K changes in both an endothermic and exothermic reaction with a change in temperature.
- Investigate and discuss why removing a product from an equilibrium system helps to produce maximum yield of that product in the Fritz Haber synthesis.



Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 180-181, 184-186

Chemistry: Newfoundland and Labrador (SR)

- pp. 465-472, 479-481

Suggested

Resource Links: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202/resource-links.html>

- Equilibrium and Le Châtelier's Principle
- Le Châtelier: Disturbing Concentration (Graphs)
- Pressure, Volume, and Le Châtelier's Principle

*Le Châtelier's Principle***Outcomes**

Students will be expected to

42.0 *explain how different factors affect chemical equilibrium*
[GCO 3]

43.0 *explain the roles of evidence, theories, and paradigms in the development of scientific knowledge*
[GCO 1]

6.0 *identify the theoretical basis of an investigation and develop a prediction and a hypothesis that are consistent with the theoretical basis*
[GCO 2]

12.0 *compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data*
[GCO 2]

15.0 *select and use apparatus and materials safely*
[GCO 2]

Focus for Learning

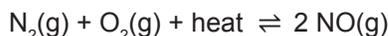
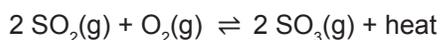
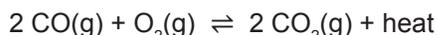
This investigation provides an opportunity to address additional inquiry-related skill outcomes from the Integrated Skills unit (e.g., 2.0, 19.0, 23.0, 31.0). Refer to the Integrated Skills unit for further elaboration.

Attitude

Encourage students to show a continuing and more informed curiosity and interest in science and science-related issues. [GCO 4]

Sample Performance Indicators

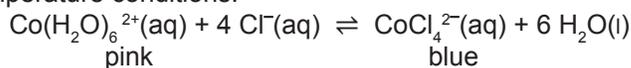
1. Refer to the three equilibrium systems below:



For each equilibrium system, predict in which direction equilibrium would shift by an increase in each of the following:

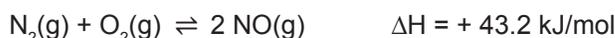
- Concentration of O_2
- Pressure
- Temperature

2. The equilibrium below was established under constant temperature conditions.



- Predict what colour change would occur if $\text{AgNO}_3\text{(aq)}$ was added to the system, and what precipitate would be produced.

3. Apply Le Châtelier's principle to predict how the yield of NO(g) could be increased.



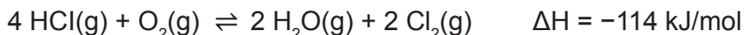
Le Châtelier's Principle

Sample Teaching and Assessment Strategies

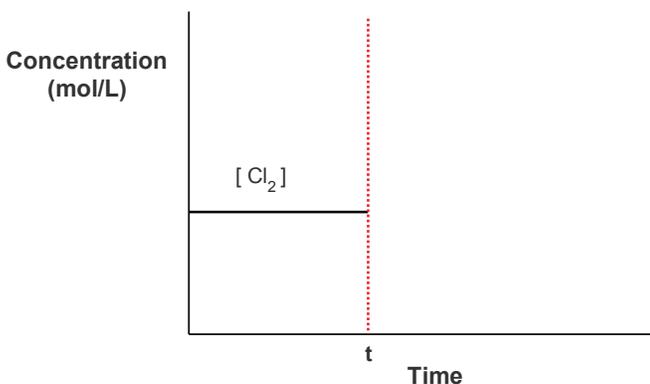
Consolidation

Students may

- Explain how the forward and reverse reaction rates in a chemical equilibrium can be disturbed by changes in the temperature, pressure/volume, and concentration (of one reactant or product), of a chemical equilibrium.
- Examine what happens when carbonated water is made. Write a chemical equation when equilibrium is reached between $\text{CO}_2(\text{aq})$ and $\text{H}_2\text{O}(\text{l})$ to form $\text{H}_2\text{CO}_3(\text{aq})$ when the container is open. Write the equation for the physical equilibrium of $\text{CO}_2(\text{g})$ and $\text{H}_2\text{O}(\text{l})$ when the container is closed.
- Consider the system below. It is allowed to reach equilibrium at $400\text{ }^\circ\text{C}$.



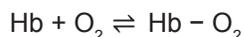
The equilibrium concentration of Cl_2 is graphed below. At t , the reaction vessel is heated and the reaction is allowed to re-establish equilibrium. Extend the line to indicate the effect on the concentration of Cl_2 .



Extension

Students may

- Research the experiments of Henri Le Châtelier that led to his understanding of chemical equilibrium systems.
- 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 wastewater.
- Design a water softener and explain how it works.
- Research the Haber process. Share learned highlights with the class.
- Explain the process of oxygen transport in the body by hemoglobin (Hb).



Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 180-181, 184-186

Chemistry: Newfoundland and Labrador (SR)

- pp. 465-472, 479-481

Section Three:
Specific Curriculum Outcomes

Unit 2: Acids and Bases

Focus

Students regularly use solutions that include acids and bases. They should be able to demonstrate understanding by selecting appropriate acids or bases for specific tasks. Students should also know potential effects of these chemicals as well as understand the relationship between acid-base theories and reactions.

Students will study the development of acid-base theory, show how theories evolve in light of new evidence, and formulate operational definitions based on laboratory observations. They will be encouraged to value the role of precise observation and careful experimentation while looking at safe handling, storage, and disposal of chemicals. Problem-solving, critical thinking, and skill building activities are integrated throughout this unit. Lab investigations to test pH and to use a standard solution to determine the concentration of an unknown substance are valuable to understanding this unit. STSE connections include the evolving scientific knowledge, evidence, and roles as well as justification of each.

In Science 1206, students studied formula writing and balancing equations and were introduced to operational acid-base concepts. In Chemistry 2202, students studied the naming of acids, moles, stoichiometric calculations, the nature of solutions, and expressing solution concentrations.

Outcomes Framework

GCO 1 (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.

- 43.0 explain the roles of evidence, theories, and paradigms in the development of scientific knowledge
- 44.0 explain how scientific knowledge evolves as new evidence comes to light and as laws and theories are tested and subsequently restricted, revised, or replaced
- 47.0 construct arguments to support a decision, or judgment, using examples and evidence and recognizing various perspectives
- 48.0 analyze society's influence on scientific and technological endeavours using examples from acid-base chemistry
- 49.0 describe science and technology based careers related to acid-base chemistry
- 57.0 explain the importance of communicating the results of a scientific or technological endeavour, using appropriate language and conventions
- 58.0 analyze and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology

GCO 2 (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.

- 5.0 state a prediction and a hypothesis based on available evidence and background information
- 8.0 evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making
- 11.0 use instruments effectively and accurately for collecting data
- 15.0 select and use apparatus and materials safely
- 16.0 demonstrate a knowledge of WHMIS standards by selecting and applying proper techniques for handling and disposing of lab materials
- 17.0 describe and apply classification systems and nomenclatures used in the sciences
- 18.0 compile and display evidence and information by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots
- 20.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables
- 27.0 identify new questions or problems that arise from what was learned
- 29.0 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results
- 31.0 work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise
- 32.0 evaluate individual and group processes used in planning, problem solving and decision making, and completing a task

GCO 3 (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.

45.0 describe various acid-base definitions up to and including the Brønsted-Lowry definition
50.0 compare strong and weak acids and bases using the concept of equilibrium (theoretical)
51.0 predict products of acid-base reactions
52.0 calculate the pH of an acid or a base given its concentration, and vice versa
53.0 compare strong and weak acids and bases using the concept of equilibrium (mathematical)
54.0 explain how acid-base indicators function
55.0 describe the interactions between H⁺ ions and OH⁻ ions using Le Châtelier's principle
56.0 determine the concentration of an acid or base solution using stoichiometry

GCO 4 (Attitude): 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.

Students are encouraged to

- consider further studies and careers in science and technology-related fields
- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas
- show concern for safety and accept the need for rules and regulations
- use factual information and rational explanations when analyzing and evaluating

SCO Continuum

GCO 3: Knowledge		
Science 1206	Chemistry 2202	Chemistry 3202
<ul style="list-style-type: none"> • name and write formulas for some common ionic and molecular compounds, using the periodic table and a list of ions • represent chemical reactions and the conservation of mass using molecular models and balanced symbolic equations • classify chemical reactions based on type • classify substances as acids, bases, or salts, based on their characteristics, name, and formula • describe how neutralization involves tempering the effects of an acid with a base or vice versa 	<ul style="list-style-type: none"> • write and name the formulas of ionic and molecular compounds, following simple IUPAC rules • define molar mass and perform mole-mass interconversions for pure substances • explain solubility, using the concept of equilibrium • define the concept of equilibrium as it pertains to solutions • use the solubility generalizations to predict the formation of precipitates • identify mole ratios of reactants and products from balanced chemical equations • perform stoichiometric calculations related to chemical equations • identify various stoichiometric applications • illustrate and explain the formation of covalent bonds • illustrate and explain the formation of ionic bonds • identify and describe the properties of molecular substances • identify and describe the properties of ionic substances • describe how ionic bonding accounts for the properties of ionic compounds • relate the properties of a substance to its structural model of ionic compounds • classify various organic compounds by determining to which families they belong, based on their names or structures • write the formula and provide the IUPAC name for a variety of derivatives • write and balance chemical equations to predict the reactions of selected organic compounds 	<ul style="list-style-type: none"> • describe various acid-base definitions up to and including the Brønsted-Lowry definition • compare strong and weak acids and bases using the concept of equilibrium (theoretical) • predict products of acid-base reactions • calculate the pH of an acid or a base given its concentration, and vice versa • compare strong and weak acids and bases using the concept of equilibrium (mathematical) • explain how acid-base indicators function • describe the interactions between H_3O^+ ions and OH^- ions using Le Châtelier's principle • determine the concentration of an acid or base solution using stoichiometry

Suggested Unit Plan It is recommended that Unit 2: Acids and Bases, be completed as the second unit of Chemistry 3202.

September	October	November	December	January	February	March	April	May	June
Unit 1 From Kinetics to Equilibrium		Unit 2 Acids and Bases			Unit 3 Thermochemistry		Unit 4 Electrochemistry		
Skills Integrated Throughout									

Application of Operational Definitions

Outcomes

Students will be expected to

44.0 explain how scientific knowledge evolves as new evidence comes to light and as laws and theories are tested and subsequently restricted, revised, or replaced [GCO 1]

5.0 state a prediction and a hypothesis based on available evidence and background information [GCO 2]

Focus for Learning

Acid-base theory development illustrates how scientific knowledge has evolved over time. In Science 1206, students were expected to classify acids and bases operationally, using diagnostic tests.

Teachers should review acids and bases by comparing some of their properties used in operationally defining acids and bases. See the table below:

Property	Acid	Base
Taste (students must never taste lab chemicals)	Taste sour (e.g., lemons, soft drink, vinegar)	Taste bitter (e.g., baking soda, toothpaste, TUMS™)
Touch (students must never touch lab chemicals)	Many are corrosive	Feels slippery and many are corrosive
Indicator tests	Turn blue litmus paper red	Turn red litmus paper blue
Reactivity	Form H ₂ (g) with some metals	Form soap with oils and fats
	Form CO ₂ (g) with carbonates	Form carbonates with CO ₂ (g)
Neutralization reactions	Acids neutralize (or partially neutralize) bases	Bases neutralize (or partially neutralize) acids
Electrical conductivity	Conductive	Conductive
pH	Less than 7.0	Greater than 7.0

Teachers should reinforce with students that both acids and bases are corrosive materials. However, common misconceptions include that acids will burn skin on contact and that bases are not corrosive.

Teachers should also state that operational definitions make no attempt to explain the observations. Operational definitions classify a substance as acidic or basic by completing a diagnostic test; this is what led to the development of the first theoretical definitions of acids and bases.

Refer to the Integrated Skills unit for elaboration on SCO 5.0.

Sample Performance Indicator

Predict whether each of the following are acidic, basic, or neutral, using operational definitions or the generalization that most foods are acidic and most cleaners are basic.

- bleach
- lemon juice
- Sprite™
- tonic water
- CLR™
- soap
- sugar
- vinegar

Confirm predictions using diagnostic tests (e.g., using litmus paper).

Application of Operational Definitions

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Discuss and demonstrate the different diagnostic tests that may be used to identify a substance as an acid, as a base, or as neutral.

Students may

- Create a concept map to identify common acids and bases (e.g., in general, most foods are acidic and most cleaners are basic).

Connection

Students may

- Predict the outcome of simple demonstrations of common chemistry experiments that involve acids and bases (e.g., reaction of baking soda and vinegar).
- Discuss the importance of knowing how to identify an unknown sample.
- Discuss what must be present in order for a solution to conduct electricity.
- Use universal pH paper to test the pH of a variety of samples (e.g., citrus fruits, shampoos, soaps).

Consolidation

Students may

- Determine which substance below will cause red litmus to change to blue. Explain.
 - $\text{HNO}_2(\text{aq})$
 - $\text{H}_2\text{SO}_4(\text{aq})$
 - $\text{NaOH}(\text{aq})$
 - $\text{NaCl}(\text{aq})$
- Investigate the relative acidity of different brands of fruit juices and/or shampoo. Share findings with the class.
- Use unknown samples provided (i.e., household or lab chemicals). Identify each as an acid or base using the diagnostic tests referenced above. For safety reasons, taste should not be included in testing.

Extension

Students may

- Research the harmful effects of mixing the wrong household chemicals.
- Explain why baby carrots can often feel slippery.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 196-197

Chemistry: Newfoundland and Labrador (SR)

- pp. 498-500

Newfoundland and Labrador teacher Resource and Solutions Manual (Digital)

Suggested

Resource Links: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202/resource-links.html> (Sign-in to the K-12 PL Site is necessary)

- Khan Academy: Acids and Bases

Acid-Base Theories

Outcomes

Students will be expected to

- 43.0 explain the roles of evidence, theories, and paradigms in the development of scientific knowledge
[GCO 1]
- 44.0 explain how scientific knowledge evolves as new evidence comes to light and as laws and theories are tested and subsequently restricted, revised, or replaced
[GCO 1]
- 45.0 describe various acid-base definitions up to and including the Brønsted-Lowry definition
[GCO 3]
- 17.0 describe and apply classification systems and nomenclatures used in the sciences
[GCO 2]
- 27.0 identify new questions or problems that arise from what was learned
[GCO 2]

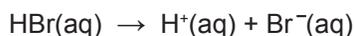
Focus for Learning

Teachers should trace the development of acid-base theories from Arrhenius theory, the modified Arrhenius theory, up to and including the Brønsted-Lowry theory.

Students should be able to classify a substance as Arrhenius, modified Arrhenius, or Brønsted-Lowry acids or bases.

Students should be able to state the definitions below, identify examples, and discuss the usefulness and limitations of each theory. Limitations should be emphasized as the source of new questions and the reason why another theory emerged; however, certain aspects of each theory remain valuable and continue to be used.

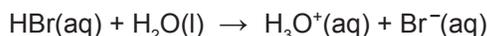
1. Arrhenius theory: An acid is a substance which, when dissolved in water, ionizes to produce hydrogen ions (H^+) and a base dissociates to produce hydroxide ions (OH^-). See examples below:



Limitations: The theory does not address the lack of evidence that a free H^+ ion exists (i.e., instability of a free H^+ ion). It also cannot explain why NH_3 has basic properties, or why CO_2 and SO_2 have acidic properties. Acid-base reactions do not always occur in aqueous solutions.

Usefulness: It is a simple, useful explanation of acids. It is the best theory to explain the dissociation of bases that are of the form metal-hydroxide, $MOH(aq)$; this is defined later in the unit as strong bases.

2. Modified Arrhenius theory: An acid is a substance which reacts with water to produce hydronium ions (H_3O^+) and a base is a substance which reacts with water to produce hydroxide ions (OH^-). See examples below:



Limitations: The theory does not predict whether the hydrogen carbonate ion will act as a base or an acid in aqueous solution. Diagnostic tests have shown that the ion acts as a base in water, as shown in Reaction 1 below. However, it is also possible to write the ion acting as an acid in water, as shown in Reaction 2 below.



Usefulness: It developed the idea of the hydronium ion, H_3O^+ . It recognizes the formation of the more stable hydronium ion over the hydrogen ion.

Continued

Acid-Base Theories

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Demonstrate the limitations of Arrhenius using sodium hydrogen carbonate (baking soda) in water.

Students may

- Brainstorm lists of acids and bases that are used daily or weekly.

Connection

Teachers may

- Demonstrate the amphoteric nature of sodium bicarbonate as it is used to clean up acid and base spills in the lab.

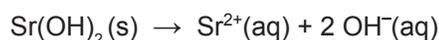
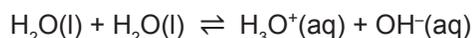
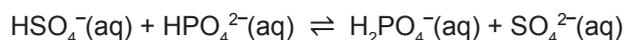
Students may

- Write equations for the dissociation of $\text{Ba}(\text{OH})_2(\text{aq})$.
- Write an ionization equation for ionization of compounds such as $\text{HClO}_3(\text{aq})$.
- Generate a list of conjugate acids and conjugate bases from a list of amphoteric species.
- Construct a timeline outlining acid-base theories.
- Predict and discuss environmental issues that may arise when attempting to neutralize an acid spill.

Consolidation

Students may

- Research how acids and bases are used to address issues such as acid indigestion, spill clean up, and erosion problems due to acid rain.
- Use different concept mapping to organize Arrhenius and Brønsted-Lowry theory definitions.
- Explain why acids and bases should not be placed next to one another in a chemical storage room (relate to the idea that acid-base reactions do not always occur in aqueous solutions).
- Determine which equation below supports the Arrhenius definition of a base.



Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 197-199

Chemistry: Newfoundland and Labrador (SR)

- pp. 500-504

Continued

Acid-Base Theories

Outcomes

Students will be expected to

43.0 explain the roles of evidence, theories, and paradigms in the development of scientific knowledge
[GCO 1]

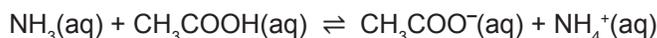
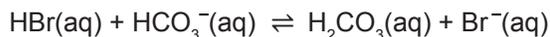
45.0 describe various acid-base definitions up to and including the Brønsted-Lowry definition
[GCO 3]

17.0 describe and apply classification systems and nomenclatures used in the sciences
[GCO 2]

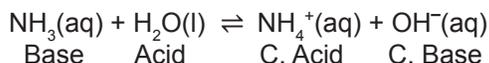
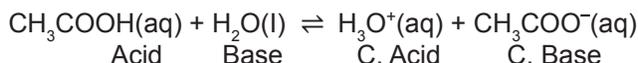
27.0 identify new questions or problems that arise from what was learned
[GCO 2]

Focus for Learning

3. Brønsted-Lowry theory defines an acid as a proton (H^+) donor and a base as a proton (H^+) acceptor. See examples below:



Students should identify the Brønsted-Lowry acid, base, conjugate acid, and conjugate base in a Brønsted-Lowry acid-base equation.



Limitations: The theory doesn't explain how some proton deficient substances still behave as acids (e.g., SO_3).

Usefulness: It can be employed to write acid-base reactions of virtually any acid or base.

Students should state that amphoteric substances are examples of species that can either accept or donate a proton. They should be able to identify amphoteric species and write equations where they act as an acid when combined with a stronger base, and where they act as a base when combined with a stronger acid.

Refer to the Integrated Skills unit for elaboration on SCOs 17.0 and 27.0.

Attitude

Encourage students to consider further studies and careers in science and technology-related fields. [GCO 4]

Sample Performance Indicator

Show that $\text{HS}^-\text{(aq)}$ is amphoteric by writing two separate Brønsted-Lowry neutralization equations. Write a chemical equation of $\text{HS}^-\text{(aq)}$ reacting with

- a strong acid, $\text{H}_3\text{O}^+\text{(aq)}$, and
- a strong base, $\text{OH}^-\text{(aq)}$.

Acid-Base Theories

Sample Teaching and Assessment Strategies

Consolidation continued

Students may

- Classify each substance below as an acid or a base:
 - Ammonia, NH_3
 - Calcium hydroxide, $\text{Ca}(\text{OH})_2$
 - Hydrochloric acid, HCl
 - Potassium hydroxide, KOH
 - Sodium carbonate, Na_2CO_3
 - Sulfuric acid, H_2SO_4
- Identify the conjugate acid-base pairs. Explain the reasoning:

$$\text{HSO}_4^-(\text{aq}) + \text{HPO}_4^{2-}(\text{aq}) \rightleftharpoons \text{H}_2\text{PO}_4^-(\text{aq}) + \text{SO}_4^{2-}(\text{aq})$$
- Explain how HCO_3^- can act as an acid and how it can act as a base.
- Determine which substance is amphoteric?

(a) H_2S (b) HS^- (c) CN^- (d) HCN
- Classify $\text{HCO}_3^-(\text{aq})$ as an acid or a base in each of the following reactions:
 - $\text{HCO}_3^-(\text{aq}) + \text{HNO}_2(\text{aq}) \rightleftharpoons \text{H}_2\text{CO}_3(\text{aq}) + \text{NO}_2^-(\text{aq})$
 - $\text{HCO}_3^-(\text{aq}) + \text{HPO}_4^{2-}(\text{aq}) \rightleftharpoons \text{CO}_3^{2-}(\text{aq}) + \text{H}_2\text{PO}_4^-(\text{aq})$

Extension

Students may

- Research and share advanced theories (e.g., the Lewis model) for very large molecules that act like acids.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 198-199

Chemistry: Newfoundland and Labrador (SR)

- pp. 505-509

Applications of Acid and Base Theories

Outcomes

Students will be expected to

- 47.0 construct arguments to support a decision, or judgment, using examples and evidence and recognizing various perspectives
[GCO 1]
- 48.0 analyze society's influence on scientific and technological endeavours using examples from acid-base chemistry
[GCO 1]
- 49.0 describe science and technology based careers related to acid-base chemistry
[GCO 1]

Focus for Learning

Students should have opportunities to use evidence to justify a decision, while also recognizing various perspectives.

Examples include

- environmental assessments on construction or industrial projects;
- natural sourced versus synthetic products (e.g., coral calcium vs. synthetic calcium supplements); and
- technological advances around the reduction of acid rain (e.g., catalytic converter, pulp and paper).

Students should have opportunities to analyze society's influence on scientific and technological endeavours. They may research natural remedies based on acid-base chemistry.

Examples include

- chewing willow bark (original source of Aspirin™) to relieve tooth pain,
- using a base to neutralize stinging nettle,
- using baking soda (mild base) to neutralize a bee sting (acidic) versus lime juice (mild acid) to neutralize a wasp sting (basic), and
- using lemon juice (acidic) to neutralize fish odours (generally basic).

Students should explore careers in acid-base chemistry.

Examples are listed below:

- Artists (e.g., using natural pigments and dyes which may be pH dependent, using hydrofluoric acid HF(aq) to etch glass)
- Chefs (e.g., acid-base cooking reactions, vinegar and baking soda or baking powder for leavening, lemon juice to help milk sour)
- Health related careers (e.g., nurses regulating blood pH of patients, drug companies producing pharmaceuticals that are acids or bases, developing pharmaceuticals and then clinical trials with in-depth study of acid-base properties)
- Mining industry workers (e.g., analyzing metal ores, acidic or basic run-off resulting from tailings of certain ores)
- Municipal workers (e.g., water treatment)

Applications of Acid and Base Theories

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Present students with a hypothetical scenario of an acid spill and ask for a clean-up solution.
- Discuss connections to old wives tales (e.g., willow bark for pain relief).

Connection

Teachers may

- Discuss how the catalytic converter reduces nitrogen oxides which contribute to acid rain.

Consolidation

Students may

- Research a career that involves acids and bases. Present findings in a multimedia format.
- Debate the benefits of natural versus synthetic source products.
- Create an infographic that outlines pros and cons of increased environmental assessments (using an industry of their choice).

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

Chemistry: Newfoundland and Labrador (SR)

- pp. 510, 563-564, 567

Suggested

Resource Links: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202/resource-links.html>

- Career Profile: Tailings Dam Project Manager
- myBlueprint

Brønsted-Lowry Acid-Base Reactions

Outcomes

Students will be expected to

50.0 compare strong and weak acids and bases using the concept of equilibrium (theoretical)
[GCO 3]

51.0 predict products of acid-base reactions
[GCO 3]

Focus for Learning

Students should recognize the organization of the Table of Relative Strengths of 0.10 mol/L Acids and Bases @ 298.15 K (25°), (acid-base table). They should use this table to determine the relative acid strength of one species compared to another and relative base strength of one species compared to another. For example, which acid is stronger: HCN or HF? Which base is stronger: HS⁻ or NH₃?

Teachers should indicate that amphoteric species can be found in both columns of the acid-base table.

Students should follow the rules for writing Brønsted-Lowry acid-base reactions. They should predict the predominant acid-base net ionic reaction using the acid-base table. They should also predict whether reactants or products are favoured in an acid-base equilibrium, should an equilibrium result. The following process may be used:

- List all species as they exist in an aqueous environment.
 - Strong acids are written as completely dissociated to H₃O⁺ and the acid's conjugate base.
 - Ionic compounds are written as completely dissociated.
 - Chemical formulas of weak acids are written as given (not ionized) since they have low percentage ionization.
 - Since all chemicals will be in aqueous (water-based) solutions and water can be a possible acid or base (see strength chart), water, H₂O, is always included in this list of chemicals which may react.

Teachers should emphasize that the ions of ionic compounds may act as acids and/or bases in solution. Otherwise, students may simply complete a double replacement reaction between ionic compounds. This would not be appropriate.

- Identify possible acids and bases according to the Brønsted-Lowry definition.
 - Possible acids have an "H" in the formula to donate; bases, in general, have a "–" charge (to be able to accept H⁺ from an acid).
 - Water, H₂O, is an amphoteric substance (even though it is neutral).
- Using the acid-base table, identify the strongest acid (SA) and strongest base (SB).
- React the strongest acid with the strongest base according to the Brønsted-Lowry theory.
 - All other species, while in solution, are spectators.
 - A single arrow should be used only when the reaction involves a strong acid (H₃O⁺) or strong base (OH⁻) and is quantitative.

Continued

Brønsted-Lowry Acid-Base Reactions

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Review Arrhenius dissociations/ionizations to determine species that are present.

Students may

- Write total ionic and net ionic equations specific to acid-base reactions.

Connection

Students may

- List four different bases on the acid-base table that will react with HSO_3^- .
- Discuss the following: Three unlabelled bottles contain the same concentration of unidentified, clear, and colourless solutions. It is known that the solutions are HCl(aq) , HCN(aq) , and NaOH(aq) ; however, it is unknown which bottle contains each solution. Outline a series of tests that could be performed to properly identify each solution.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 202-204, 208-209

Chemistry: Newfoundland and Labrador (SR)

- pp. 524-526, 565

Suggested

Table of Relative Strengths of 0.10 mol/L Acids and Bases @ 298.15 K (25°) (Acid-Base Table)

Brønsted-Lowry Acid-Base Reactions

Sample Teaching and Assessment Strategies

Consolidation

Students may

- Use the acid-base table to identify the stronger acid or stronger base in each pair.
 - HClO, HF
 - hydrogen borate, hydrogen carbonate
 - hydrogen sulfate, ethanoic acid
 - SO_3^{2-} , CO_3^{2-}
- Predict the products for the following Bronsted-Lowry acid-base reactions:
 - HCl and NaOH
 - HI and NH_3
 - HF and $\text{Ca}(\text{OH})_2$
 - H_2CO_3 and K_2HBO_3

Extension

Students may

- Predict the products of an acid-base reaction between HBO_3^{2-} and SO_3^{2-} (in this example, HBO_3^{2-} would act as both the acid and the base since it is a stronger base than SO_3^{2-}).
- Research the use of buffers in various commercial science industries (e.g., soft drinks, buffered Aspirin™, processed foods, yogurt, industrial chemical processes such as latex paint).

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 202-204, 208-209

Chemistry: Newfoundland and Labrador (SR)

- pp. 516, 519-520, 524-526, 565

Suggested

Resource Links: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202/resource-links.html>

- pH Scale (basic)
- pH Scale (numeric/particle)
- pH Scale (simulation)

*pH Solutions Lab***Outcomes**

Students will be expected to

52.0 calculate the pH of an acid or a base given its concentration, and vice versa
[GCO 3]

15.0 *select and use apparatus and materials safely*
[GCO 2]

16.0 demonstrate a knowledge of WHMIS standards by selecting and applying proper techniques for handling and disposing of lab materials
[GCO 2]

31.0 work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise
[GCO 2]

32.0 evaluate individual and group processes used in planning, problem solving and decision making, and completing a task
[GCO 2]

Focus for Learning

Students should complete a self-directed lab investigation to explore the difference in pH between two solutions and their comparative concentrations of hydronium or hydroxide.

Students should be given successively dilute solutions of strong acids and strong bases by a factor of 10 and observe pH using either a pH meter or pH paper.

Based on the results of this investigation, students should conclude that a difference in 2 in pH is equivalent to a factor of 100 (10×10 or 10^2) in hydronium ion concentration. That is, a difference in 1 in pH is a factor of 10 in $[\text{H}_3\text{O}^+(\text{aq})]$.

During this investigation, students will be working with dilute solutions of strong acids and bases. Teachers should mark the containers of the $\text{HCl}(\text{aq})$ and $\text{NaOH}(\text{aq})$ with appropriate WHMIS symbols. Accordingly, students should have a working knowledge of the potential hazards of working with such solutions, and be able to handle and dispose of the materials appropriately.

Refer to the Integrated Skills unit for further elaboration on SCOs 15.0, 16.0, 31.0, and 32.0. This investigation also provides an opportunity to address additional inquiry-related skill outcomes from the Integrated Skills unit (e.g., 9.0, 10.0, 28.0, 29.0).

Attitude

Encourage students to

- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas, and
- show concern for safety and accept the need for rules and regulations. [GCO 4]



*pH Solutions Lab***Sample Teaching and Assessment Strategies****Activation**

Teachers may

- Discuss the pH of different common household acids and their relative hazard level. That is, battery (sulfuric) acid has a pH of 1, while orange juice (citric acid) has a pH of 3.5.
- Pose the following question:
 - How will the dilution of a strong acid or base affect the values of $[\text{OH}^-]$ and $[\text{H}_3\text{O}^+]$?

Connection

Teachers may

- Discuss the Richter scale as a logarithmic scale used in science.

Consolidation

Students may

- Compare the reactivity of acids with different pH values (before and after dilution) by adding in a sample of reactive metal (i.e., Mg) and observing the relative reaction rates.
- Compare the conductivity of acids with different pH values (before and after dilution) using a conductivity meter.

Resources and Notes**Authorized**

Chemistry: Newfoundland and Labrador (TR)

- pp. 202-204

Chemistry: Newfoundland and Labrador (SR)

- p. 532

Teaching and Learning Strategies: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202.html>

- Predicting Products of Brønsted-Lowry Acid-Base Reactions

Acid-Base Calculations

Outcomes

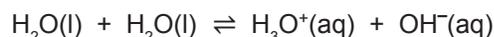
Students will be expected to

52.0 calculate the pH of an acid or a base given its concentration, and vice versa
[GCO 3]

Focus for Learning

Students should be able to state that water auto-ionizes to produce H_3O^+ and OH^- . This can be observed by using a very sensitive conductivity meter to measure the conductivity of deionized water. They should identify that pure water, a molecular compound, conducts electricity to a very small degree; this is because approximately two out of every billion water molecules will be present in the ionic form.

Students should be able to write the equilibrium constant for water, K_w , noting the value, and its effect on the equilibrium position (K_w is an equilibrium constant and is temperature dependent).



$$K_w = [\text{H}_3\text{O}^+][\text{OH}^-]$$

Students should explain that since the chemical equation above shows hydronium and hydroxide ions being formed in a one-to-one ratio, the molar concentrations of these species are equal. Measurements put the concentration of hydronium ions in pure water at 1.0×10^{-7} at 25°C . By substitution, the value of the equilibrium constant for water can be calculated:

$$K_w = [\text{H}_3\text{O}^+][\text{OH}^-] = (1.0 \times 10^{-7})(1.0 \times 10^{-7}) = 1.0 \times 10^{-14}$$

Since K values are temperature dependent, it is important that students understand that this value applies only to water at 25.0°C . In practice, this value for K_w is often used without specifying the temperature, as long as it is reasonably close to 25.0°C .

pH and pOH are defined as

$$\text{pH} = -\log[\text{H}_3\text{O}^+] \text{ and } \text{pOH} = -\log[\text{OH}^-]$$

Students should also be able to use the relationship, $\text{pH} + \text{pOH} = 14$. This relationship can be derived from the K_w expressions as shown below. Students are not required to reproduce this derivation. Students may find it helpful if teachers demonstrate the mathematical progression below, yet students are not expected to be able to state it.

$$K_w = [\text{H}_3\text{O}^+][\text{OH}^-]$$

$$1.0 \times 10^{-14} = [\text{H}_3\text{O}^+][\text{OH}^-]$$

$$-\log(1.0 \times 10^{-14}) = -\log([\text{H}_3\text{O}^+][\text{OH}^-])$$

$$14 = (-\log[\text{H}_3\text{O}^+]) + (-\log[\text{OH}^-])$$

From the above, a teacher may illustrate the reasoning behind why the pH scale ranges from 0 to 14 (for Chemistry 3202), and the origin of the pH and pOH logarithm formulas. Note: For high concentrations, the pH scale can be below 0 or above 14.

Students should perform calculations that involve rearranging K_w for either $[\text{H}_3\text{O}^+]$ or $[\text{OH}^-]$. They should be able to compare the pH (or pOH) of two different solutions, and relate a difference of 1 in pH (or pOH) as a factor of 10 in $[\text{H}_3\text{O}^+(\text{aq})]$ or $[\text{OH}^-(\text{aq})]$.

Teachers should review the scientific conventions for significant figures in logarithms.

Continued

Acid-Base Calculations

Sample Teaching and Assessment Strategies

Activation

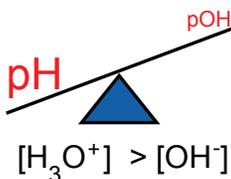
Teachers may

- Pose the following questions:
 - Does pure water conduct electricity?
 - How will the dilution of a strong acid or base affect the values of pH, pOH, $[\text{OH}^-]$ and $[\text{H}_3\text{O}^+]$?
 - Water is what type of substance?

Connection

Teachers may

- Use the visual below to discuss its accompanying statements:
 1. Relationships exist between pH, pOH, $[\text{H}_3\text{O}^+]$ and $[\text{OH}^-]$.
 2. A neutral solution has $[\text{H}_3\text{O}^+] = [\text{OH}^-]$.
 3. Every aqueous solution has both H_3O^+ and OH^- present, as required by the auto-ionization of water and K_w .
 4. pH (or pOH) changes of 1 actually represent concentration changes of a factor of 10.



Students may

- Show the connection between $[\text{H}_3\text{O}^+]$, $[\text{OH}^-]$, pOH, and pH of a solution by completing the following tables.

$[\text{H}_3\text{O}^+]$ (mol/L)	pH
1.0	
0.10	
0.010	
0.0010	

$[\text{OH}^-]$ (mol/L)	pOH	pH
1.0		14.00
0.10	1.00	
	2.00	
		11.00

Resources and Notes

Authorized

Appendices

- Appendix A: Scientific Conventions

Chemistry: Newfoundland and Labrador (TR)

- pp. 202-204

Chemistry: Newfoundland and Labrador (SR)

- pp. 526-531

Acid-Base Calculations

Outcomes

Students will be expected to

52.0 calculate the pH of an acid or a base given its concentration, and vice versa
[GCO 3]

Focus for Learning

Students should be able to explain the following:

- A pH decrease of x means the $[\text{H}_3\text{O}^+]$ increases by 10^x .
- A pH increase of x means the $[\text{H}_3\text{O}^+]$ decreases by 10^x .
- As a solution becomes less basic, its pH decreases.
- As a solution becomes more basic, its pH increases.
- When concentrations of two or more acids (or bases) are equal, their pH will tell you which is stronger.

Teachers should reinforce

- the relationships between pH, pOH, $[\text{H}_3\text{O}^+]$, and $[\text{OH}^-]$;
- that a neutral solution has $[\text{H}_3\text{O}^+] = [\text{OH}^-]$;
- that every aqueous solution has both H_3O^+ and OH^- present, as required by the auto-ionization of water and K_w ; and
- that pH (or pOH) changes of 1 actually represent concentration changes of 10.

Students should be able to calculate any of $[\text{H}_3\text{O}^+]$, $[\text{OH}^-]$, pH, and pOH, given

- at least one of the four quantities listed,
- the concentration of a strong monoprotic acid or strong base, or
- the mass of a strong monoprotic acid or strong base in a given volume of solution.

Teachers should note that calculations involving dilution are not an expectation.

Sample Performance Indicator

Solution A has a $\text{H}_3\text{O}^+(\text{aq})$ concentration of 0.010 mol/L. Solution B has a $\text{H}_3\text{O}^+(\text{aq})$ concentration of 0.00010 mol/L. Follow the steps below:

1. Calculate the $\text{OH}^-(\text{aq})$ ion concentration in each solution.
2. Calculate the pH and pOH of each solution.
3. Determine which solution is the most acidic: solution A or solution B.
4. Determine the difference in pH between solution A and solution B.
5. Determine which solution (A or B) has a greater concentration of $\text{H}_3\text{O}^+(\text{aq})$. How many times greater is the $\text{H}_3\text{O}^+(\text{aq})$ concentration in that solution compared to the other?
6. Determine the pOH, $[\text{H}_3\text{O}^+]$ $[\text{OH}^-]$ of a $\text{CH}_3\text{COOH}(\text{aq})$ solution with a pH of 5.20.

Acid-Base Calculations

Sample Teaching and Assessment Strategies

Consolidation

Students may

- Calculate the pH of the solution formed when 5.25 g of $\text{Ba}(\text{OH})_2$ is dissolved in 100.0 mL of water.
- Answer the following questions:
 - A blood sample has a pH of 7.34. What is the hydronium ion concentration? How can hydronium ions exist in this basic solution?
 - A woman drops an open bottle of strong cleaner into a small frog pond in her backyard. The pH of the pond rises from 6.8 to 8.8 during that afternoon. What is the magnitude of the pH change? Is this a cause for concern? Why or why not? Suggest a method to restore the original pH level.
 - Due to a heavy rainfall, the pH of the water in a bog hole changed from 3.8 to 5.8. What is true of the bog hole water after the rainfall? Is $[\text{H}_3\text{O}^+]$ two times greater, two times lower, 100 times greater, or 100 times lower? Explain.
- Complete a lab investigation to measure pH of a variety of strong acid solutions and calculate $[\text{H}_3\text{O}^+]$, $[\text{OH}^-]$, and pOH from the data.
- Calculate the pH of a window cleaning solution that has a hydroxide ion concentration of 7.9×10^{-4} mol/L.
- Complete the table

$[\text{H}_3\text{O}^+]$	pH	$[\text{OH}^-]$	pOH
	3.00		
0.125			
		0.550	
			5.00

Extension

Students may

- Research the value of K_w at 0 °C and 50 °C. Determine what happens to the value of pH at those temperatures.
- Explain how the pH of a neutral solution is temperature dependent.

$$2 \text{H}_2\text{O}(\text{l}) + \text{heat} \rightleftharpoons \text{H}_3\text{O}^+(\text{aq}) + \text{OH}^-(\text{aq})$$
- Use calculations to show that the pH scale is not limited to the traditional 0 to 14 range.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 202-204

Chemistry: Newfoundland and Labrador (SR)

- pp. 526-531

Acid-Base Equilibrium Calculations

Outcomes

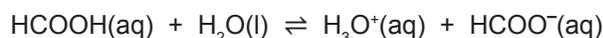
Students will be expected to

53.0 compare strong and weak acids and bases using the concept of equilibrium (mathematical)
[GCO 3]

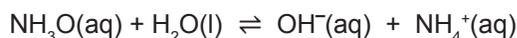
Focus for Learning

Teachers should emphasize that pH calculations to this point have involved only strong acids or bases. Students should make the connection that, for weak acids and bases, which do not ionize 100%, an equilibrium is established in water. Teachers should then define K_a and K_b qualitatively and write the equilibrium constant expression from the equation of reaction with water.

Teachers should emphasize that the first step in calculating the pH and/or the pOH of weak acids and/or weak bases involves writing equilibrium equations to show the ionization. These equations lead to the formula for the equilibrium constant:



$$K_a = \frac{[\text{H}_3\text{O}^+][\text{HCOO}^-]}{[\text{HCOOH}]}$$



$$K_b = \frac{[\text{OH}^-][\text{NH}_4^+]}{[\text{NH}_3]}$$

Teachers should reinforce that percent ionization values are concentration dependent. Students should note that percent ionization values on the acid-base table are for 0.10 mol/L solutions @ 298.15 K or 25 °C only. This is why K_a (or K_b) are used in acid-base equilibria.

A common misconception is that strength and concentration are terms which may be used interchangeably. Teachers should differentiate between strength and concentration operationally (e.g., pH, electrical conductivity). Students should state that concentration refers to the amount of solute present per volume and strength refers to the amount of ionization or dissociation into H_3O^+ or OH^- .

Students should compare the relative strength of an acid or a base in terms of percent ionization.

Students should also note that K_a values are listed on the strength table and should make the connection with K_a and acid strength. The same relationship exists between K_b and base strength.

Students should complete calculations to determine the following:

- The value of one of K_a (or K_b), given all equilibrium concentrations
- An equilibrium concentration, given K_a (or K_b) and all other equilibrium concentrations
- The value of K_a (or K_b), given initial concentration of a weak acid or weak base and pH (or pOH)
- pH (or pOH), given the initial concentration of a weak acid or a weak base and K_a (or K_b); include examples involving the use of the quadratic formula; students will be given K_b when asked to find the pH of a weak base

Continued

Acid-Base Equilibrium Calculations

Sample Teaching and Assessment Strategies

Activation

Students may

- Test the pH of a variety of acids (strong and weak) of equal concentration and compare their pH values.
- Discuss the strength of acids used in everyday life:
 - Why can we drink carbonated beverages that contain carbonic acids and not drink battery acid that contains sulfuric acid?
- Classify the following in terms of concentration and strength.

Sample	Strength (strong/weak)	Concentration (concentrated/dilute)
0.10 mol/L HCl		
0.10 mol/L HF		
0.10 mol/L NH ₃		
6.0 mol/L NaOH		

Connection

Students may

- Calculate the pH of 0.10 mol/L solutions of HCl(aq) and CH₃COOH(aq) and then measure using a pH probe. Explain the discrepancy.
- Add similar sized pieces of magnesium metal to equal volumes of 0.10 mol/L solutions of HCl(aq) and CH₃COOH(aq) to compare the rate of reaction/production of H₂(g). Explain why there is a difference in rate.
- Complete the following:
 - Use K_a to calculate the pH and percent ionization of 0.10 mol/L acetic acid.
 - Use K_a to calculate the pH and percent ionization of 0.20 mol/L acetic acid.
 - Knowing that K_a is independent of concentration, explain why using percent ionization to calculate pH might be problematic.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 202-206

Chemistry: Newfoundland and Labrador (SR)

- pp. 522-524, 534-550

Acid-Base Equilibrium Calculations

Outcomes

Students will be expected to

53.0 compare strong and weak acids and bases using the concept of equilibrium (mathematical)
[GCO 3]

Focus for Learning

Students are not expected to calculate pH of an amphoteric substance.

The suggested method of organizing known and unknown data involving initial concentrations is to use table format, often referred to as an initial concentration, change in concentration, equilibrium concentration (ICE) table. All concentrations in the table are in units of mol/L which can be represented by [].

Students should solve problems such as the following: Calculate the K_a for a 0.10 mol/L formic acid solution, given its pH = 2.09.

Teachers should note that when calculating pH (or pOH), given K_a (or K_b), the magnitude of K_a (or K_b) has a major impact on how these problems are solved. If K_a (or K_b) is small in relation to the initial concentration of acid (or base), a simplifying assumption may be made. For the purpose of Chemistry 3202, the simplifying assumption requires that K_a (or K_b) must be at least five hundred times smaller than the initial acid (or base) concentration (which is equivalent to less than 5% of the acid or base reacting with water).

$$\frac{[\text{HA}]_{\text{initial}}}{K_{\text{acid}}} < 500$$

Quadratic formula must be used

$$\frac{[\text{HA}]_{\text{initial}}}{K_{\text{acid}}} > 500$$

Simplifying assumption must be stated (i.e., amount dissociated (x) is negligible compared to the initial concentration of the acid or for example: $0.025 - x = 0.025$)

Teachers should provide the Quadratic Formula (see column 4 reference).

Students are not expected to calculate K_b from a given K_a .

Sample Performance Indicators

- Calculate the pH of a 0.35 mol/L solution of methylamine $\text{CH}_3\text{NH}_2(\text{aq})$ which has a K_b of 4.38×10^{-4} .
 $\text{CH}_3\text{NH}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{CH}_3\text{NH}_3^+(\text{aq}) + \text{OH}^-(\text{aq})$.
- Calculate the pH of a 0.15 mol/L solution of nitrous acid solution, given the K_a is 7.2×10^{-4} .

Acid-Base Equilibrium Calculations

Sample Teaching and Assessment Strategies

Consolidation

Students may

- Calculate the pH of an aspirin solution, given K_a for Aspirin™ ($\text{HC}_9\text{H}_7\text{O}_4$) is 3.3×10^{-4} . The initial concentration is 0.022 mol/L,
- Measure and compare the pH of 0.10 mol/L solutions of $\text{HCl}(\text{aq})$ and $\text{CH}_3\text{COOH}(\text{aq})$. Justify why they are different.
- Answer the following questions:
 - Calculate the pH of a 0.50 mol/L ethanoic acid solution, given the $K_a = 1.8 \times 10^{-5}$.
 - An unknown acid solution has an initial concentration of 0.285 mol/L and a pH of 3.265. Is the acid strong or weak?
 - A 0.100 mol/L solution of an unknown acid has a pH of 3.678. Determine the identity of this acid.
- Consider the solutions below and answer the questions which follow.

Solution A	Solution B
0.10 mol/L	0.10 mol/L
pH = 1.00	pH = 2.00

- Which solution is a strong acid? Justify your choice.
- Which solution should have greater electrical conductivity? Explain.
- Which solution has the slower reaction rate with zinc metal, $\text{Zn}(\text{s})$? Explain.

Extension

Students may

- Explore the relationship between K_a of a weak acid and K_b of its conjugate base ($K_a \times K_b = K_w$).

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 204-205

Chemistry: Newfoundland and Labrador (SR)

- pp. 534-545
 - p. 537 (ICE Table example)
 - p. 542-543 (Quadratic formula)

Acid-Base Indicators

Outcomes

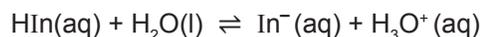
Students will be expected to

54.0 explain how acid-base indicators function
[GCO 3]

55.0 describe the interactions between H⁺ ions and OH⁻ ions using Le Châtelier's principle
[GCO 3]

Focus for Learning

Students should be able to define an acid-base indicator. They should also be able to predict and interpret results using indicators. Students should understand that a given indicator has a weak acid (HIn) and has a conjugate base form (In⁻). The observed colour of the indicator is dependent upon which form is predominant in solution. The general equilibrium below may then be applied to any indicator.



Colour A

Colour B

Students should solve problems in which a selection of indicators is used to differentiate between solutions of differing pH values.

Students should use Le Châtelier's principle to predict which form of an indicator is favoured under specified conditions, such as the addition of the indicator to an acid or a base.

Sample Performance Indicators

- Alizarin yellow R indicator is added to a solution whose pH is not known. The colour observed is yellow. When another sample of the solution is tested with chlorophenol red, it becomes red, and when tested with thymolphthalein indicator, a sample turns blue. What is the approximate pH range of the solution? Explain.
- Alizarin yellow R indicator (abbreviated HAY) has an approximate pH range of 10.1 to 12.0. The weak acid form is yellow and the conjugate base form is red.
 - Write the equation for the reaction of alizarin yellow R indicator with water.
 - Which form of the alizarin yellow R indicator has a higher concentration in a 1.00×10^{-5} mol/L NaOH solution? Explain.
 - Two drops of alizarin yellow R have been added to a 0.100 mol/L NaOH solution. Name a compound that can be added to the mixture to cause the colour of the indicator to change from red to yellow. Justify your choice with reference to Le Châtelier's principle.

Acid-Base Indicators

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Demonstrate a variety of indicators.
- Introduce a variety of natural indicators such as those found in red cabbage and other natural dyes.

Students may

- Use indicators to determine the pH of various acids and bases.

Connection

Students may

- Determine the colour of thymol blue indicator in a solution that has $[\text{H}_3\text{O}^+] = 5.6 \times 10^{-5} \text{ mol/L}$.
- Recall and discuss the need to test the pH of pools, hot tubs, and fish tanks, as well as the need to add appropriate chemicals to maintain appropriate pH.
- Estimate the pH of each solution when samples of solutions with three different pHs are tested using a variety of indicators.
- Identify a pH = 2.0 solution versus a pH = 4.0 solution, given appropriate indicators.
- Determine the pH range of a solution, given the behaviour of two appropriate indicators.
- Identify the colour of an indicator, given the pH of a solution.
- Answer the following question: One form of the chemical indicator, HIn^- , is yellow. If acid is added and the indicator turns red, which is correct?

	Red	Yellow
A	In^{2-}	H_2In
B	In^{2-}	HIn^-
C	HIn^-	H_2In
D	H_2In	HIn^-

Consolidation

Students may

- Develop a plan, using appropriate indicators and instruments, to determine the pH of a variety of unknown solutions. If approved by the teacher, the test may be run.

Extension

Students may

- Research and share results related to how the pH of pool water is determined, and how the colour of hydrangeas can be changed.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 206-207

Chemistry: Newfoundland and Labrador (SR)

- pp. 551-562

Titration

Outcomes

Students will be expected to

- 56.0 determine the concentration of an acid or base solution using stoichiometry [GCO 3]
- 57.0 explain the importance of communicating the results of a scientific or technological endeavour, using appropriate language and conventions [GCO 1]
- 58.0 analyze and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology [GCO 1]
- 8.0 evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making [GCO 2]
- 11.0 use instruments effectively and accurately for collecting data [GCO 2]

Focus for Learning

Teachers should emphasize the proper use of chemical equations to solve titration problems. The acid-base neutralization reaction of a titration is written in the same format as a double replacement reaction (Chemistry 2202). Students should write a balanced chemical equation for the given acid-base titration. Titration processes will always involve quantitative reactions. Stoichiometric titration calculations should not be limited to 1:1 mole ratios. At least one reactant must be a strong acid or a strong base.

Teachers should model the complete titration process and demonstrate the proper use of equipment.

Students should be able to identify apparatus and define the following terminology that is involved with titrations: pipette, burette, titrant, endpoint, equivalence point, and indicator. They should also be able to make a clear distinction between the equivalence point and the indicator endpoint.

Students should complete a lab investigation of a titration experiment and related calculations to determine the concentration of an acid or base solution. They are not required to standardize the titrant; a standardized titrant should be provided to students.



Teachers should discuss the omission of outliers (not necessarily the first trial) in titrations. Skills should include

- selecting an appropriate acid-base indicator to perform a titration;
- manipulating burettes and other instruments used for titrations;
- reading a burette volume, in millilitres, to two decimal places;
- performing a correct estimation of the second decimal place;
- averaging data from two or more titration trials which have acceptable endpoint colours and are within ± 0.1 mL of titrant delivered;
- presenting a detailed experimental report according to specific standards; and
- working cooperatively while performing titrations.

Refer to the Integrated Skills unit for further elaboration on SCOs 8.0 and 11.0. This investigation also provides an opportunity to address additional inquiry-related skill outcomes from the Integrated Skills unit (e.g., 3.0, 9.0, 10.0, 22.0).

Attitude

Encourage students to use factual information and rational explanations when analyzing and evaluating. [GCO 4]

Titration

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Review, from Chemistry 2202, the balancing of chemical equations and stoichiometry.

Students may

- Discuss how they would safely dispose of acids and bases.
- Share their knowledge on the process of titration.

Connection

Teachers may

- Ask why a burette, not a graduated cylinder, is used in a titration.

Students may

- Examine diagrams of apparatus used in titrations and describe the correct use of each (e.g., burette and Erlenmeyer flask).
- Use 2.00 g of solid potassium hydrogen phthalate to titrate with a NaOH(aq) solution. Calculate the molarity of the NaOH(aq) solution.
- Use Vernier Drop Counters™ to perform a drop-by-drop titration.
- View an apparatus that might be used in a future acid-base titration experiment. Discuss its safe and proper use.
- Construct a foldable to outline titration equipment and purpose.

Consolidation

Students may

- Use NaOH(aq) solution with a pH of 10.50. Calculate the volume of 0.010 mol/L HCl(aq) that would be required to titrate this solution to the equivalence point. Before beginning, determine additional information required to solve this problem.
- Use the data in the table to calculate the molar concentration of the HCOOH(aq) solution. Note: Four 10.0 mL samples of a HCOOH(aq) solution were titrated with 0.25 mol/L NaOH(aq).

Trial (in mL)	1	2	3	4
Final Burette Reading	9.75	17.60	25.40	33.25
Initial Burette Reading	0.05	9.75	17.60	25.40
Titrant Volume Used				

Extension

Students may

- Investigate the use of titration in a breath analyzing machine, and/or how other types of titrations are used in analytical chemistry (e.g., determine the concentration of chloride ions in tap water).

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 206-207

Chemistry: Newfoundland and Labrador (SR)

- pp. 551-562

Suggested

Resource Links: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202/resource-links.html>

- Setting up and Performing a Titration (video)
- Titration (simulation)
- Titration Curves (calculations)

Titration

Outcomes

Students will be expected to

56.0 determine the concentration of an acid or base solution using stoichiometry [GCO 3]

18.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots [GCO 2]

20.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables [GCO 2]

29.0 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results [GCO 2]

Focus for Learning

Students should complete a lab investigation where they use a standard solution to determine the concentration of an unknown, construct a pH curve, and determine the K_a of a weak acid.



Students should be able to interpret what a titration curve means in terms of neutralization. They should be able to sketch a titration curve (pH curve) and identify

- the equivalence point;
- the pH at the equivalence point;
- the type of titrant (strong acid or weak acid, strong base or weak base); and
- the type of unknown (strong acid or weak acid, strong base or weak base).

Titration curves that should be included are

- strong acid with strong base,
- strong acid with weak base, and
- strong base with weak acid.

Titration curves should be limited to one equivalence point (i.e., monoprotic or monobasic sample solutions being titrated).

Students should qualitatively determine the appropriate choice of indicator to fit the pH value at the stoichiometric equivalence point for an acid-base titration.

Students should choose appropriate acid-base indicators using an acid-base indicator table, given the pH at the equivalence point or the titration curve for the neutralization.

Refer to the Integrated Skills unit for further elaboration on SCOs 18.0, 20.0, and 29.0. This investigation also provides an opportunity to address additional inquiry-related skill outcomes from the Integrated Skills unit (e.g., 12.0, 13.0, 16.0, 24.0, 27.0).

Sample Performance Indicator

A sample of hypochlorous acid, HOCl(aq) , is titrated with excess lithium hydroxide solution, LiOH(aq) . Complete the following steps:

1. Label the axes and sketch a curve indicating the pH changes that occur as LiOH is added.
2. Label the equivalence point on the graph. Predict the approximate pH at the equivalence point and suggest a suitable indicator for this titration.
3. Define equivalence point.

Titrations

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Discuss graphing as a means of communication. Review components of different types of graphs. Remind students that not all graph data is linear.
- Guide students to generate a titration curve, given a set of data.

Connection

Students may

- Discuss what is key when choosing an indicator for an accurate titration. For a given acid-base titration, what colour change will be observed for a selected indicator?
- Participate in a lab investigation to calculate K_a (or K_b), given the initial concentration and pH.
- Complete a titration in which the reported concentration on a household product is verified (e.g., pickling vinegar with sodium hydroxide or Aspirin™ with potassium hydroxide).
- Discuss equivalence point and endpoint. Why it is important that both occur at approximately the same pH in a titration?

Consolidation

Students may

- Complete a lab investigation to construct a pH curve and determine the K_a of a weak acid.
- Use Vernier™ interfaces (e.g., Logger Pro™ software) to produce a titration curve. Analyze the curve and compare the use of technology to plotting the data by hand.
- Sketch and label titration curves for each titration and suggest an indicator suitable to detect the equivalence point.
 - 0.10 mol/L HF(aq) titrated with 0.10 mol/L NaOH(aq)
 - 0.10 mol/L NaCN(aq) titrated with 0.10 mol/L HCl(aq)
- Explain indicators they might use when a solution of HCl(aq), a strong acid, is added to a solution of NaF(aq), a weak base.

Extension

Students may

- Conduct an experiment focusing on an acid-base equilibrium and indicators using Le Châtelier's principle. Report findings.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 206-207, 209-211

Chemistry: Newfoundland and Labrador (SR)

- pp. 551-562, 566

Section Three:
Specific Curriculum Outcomes

Unit 3: Thermochemistry

Focus

Thermochemistry includes energy changes that occur with physical and chemical processes. Students will study concepts and issues related to the generation of energy. They will be encouraged to develop interest in global energy issues and to consider solutions to associated problems. Students will compare different ways of producing energy as they study open, closed, and integrated systems, the difference between heat and temperature, enthalpy changes, and calorimetry. They will predict the amount of heat generated in a variety of combustion reactions using bond energies, heats of formation, and Hess's law.

Planning, recording, analyzing, and evaluating skill building activities are integrated throughout this unit. Lab investigations to determine specific heat capacity and to use heating and cooling curves are valuable to student learning. STSE connections include the development of technologies based on thermochemical concepts.

Science 1206 included balancing chemical equations. Heat and temperature were discussed in the weather dynamics unit. Chemistry 2202 outcomes useful for this unit include measuring amounts of moles as well as the energy transformations associated with bond breaking and forming.

Outcomes Framework

GCO 1 (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.

- 66.0 analyze and describe examples where technologies were developed based on scientific understanding
- 67.0 analyze from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology
- 68.0 propose courses of action on social issues related to science and technology, taking into account an array of perspectives, including that of sustainability
- 71.0 distinguish between questions that can be answered by science and those that cannot, and between problems that can be solved by technology and those that cannot
- 72.0 analyze the knowledge and skills acquired in their study of science to identify areas of further study related to science and technology
- 75.0 analyze why scientific and technological activities take place in a variety of individual and group settings
- 76.0 describe the importance of peer review in the development of scientific knowledge

GCO 2 (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.

- 3.0 design an experiment identifying and controlling major variables
- 4.0 propose alternate solutions to a given practical problem, identify the potential strengths and weaknesses of each, and select one as the basis for a plan
- 8.0 evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making
- 13.0 use library and electronic research tools to collect information on a given topic
- 14.0 select and integrate information from various print and electronic sources from several parts of the same source
- 15.0 select and use apparatus and materials safely
- 18.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots
- 21.0 apply and assess alternative theoretical models for interpreting knowledge in a given field
- 30.0 identify multiple perspectives that influence a science-related decision or issue
- 31.0 work cooperatively with team members to develop and carry out a plan and troubleshoot problems as they arise

GCO 3 (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.

- 59.0 explain temperature and heat using the concept of kinetic energy and the particle model of matter
- 60.0 distinguish between a system and surroundings and the relationship of each to the universe
- 61.0 define specific heat
- 62.0 calculate and compare the energy involved in changes of temperature
- 63.0 define endothermic reaction, exothermic reaction, enthalpy, bond energy, heat of reaction, and molar enthalpy
- 64.0 illustrate changes in energy of various chemical reactions, using potential energy diagrams
- 65.0 calculate and compare the energy involved in changes of state and temperature
- 69.0 calculate and compare the energy involved in chemical reactions
- 70.0 determine experimentally the changes in energy of various chemical reactions
- 73.0 compare the molar enthalpies of several combustion reactions involving organic compounds
- 74.0 write and balance thermochemical equations including the combustion reactions of alkanes
- 77.0 calculate the changes in energy of various chemical reactions using bond energy, heats of formation, and Hess's law

GCO 4 (Attitude): 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.

Students are encouraged to

- acquire, with interest and confidence, additional science knowledge and skills, using a variety of resources and methods, including formal research
- value the processes for drawing conclusions
- appreciate that the applications of science and technology can raise ethical dilemmas
- value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not
- be aware of the direct and indirect consequences of their actions

SCO Continuum

GCO 3: Knowledge		
Science 1206	Chemistry 2202	Chemistry 3202
<ul style="list-style-type: none"> name and write formulas for some common ionic and molecular compounds, using the periodic table and a list of ions represent chemical reactions and the conservation of mass using molecular models and balanced symbolic equations classify chemical reactions based on type 	<ul style="list-style-type: none"> write and name the formulas of ionic and molecular compounds, following simple IUPAC rules define molar mass and perform mole-mass interconversions for pure substances identify mole ratios of reactants and products from balanced chemical equations perform stoichiometric calculations related to chemical equations describe how intermolecular forces account for the properties of molecular compounds relate the properties of a substance to its structural model describe the process of dissolving, using concepts of intramolecular and intermolecular forces classify ionic, molecular, and metallic substances according to their properties explain the large number and diversity of organic compounds with reference to the unique nature of the carbon atom classify various organic compounds by determining to which families they belong, based on their names or structures write the formula and provide the IUPAC name for a variety of aliphatic compounds write and balance chemical equations to predict the reactions of selected organic compounds 	<ul style="list-style-type: none"> explain temperature and heat using the concept of kinetic energy and the particle model of matter distinguish between a system and surroundings and the relationship of each to the universe define specific heat calculate and compare the energy involved in changes of temperature define endothermic reaction, exothermic reaction, enthalpy, bond energy, heat of reaction, and molar enthalpy illustrate changes in energy of various chemical reactions, using potential energy diagrams calculate and compare the energy involved in changes of state and temperature calculate and compare the energy involved in chemical reactions determine experimentally the changes in energy of various chemical reactions compare the molar enthalpies of several combustion reactions involving organic compounds write and balance thermochemical equations including the combustion reactions of alkanes calculate the changes in energy of various chemical reactions using bond energy, heats of formation, and Hess's law

Heat Versus Temperature

Outcomes

Students will be expected to

59.0 explain temperature and heat using the concept of kinetic energy and the particle model of matter [GCO 3]

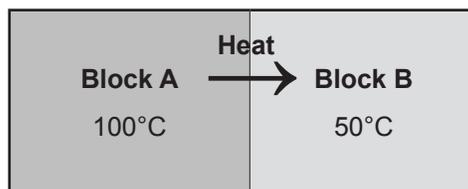
Focus for Learning

Teachers should review concepts of temperature, heat, and kinetic energy covered in Unit 1. Students were introduced to this topic in Science 7 and revisited the topic again in Science 1206; however, a review of this topic is recommended.

Students should define temperature as a measure of the average kinetic energy of the particles in a substance.

They should be able to identify and describe the relationship between a change in temperature and the motion of particles. An increase in temperature is directly proportional to an increase in particle motion, and vice versa.

Students should describe heat as a transfer of thermal energy. One example of heat flow involves temperature change. Heat flows from matter with higher average kinetic energy (E_k) (higher temperature) to matter with lower average kinetic energy (lower temperature). When two samples are in thermal contact, energy transfers until thermal equilibrium is achieved.



Sample Performance Indicator

Two bundles of copper wire have the same masses, but different temperatures.

1. What can you say about the average kinetic energy of the copper atoms in each bundle?
2. What happens when the two bundles are in thermal contact?
3. What would happen if the two bundles had the same temperature?

Heat Versus Temperature

Sample Teaching and Assessment Strategies

Activation

Students may

- Discuss what happens when they place ice cubes in drinks.
- Consider what happens to an ice cube placed in the palm of their hand.
 - Why does it melt?
 - To where is the energy transferred?

Connection

Students may

- Explore the use of hand warmers and cold packs. Use these items to qualitatively identify heat transfer.

Consolidation

Students may

- Research the medical uses of liquid nitrogen. Topics of interest for research may include cryo-preservation and wart removal.

Extension

Students may

- Research and present information on one or more of the following topics:
 - Early theories of heat (e.g., heat was thought of as a fluid called caloric)
 - Home heating sources and refrigerators
 - Initiatives in residential heating and cooling as it relates to insulation

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 219-220

Chemistry: Newfoundland and Labrador (SR)

- pp. 582-583

Newfoundland and Labrador teacher Resource and Solutions Manual (Digital)

Suggested

Resource Links: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202/resource-links.html> (Sign-in to the K-12 PL Site is necessary)

- CurioCity: Thermopower and the Body Heat-Powered Flashlight

First Law of Thermodynamics

Outcomes

Students will be expected to

60.0 distinguish between a system and surroundings and the relationship of each to the universe
[GCO 3]

13.0 use library and electronic research tools to collect information on a given topic
[GCO 2]

14.0 select and integrate information from various print and electronic sources from several parts of the same source
[GCO 2]

Focus for Learning

Students should be able to state and apply the first law of thermodynamics (i.e., that energy cannot be created or destroyed). It is summarized as:

$$q_{\text{universe}} = 0$$

$$q_{\text{universe}} = q_{\text{system}} + q_{\text{surroundings}}$$

thus $q_{\text{system}} = -q_{\text{surroundings}}$

A system is a substance or a group of substances undergoing a change such as thermal, physical, or chemical. The surroundings include anything in thermal contact with the system. Together, a system and its surroundings make up the universe.

Students should identify that energy can be exchanged between a system and its surroundings through heat lost or gained by a system:

$$q_{\text{system}} = -q_{\text{surroundings}}$$

Students should differentiate among open, closed, and isolated systems. They should research examples that help explain each and integrate this information by differentiating among the three.

1. A system that is open to the flow of energy, but closed to the flow of matter is called a closed system (e.g., unopened can of soda, inflated ball).
2. A system that is open to the flow of energy and matter is called an open system (e.g., opened can of soda, beaker on a bench).
3. A system that is closed to the flow of energy and matter is an isolated system (e.g., Thermos™, cooler, bomb calorimeter).

Refer to the Integrated Skills unit for elaboration on SCOs 13.0 and 14.0.

Attitude

Encourage students to acquire, with interest and confidence, additional science knowledge and skills, using a variety of resources and methods, including formal research. [GCO 4]

Sample Performance Indicator

For each description, identify the system and the surroundings. Classify each system as open, closed, or isolated. Justify your choices.

1. Gas fills a balloon.
2. A marshmallow burns in air.
3. A thermos keeps hot chocolate warm.
4. An ice cube melts in the palm of a hand.

First Law of Thermodynamics

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Introduce and discuss situations where students experience heat exchange (e.g., heat while sitting around a campfire).

Students may

- Explain what is meant by conservation of energy.
- Provide examples to illustrate how energy can be converted from one form to another. For example, list the forms of energy that come from the chemical potential energy of the explosive substance when an explosion occurs. Or, consider the energy of gunpowder in a bullet when stored chemical energy gets converted to E_k of the bullet (velocity and momentum), sound, heat, light, and recoil of the gun.

Connection

Students may

- Discuss the following statement: If a frying pan is placed on a wood stove, the heat gained by the pan (211 kJ of heat) is equal to the amount of heat lost by the wood stove (-211 kJ of heat).
- Discuss the use of ice packs for reducing swelling during injury.
- Compare energy lost to the surroundings when using various types of light bulbs (e.g., incandescent, LED, CFL).

Consolidation

Students may

- Research (individually or in groups) and contribute to a class blog on one or more of the topics listed below:
 - Heat flow aspects of global warming
 - Refrigeration, household heating systems, and cookware design
 - The value of insulating a home

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- p. 219

Chemistry: Newfoundland and Labrador (SR)

- p. 583

Suggested

Resource Links: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202/resource-links.html>

- Thermochemistry (virtual labs and activities)

Calculating Heat

Outcomes

Students will be expected to

61.0 define specific heat
[GCO 3]

62.0 calculate and compare the energy involved in changes of temperature
[GCO 3]

Focus for Learning

Students were introduced to heat capacity (C), specific heat capacity (c), and the joule (J) in previous science courses. They also qualitatively compared specific heat capacities of common materials.

Teachers should illustrate changes in temperature through the concepts of heat capacity (C) and specific heat capacity (c). Teachers should discuss various substances with different specific heat capacities and their ability to absorb or release heat. Students should explain that the temperature change depends on the type of material, the mass of the material, and the amount of heat transfer (it takes more thermal energy to raise the temperature of substances with high specific heat capacities).

Specific heat capacity (c) of a substance is the quantity of thermal energy required to raise the temperature of 1 g of that substance by 1 °C. Heat capacity (C) is the quantity of thermal energy required to raise the temperature of a particular object by 1 °C.

Students should complete calculations using: $q = mc\Delta T$, $q = C\Delta T$, and substitute those equations into $q_{\text{system}} = -q_{\text{surroundings}}$. Specifically, students should be able to solve for each variable when provided the others (including T_i and T_f).

In Science 8, students calculated density using $d = m/V$. For simplicity of calculations, assume that one gram of water is equivalent to one millilitre of water at 25 °C.

Sample Performance Indicators

- 175 g of iron and 175 g of aluminum are placed in a hot water bath and are warmed to 85.0 °C. The metal samples are removed and cooled to 21.5 °C. Which sample undergoes the greater heat change: iron or aluminum ($c_{\text{Fe}} = 0.444 \text{ J/g}\cdot\text{°C}$ and $c_{\text{Al}} = 0.900 \text{ J/g}\cdot\text{°C}$)?
- Calculate the specific heat capacity of an alloy if a 15.4 g sample undergoes a heat change of 393 J when it is heated from 0.0 °C to 37.6 °C.

Calculating Heat

Sample Teaching and Assessment Strategies

Activation

Students may

- Observe the effect of equivalent sized ice cubes placed on different solids (i.e., a frying pan vs. cutting board).

Connection

Students may

- Compare the thawing of a specific type of frozen food on a metal cookie sheet that is in contact with a metal sink with placing the same size and type of food on a wooden cutting board, a foam plate, and/or a ceramic plate.
- Discuss the influence of bodies of water on climate.

Consolidation

Students may

- Complete the following:
 1. A student is required to use 225 mL of hot water in a lab procedure. Calculate the heat change involved in raising the temperature of 225 mL of water from 20.0 °C to 100.0 °C.
 2. A frying pan with a heat capacity of 1.20 kJ/°C is heated from 22 °C to 198 °C. Calculate the heat change.
 3. Compare the heat required to raise the temperature of 250 g of water by 50 °C to the heat required to raise the temperature of 2000 g of water by 50 °C.
 4. Compare the heat required to raise the temperature of a 1 kg aluminum frying pan by 200 °C and a 1 kg iron frying pan by 200 °C ($c_{\text{Fe}} = 0.444 \text{ J/g}\cdot\text{°C}$ and $c_{\text{Al}} = 0.900 \text{ J/g}\cdot\text{°C}$).

Extension

Students may

- Research the application of thermal heat sinks.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 220-221

Chemistry: Newfoundland and Labrador (SR)

- pp. 589-594

Enthalpy Changes

Outcomes

Students will be expected to

63.0 define endothermic reaction, exothermic reaction, enthalpy, bond energy, heat of reaction, and molar enthalpy [GCO 3]

Focus for Learning

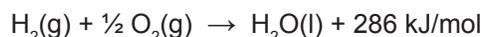
Students should be able to define the following:

- endothermic reaction
- exothermic reaction
- enthalpy
- heat of reaction
- enthalpy change
- molar enthalpy
- enthalpy notation

Students should explain that enthalpy change ($\Delta_r H$) is the energy lost or gained during a chemical change or phase change at constant pressure.

Students should relate endothermic and exothermic chemical reactions to energy transfer using the terms system and surroundings. They were introduced to the concept of endothermic and exothermic reactions in Unit 1. For endothermic reactions, a system absorbs thermal energy from its surroundings. For exothermic reactions, a system releases thermal energy to its surroundings. Endothermic or exothermic reactions should be written with a positive or negative $\Delta_r H$, or with the energy term as a reactant or a product.

For example, $\text{H}_2(\text{g}) + \frac{1}{2} \text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l}) \quad \Delta_r H = -286 \text{ kJ/mol}$
and



Teachers may refer to bonding concepts addressed in Chemistry 2202 to predict the sign of $\Delta_r H$ for common physical and chemical changes. Students should recognize that for any thermochemical change, the $\Delta_r H$ of the reverse process is equal in magnitude but opposite in sign to the forward process (e.g., $\Delta_{\text{cond}} H = -\Delta_{\text{vap}} H$).

Teachers should indicate that physical changes involve a change of state. For example, consider these phase change examples for H_2O and how they are similar and different.

Fusion or melting: $\text{H}_2\text{O}(\text{s}) + 6.02 \text{ kJ/mol} \rightarrow \text{H}_2\text{O}(\text{l})$	Solidification or freezing: $\text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2\text{O}(\text{s}) + 6.02 \text{ kJ/mol}$
Evaporation: $\text{H}_2\text{O}(\text{l}) + 40.7 \text{ kJ/mol} \rightarrow \text{H}_2\text{O}(\text{g})$	Condensation: $\text{H}_2\text{O}(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l}) + 40.7 \text{ kJ/mol}$
Sublimation: $\text{H}_2\text{O}(\text{s}) + 46.7 \text{ kJ/mol} \rightarrow \text{H}_2\text{O}(\text{g})$	Deposition: $\text{H}_2\text{O}(\text{g}) \rightarrow \text{H}_2\text{O}(\text{s}) + 46.7 \text{ kJ/mol}$

In each example above, the energy term is included in the thermochemical equation. However, each change can also be represented using enthalpy ($\Delta_r H$) notation.



Subscripts in enthalpy notation are included to show the type of enthalpy change occurring. Students should also write thermochemical equations to represent a variety of processes including $\Delta_c H$, $\Delta_f H$, $\Delta_{\text{fus}} H$, $\Delta_{\text{sol}} H$, and the more general $\Delta_r H$.

Continued

Enthalpy Changes

Sample Teaching and Assessment Strategies

Activation

Students may

- Provide some examples of chemical reactions and processes that release energy (e.g., campfire) and/or absorb energy (e.g., making ice cubes, nail polish remover feels cool as it evaporates from fingers).
- Classify each of these changes as endothermic or exothermic:
 - burning coal
 - decomposing iron ore
 - freezing water
 - melting sugar
 - vaporizing alcohol

Connection

Students may

- Describe the feeling of being extra cool, especially on a windy day, when first getting out of the water after swimming.
- Investigate why hand sanitizer feels cool on their hands.
- Relate the words endothermic and exothermic to other words as a way to help remember the meaning and context. For example, the word 'exit' can be used to help remember that exothermic reactions release energy.

Consolidation

Students may

- Participate in an activity where various chemicals (e.g., ammonium chloride, calcium chloride, sodium hydroxide) are dissolved in water. Using this activity, communicate the difference between exothermic and endothermic reactions.
- Determine the molar enthalpy of combustion, $\Delta_c H$, for $C_3H_6(g)$ using the thermochemical equation below.

$$C_3H_6(g) + \frac{9}{2} O_2(g) \rightarrow 3 CO_2(g) + 3 H_2O(g) + 2059.5 \text{ kJ/mol}$$
- Determine the molar enthalpy of formation for silver chloride.

$$2 Ag(s) + Cl_2(g) \rightarrow 2 AgCl(s) + 254 \text{ kJ/mol}$$

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 220-222

Chemistry: Newfoundland and Labrador (SR)

- pp. 584-585, 595-603

Enthalpy Changes

Outcomes

Students will be expected to

63.0 define endothermic reaction, exothermic reaction, enthalpy, bond energy, heat of reaction, and molar enthalpy [GCO 3]

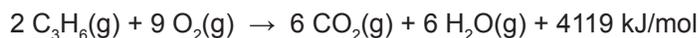
Focus for Learning

ΔH indicates a change in enthalpy that occurs during a chemical or physical process. For example, when certain amounts of elements combine to form compounds, or ice melts to liquid water.

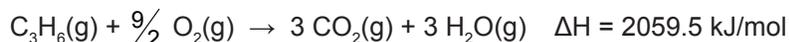
Every ΔH value, therefore, should be written with a subscript, and each should be measured in kJ/mol. The kJ/mol describes the amount of enthalpy (kJ) that changes per mole of species/reactant that changes.

The stoichiometric coefficients in a balanced chemical reaction are unitless but are often used to express moles of substances reacting.

Note: When an energy value is given as a term in a chemical reaction, it should be written with units of kJ/mol as shown below.



Per mole reaction refers to the balanced equation. The reaction above could be written as



Students predicted products and balanced hydrocarbon combustion reactions in Chemistry 2202. In Chemistry 3202, balanced hydrogen combustion reactions should be provided.

Students should determine molar enthalpy changes from a given thermochemical equation.

Sample Performance Indicator

Consider the equation below for propanoic acid, then answer the questions that follow:



1. What is the molar enthalpy for the combustion of $\text{C}_3\text{H}_6\text{O}_2(\text{aq})$?
2. What is the molar enthalpy for the production of $\text{CO}_2(\text{g})$?
3. What is the molar enthalpy for the production of $\text{H}_2\text{O}(\text{g})$?

Enthalpy Changes

Sample Teaching and Assessment Strategies

Extension

Students may

- Research and create a video to share information on
 - the protection of crops using water vapour during spring frost (e.g., strawberries, oranges), or
 - how to keep a greenhouse warm during the night as trapped water vapour inside condenses and releases energy ($\Delta_{\text{cond}}H = -\Delta_{\text{vap}}H$).

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 220-222

Chemistry: Newfoundland and Labrador (SR)

- pp. 595-603

Enthalpy Changes (Chemical)

Outcomes

Students will be expected to

64.0 illustrate changes in energy of various chemical reactions, using potential energy diagrams [GCO 3]

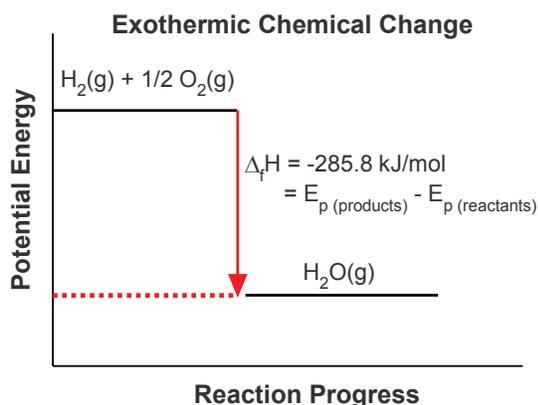
Focus for Learning

Students should use and interpret the change in enthalpy ($\Delta_r H$) notation for communicating energy changes. This includes the following discussion on bond breaking and bond formation:

- Identify and explain that chemical changes and phase changes involve changes in potential energy only.
- Energy is required to break bonds and energy is released when bonds are formed.

Students should illustrate the difference between endothermic and exothermic changes, both chemical and physical, by drawing potential energy diagrams.

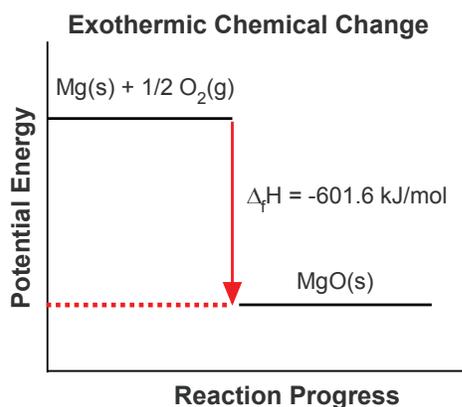
Given a thermochemical equation, students should be able to draw an enthalpy diagram, and vice versa.



Sample Performance Indicators

1. For the reaction below, draw and label an enthalpy diagram.

$$\text{CO(g)} + 2 \text{NO(g)} \rightarrow 2 \text{CO}_2\text{(g)} + \text{N}_2\text{(g)} + 747 \text{ kJ/mol}$$
2. Write the balanced thermochemical equation for the reaction represented by the potential energy diagram below.



Enthalpy Changes (Chemical)

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Review chemical reaction on a molecular level and discuss what occurs during a chemical change. An online search for 'gummy bear and potassium chlorate' will provide options for videos to help illustrate this topic.

Consolidation

Students may

- Complete an activity in which 2 g of anhydrous CuSO_4 is added to 100 mL of water. Record the initial temperature of the water and the highest temperature attained by the solution upon addition of the anhydrous CuSO_4 .

Answer the questions below:

- Does this reaction absorb or release heat? How do you know?
- What do you think the temperature change for this reaction would have been if only half of the quantity of anhydrous $\text{CuSO}_4(\text{s})$ had been added to the same volume of water?

Extension

Students may

- Research the CANDU reactor and discuss the advantages and disadvantages of nuclear energy as a power source.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 220-222

Chemistry: Newfoundland and Labrador (SR)

- pp. 598-603

Suggested

Resource Links: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202/resource-links.html>

- Enthalpy of solution: Cold Packs (simulation)
- Thermite Reaction (video)

Heating and Cooling Curves

Outcomes

Students will be expected to

65.0 calculate and compare the energy involved in changes of state and temperature [GCO 3]

18.0 *compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots* [GCO 2]

Focus for Learning

In Science 1206, students worked with heating and cooling curves. They used data to generate a heating or a cooling curve (e.g., heating ice from a solid state to boiling). Students should construct a heating or a cooling curve for a specific substance, given the appropriate data (melting point and boiling point). They should draw and interpret heating and cooling curves which include phase changes.

Students should apply the concepts of kinetic and potential energy to the heating and cooling curve (e.g., kinetic energy of solid methanol increases when the temperature increases, while potential energy increases during the phase change as energy is added). Students should recall (from Chemistry 2202) intermolecular forces (H-bonding, D-D, and LDF). Teachers should limit the discussion of intermolecular forces: bond breaking is endothermic and bond forming is exothermic. Interpreting related diagrams should focus on identifying regions of increasing and decreasing kinetic or potential energy.

Teachers should emphasize the following:

- Phase changes involve a change in potential energy (E_p). Since there is no temperature change of the system, the formula $q = mc\Delta T$ cannot be used to calculate energy lost or gained (the energy change is calculated using $q = n\Delta_r H$).
- Changes of temperature always involve a change in kinetic energy (E_k). The formula $q = mc\Delta T$ can be used to calculate energy lost or gained.

Students should be able to complete the following:

- Solve for each variable in $q = mc\Delta T$ and $q = n\Delta_r H$. Quantities of substances should be limited to masses or amounts in moles.
- Sketch and use heating and cooling curves to represent and explain changes in potential and kinetic energy of a system. Identify regions of heating and cooling curves where changes in kinetic and potential energy occur (e.g., draw and interpret a graph for the conversion of methanol at $-120\text{ }^\circ\text{C}$ to vapour at $120\text{ }^\circ\text{C}$; melting and boiling points of methanol are $-97.7\text{ }^\circ\text{C}$ and $64.0\text{ }^\circ\text{C}$).
- Calculate the total heat for a heating or cooling curve for a multistep process that includes a temperature and phase change.

Refer to the Integrated Skills unit for elaboration on SCO 18.0.

Sample Performance Indicator

On a winter day, at $-15.0\text{ }^\circ\text{C}$, a camper places 750.2 g of snow into a pot over an open fire and heats the water to $37.0\text{ }^\circ\text{C}$.

- Sketch a heating curve for the system and indicate the phase or phase change for each section of the graph.
- Theoretically describe each part of the heating curve by labelling each section as a change in kinetic or potential energy.
- Label each section with the formulas that would be used to calculate the total energy change of the system.
- Calculate the total energy required.

Heating and Cooling Curves

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Ask a series of questions to review intermolecular forces (LDF, D-D, and H-bonding) studied in Chemistry 2202.

Students may

- Brainstorm a list of factors that affect the amount of heat that will be absorbed or released during a phase change or a chemical reaction. Discuss as a class.

Connection

Students may

- Work in small groups to discuss the questions below. Share group responses with the class.
 - Why does steam at 100 °C give you a more severe burn than an equal mass of water at 100 °C?
 - Use energy transfer to explain the following scenario: If you were lost in the woods in winter, in order to help prevent hypothermia, you would drink water from a stream rather than eat snow or ice.

Consolidation

Students may

- Calculate the energy required to melt 54.06 g of ice.
- Design an activity where a piece of ice (or other material) of known mass is heated in a known volume of water. Calculate the total energy absorbed by the ice.
- Discuss how to make homemade ice cream using salt and ice.
- Determine the heat of condensation for 25.0 moles of ammonia gas that is liquefying ($\Delta_{\text{vap}}H = 23.3 \text{ kJ/mol}$).

Extension

Students may

- Research the role of CO₂ in fire extinguishers.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 220-222

Chemistry: Newfoundland and Labrador (SR)

- pp. 586-587, 601-604

Suggested

Resource Links: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202/resource-links.html>

- CurioCity: Why is it so hot underground?

Applications of Heat Technology

Outcomes

Students will be expected to

- 66.0 analyze and describe examples where technologies were developed based on scientific understanding [GCO 1]
- 67.0 analyze from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology [GCO 1]
- 68.0 propose courses of action on social issues related to science and technology, taking into account an array of perspectives, including that of sustainability [GCO 1]
- 72.0 analyze the knowledge and skills acquired in their study of science to identify areas of further study related to science and technology [GCO 1]
- 30.0 identify multiple perspectives that influence a science-related decision or issue [GCO 2]

Focus for Learning

Students should describe examples where technologies were developed based on scientific understanding of thermochemical concepts. They should consider multiple perspectives, pose questions, and suggest solutions to problems that arise.

Some examples are listed below.

- Geothermal wells and/or deep water cooling: Discuss the risks and benefits to society and the environment, including the sustainability of using these technologies.
- Heat pumps: Discuss advantages and disadvantages for use in homes.
- Burning coal or other combustible materials to generate electricity: Analyze the risks and benefits.
- Emissions of greenhouse gases: Compare a variety of sources and propose courses of action for their reduction.
- Heat sinks: Discuss their development and use (high heat capacity materials; ceramics or metal alloys) for the dissipation of heat for electronics.
- Materials that can be used as brake pads: Discuss the development of materials that handle the enormous amount of heat generated when brakes are applied (asbestos materials can no longer be used due to associated health risks).
- Refrigerants to replace CFCs (chlorofluorocarbons): Study the development of alternate materials that could be used since it was discovered that CFCs were involved as catalysts in ozone depletion.
- Thermal paper making process: Analyze the conversion from an acid-base production of paper from wood pulp to a more efficient and environmentally friendlier thermal process (e.g., Corner Brook Pulp and Paper).

Refer to the Integrated Skills unit for elaboration on SCO 30.0.

Attitude

Encourage students to

- appreciate that the applications of science and technology can raise ethical dilemmas,
- be aware of the direct and indirect consequences of their actions, and
- value the processes for drawing conclusions. [GCO 4]

Applications of Heat Technology

Sample Teaching and Assessment Strategies

Connection

Students may

- Discuss and calculate: Geothermal energy is obtained by pumping water down to the hot rock at the mantle of the Earth. The heat in the rock causes the water to boil and the resulting steam is collected. Calculate the energy change for the condensation of 100 kg of steam obtained from geothermal wells.

Consolidation

Students may

- Research the following:
 - Some areas in Canada use either geothermal wells for heat or deep water cooling for air conditioning.
 - Deep water cooling is an alternative energy to air conditioning.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 225-227

Chemistry: Newfoundland and Labrador (SR)

- pp. 582, 589, 616, 622-629

Suggested

Resource Links: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202/resource-links.html>

- Heating Curves (simulation)

Calculating Enthalpy Changes Using Calorimetry

Outcomes

Students will be expected to

65.0 calculate and compare the energy involved in changes of state and temperature [GCO 3]

8.0 evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making [GCO 2]

18.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots [GCO 2]

31.0 work cooperatively with team members to develop and carry out a plan and troubleshoot problems as they arise [GCO 2]

Focus for Learning

Students should be able to perform a variety of calorimetry calculations. For example, students can determine the mass (such as 30 g–50 g) of a metal object and place it in boiling water ($T_i = 100\text{ }^\circ\text{C}$). Giving the mass enough time to reach thermal equilibrium, it is then placed in an insulated cup at room temperature with 50.0 mL of water, where it is allowed to reach thermal equilibrium again (T_f). With the data collected, students can then calculate the specific heat capacity of the unknown metal object.

Students should complete a calorimetry lab investigation to determine the specific heat capacity of a metal by measuring temperature change and a first law of thermodynamics.

Teachers should discuss the basis of simple calorimetry. The energy change of the system is accounted for entirely by the temperature change of the calorimeter water.

Teachers should reinforce that there are important assumptions associated with simple coffee cup calorimeters:

- Only the calorimeter water absorbs or releases energy.
- One millilitre of a dilute solution can be assumed to have a mass of one gram.
- The specific heat capacity of the solution is the same as the specific heat capacity of the water.
- If a solute is added to the water in the calorimeter, the mass of the solute should not be combined with the mass of the water.
- The mass of the solute is not added to the mass of the water because we are assuming that only the water is absorbing or releasing energy.

Teachers should note that when dissolving ionic compounds in water, the mass of the solute is negligible. Therefore, the mass of the aqueous solution is equal to the mass of water only. Do not combine masses.

Refer to the Integrated Skills unit for further elaboration on SCOs 8.0, 18.0, and 31.0. This investigation also provides an opportunity to address additional inquiry-related skill outcomes from the Integrated Skills unit (e.g., 4.0, 7.0, 9.0, 10.0, 22.0).

Sample Performance Indicators

1. A 2.00 g sample of ceramic material was heated to $200.00\text{ }^\circ\text{C}$ and added to a simple calorimeter with 50.0 mL of water. The temperature in the calorimeter changed from $24.87\text{ }^\circ\text{C}$ to $27.15\text{ }^\circ\text{C}$. Calculate the specific heat of the ceramic material.
2. 7.25 g of KOH(s) is dissolved in 225 mL of water in a coffee cup calorimeter. If the temperature of the water increased by $3.4\text{ }^\circ\text{C}$, calculate the molar heat of solution for KOH(s).



Calculating Enthalpy Changes Using Calorimetry

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Discuss what a calorimeter is, how it measures heat transfer, and how it works.

Connection

Students may

- Brainstorm and discuss limitations of a calorimeter activity.
- Identify sources of error associated with calorimetry experiments.

Consolidation

Students may

- Carry out an experiment that uses a calorimeter. Measure the amount of heat transferred when a cold metal is placed in the calorimeter.
- Calculate the heat of solution when 4.00 g of calcium chloride, $\text{CaCl}_2(\text{s})$, is dissolved in 100.0 g of water in a simple calorimeter. Before the $\text{CaCl}_2(\text{s})$ was added, the water temperature was 22.0 °C. After all the $\text{CaCl}_2(\text{s})$ had dissolved, the water temperature was 24.2 °C.

Extension

Students may

- Research
 - jobs in the food sciences field that use calorimetry; and/or
 - the role of calorimetry and heat capacities in engineering and applications in advanced materials (e.g., heat shields on space vehicles; electricity applications such as conductors, insulators, or heat dissipation material for aircraft and car braking systems).

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 220-222

Chemistry: Newfoundland and Labrador (SR)

- pp. 589-594

Calculating Enthalpy Changes Using Calorimetry

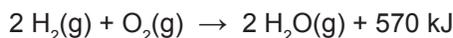
Outcomes

Students will be expected to

- 69.0 calculate and compare the energy involved in chemical reactions
[GCO 3]
- 70.0 determine experimentally the changes in energy of various chemical reactions
[GCO 3]
- 71.0 distinguish between questions that can be answered by science and those that cannot, and between problems that can be solved by technology and those that cannot
[GCO 1]
- 3.0 design an experiment identifying and controlling major variables
[GCO 2]
- 4.0 propose alternate solutions to a given practical problem, identify the potential strengths and weaknesses of each, and select one as the basis for a plan
[GCO 2]
- 15.0 *select and use apparatus and materials safely*
[GCO 2]

Focus for Learning

Given a thermochemical reaction, students should be able to solve for all variables in the formula $q = n\Delta_rH$. For example, How much heat is released in the combustion of 5.0 g of hydrogen?



Heats of reaction can be determined experimentally.

Students should design and carry out a lab investigation that demonstrates the first law of thermodynamics. Through observation, students should compare the energy changes associated with endothermic and exothermic changes. Students may dissolve NaOH(s) with NH₄Cl(s) and record qualitative temperature observations.

Students should choose an appropriate container in which to prepare their solutions, and observe, via touch, the energy changes associated with each reaction.

Students should consider the heat capacity of the material of possible devices that could be used as a calorimeter (i.e., a tin can vs. a glass beaker vs. a foam cup).

Refer to the Integrated Skills unit for further elaboration on SCOs 3.0, 4.0, and 15.0. This investigation also provides an opportunity to address additional inquiry-related skill outcomes from the Integrated Skills unit (e.g., 6.0, 17.0, 26.0, 28.0).



Calculating Enthalpy Changes Using Calorimetry

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Ask students to compare energy changes for common physical and chemical changes that they have experienced. For example, a teacher may ask the student to identify which process releases more heat: water condensing or propane burning.

Connection

Students may

- Design either a hot or a cold pack for treating injuries. Some suggested chemicals to use during the investigation include
 - ammonium chloride,
 - calcium chloride, and
 - lithium chloride.
- Compile a list of chemicals that would be best suited for use in preparing hot or cold packs. Justify choices.

Consolidation

Students may

- Solve the following problem: A 1.23 g sample of ethyne, $C_2H_2(g)$, undergoes complete combustion in an oxygen bomb calorimeter, resulting in a temperature increase of $9.50\text{ }^\circ\text{C}$. The heat capacity of the calorimeter is $6.49\text{ kJ/}^\circ\text{C}$. Calculate the molar heat of combustion for ethyne.

Extension

Students may

- Use simple calorimetry to determine the molar enthalpy of neutralization of an acid and a base.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 220-222

Chemistry: Newfoundland and Labrador (SR)

- pp. 589-594

Calculating Enthalpy Changes Using Calorimetry

Outcomes

Students will be expected to

- 73.0 compare the molar enthalpies of several combustion reactions involving organic compounds [GCO 3]
- 74.0 write and balance thermochemical equations including the combustion reactions of alkanes [GCO 3]
- 75.0 analyze why scientific and technological activities take place in a variety of individual and group settings [GCO 1]
- 76.0 describe the importance of peer review in the development of scientific knowledge [GCO 1]

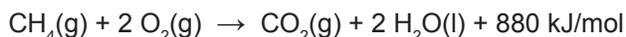
Focus for Learning

As a continuation of the first law of thermodynamics, students should perform calculations using combustion reactions in bomb calorimeters.

Bomb calorimeters are used to study and precisely measure the heat released during combustion reactions, whereby the heat capacity (C) and the change in temperature of the calorimeter are used to calculate heat.

Students have prior experience in writing formulas for hydrocarbons and in writing and balancing complete combustion reactions. They should be able to include the energy term within the complete combustion equation.

For example:



Teachers should convey the importance of using critical analysis in scientific research. When working in groups, scientists can pool expertise and gain a variety of perspectives that will advance scientific knowledge. When working individually, scientists may feel they are more productive and are better able to foster ingenuity. For example, students may analyze how many technologists, scientists, and agencies share their work on the determination of such things as alternative fuels and explosives. They may also conduct research on individuals who have personal insight and motivation that has led to exciting discoveries and innovations (such as the discovery of dynamite by Nobel, who donated his fortune to create the Nobel Prizes).

Sample Performance Indicators

1. A 0.910 g sample of sucrose, $\text{C}_{12}\text{H}_{22}\text{O}_{11}(\text{s})$, is burned in a bomb calorimeter and the temperature of the calorimeter and contents increased from 22.5 °C to 27.5 °C. If the heat capacity of the calorimeter and contents was 4.50 kJ/°C, calculate the molar heat of combustion of sucrose.
2. In separate trials, several 2.00 g samples of benzene, $\text{C}_6\text{H}_6(\text{l})$ were burned in a bomb calorimeter. An average temperature change of 9.62 °C was recorded. Given that the molar heat of combustion of benzene is -3268 kJ/mol, calculate the heat capacity of the bomb calorimeter.

Calculating Enthalpy Changes Using Calorimetry

Sample Teaching and Assessment Strategies

Activation

Students may

- Brainstorm and list different types of fuels. Discuss why different fuels are used for different applications.

Connection

Students may

- Relate how the common uses of various fuels depend, in part, on how much energy they produce.
- Make a conjecture about the values of molar enthalpies of combustion of hydrocarbons based upon bond type (i.e., single, double, and triple covalent bonds).

Consolidation

Students may

- Participate in an activity related to the enthalpy of combustion of a candle. Compare literature values of various hydrocarbons to the experimental value found for candle wax.
- Investigate how technologists, scientists, and agencies determine the heat content of foods, fuels, and explosives.
- Calculate how many moles of methanol must burn to raise the temperature of 120.0 g of aluminum by 92.0 °C. Assume all heat is absorbed by the aluminum, $c_{Al} = 0.900 \text{ J/g}\cdot\text{°C}$, and the molar heat of combustion of methanol, $\text{CH}_3\text{OH(l)}$, is -239 kJ/mol .

Extension

Students may

- Research the role of the Canadian Food Inspection Agency in the determination of food labelling. Share information.
- Analyze a nutrition label to determine
 - the amount of food required to jog for one hour,
 - the number of calories consumed by eating one serving,
 - the number of kilojoules when converted from calories, and
 - the fuel value in one serving.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 220-222

Chemistry: Newfoundland and Labrador (SR)

- pp. 589-594

Suggested

Resource Links: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202/resource-links.html>

- CurioCity: Senior Chemistry Technology

Applications of Hess's Law

Outcomes

Students will be expected to

77.0 calculate the changes in energy of various chemical reactions using bond energy, heats of formation, and Hess's law [GCO 3]

Focus for Learning

Teachers should emphasize that there are many chemical reactions whose energy changes cannot safely be measured using calorimetry. The enthalpy change is determined using simple arithmetic and logical deduction. Hess's law of heat summation states: Enthalpy depends only upon the initial and final state of the reactants or products and not on the specific pathway taken to get from the reactants to the products. Students should determine enthalpy using three applications of Hess's law (as opposed to calorimetry). Teachers should discuss with students the relative merits (e.g., positives, negatives, accuracy, precision, convenience) of each method.

Hess's Law of Heat Summation

1. Algebraic Method

Students should use addition of chemical equations and corresponding enthalpy changes to compute the enthalpy change of the overall reaction. Teachers should limit the number of equations to four or less.

2. Standard Molar Enthalpy of Formation

Students should calculate the changes in the energy of various chemical reactions using heats of formation, $\Delta_f H^\circ$. They should use Hess's law equation to calculate the enthalpy of a chemical reaction.

$$\Delta_r H^\circ = \sum v \Delta_f H^\circ_{\text{products}} - \sum v \Delta_f H^\circ_{\text{reactants}}$$

It should be noted that v in the formation enthalpy formula refers to balancing coefficients as per the IUPAC Green Book.

By using a table of standard molar enthalpies of formation, students can substitute into the expression and calculate an enthalpy change for a reaction. It is more efficient than having to manipulate and add two or more thermochemical equations.

Students should define the standard molar enthalpy of formation (molar heat) $\Delta_f H^\circ$ for a compound as the enthalpy change that occurs when the compound is formed from its elements in their standard states. The molar enthalpy of formation of an element in its standard state is 0 kJ/mol.

A common error for students is to reverse products and reactants in the heats of formation formula.

Continued

Applications of Hess's Law

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Introduce an analogy using sea level (zero metres) as a reference point when discussing molar enthalpy of formation of an element in its standard state. All other measure of energy can be above (+) or below (-) the reference point.

Students may

- Evaluate and discuss the phrase, "There are many ways to the top of a mountain but the view from the top is always the same." Brainstorm examples of how a result may not depend on the path taken (state function). For example, the whole class may be expected to meet at a specific location later in the day. Each person may take a different route, but the destination (outcome) will be the same.

Connection

Teachers may

- Introduce and discuss an example, from graphite and oxygen gas, of the formation of carbon dioxide. This reaction results in the release of 393.5 kJ of energy per mole of carbon dioxide formed. C(graphite) and O₂(g) are the standard states of carbon and oxygen at standard conditions.



Students may

- Research examples in other science curriculum areas where Hess's law can be applied.
- Research the process of ATP production from metabolizing glucose.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 222-224

Chemistry: Newfoundland and Labrador (SR)

- pp. 605-615

Applications of Hess's Law

Outcomes

Students will be expected to

77.0 calculate the changes in energy of various chemical reactions using bond energy, heats of formation, and Hess's law
[GCO 3]

4.0 propose alternate solutions to a given practical problem, identify the potential strengths and weaknesses of each, and select one as the basis for a plan
[GCO 2]

21.0 apply and assess alternative theoretical models for interpreting knowledge in a given field
[GCO 2]

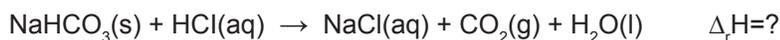
31.0 work cooperatively with team members to develop and carry out a plan and troubleshoot problems as they arise
[GCO 2]

Focus for Learning

Students should perform a calorimetry lab investigation to demonstrate Hess's law. For example, students can calculate the molar enthalpy change for the decomposition of sodium bicarbonate:



by conducting calorimetry measurements for each reaction below and then manipulating and adding the enthalpies of these equations:



3. Average Bond Energies

Students should:

- Calculate the changes in the energy of various chemical reactions using average bond energies; $\Delta_r H$ calculated by this method is considered an approximation since bond energies from data tables are based on average bond energies.
- Recall that bond breaking is an endothermic process. As such, all bond energies are positive.
- Use the summation of bond energies equation to calculate the estimated enthalpy of a chemical reaction.

$$\Delta_r H = \sum \text{bond energies}_{\text{reactants}} - \sum \text{bond energies}_{\text{products}}$$

Teachers should emphasize that the order of terms in the bond energy formula is the opposite of the order used in the heat of summation calculations. Teachers should also review the concept of single, double, and triple bonds from Chemistry 2202, Unit 2.

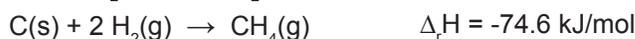
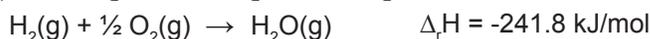
Refer to the Integrated Skills unit for elaboration on SCOs 4.0, 21.0, and 31.0. This investigation also provides an opportunity to address additional inquiry-related skill outcomes from the Integrated Skills unit (e.g., 11.0, 12.0, 16.0).

Attitude

Encourage students to value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not. [GCO 4]

Sample Performance Indicator

Determine the enthalpy of reaction for



Applications of Hess's Law

Sample Teaching and Assessment Strategies

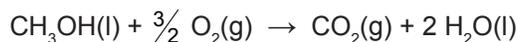
Consolidation

Students may

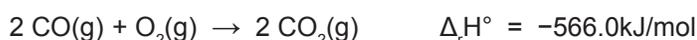
- Compare the two ways that Hess's law can be stated:
 1. The heat evolved or absorbed in a chemical process is the same whether the process takes place in one step or over several steps.
 2. If two or more thermochemical equations can be added together to produce an overall equation, the sum of the enthalpy terms of the thermochemical equations equals the enthalpy change of the overall equation.
- Consider that small amounts of oxygen gas can be produced in a laboratory by heating potassium chlorate, KClO_3 . Calculate the enthalpy change of this reaction using enthalpies of formation.



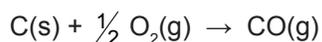
- Use average bond energies to calculate the enthalpy change for the combustion of ethanol.
- Calculate the enthalpy of the reaction below using bond energies.



- Carry out a lab investigation that relates to Hess's law and the enthalpy of combustion of magnesium.
- Refer to the thermochemical equations below:



Use Hess's law of heat summation. Calculate the molar enthalpy for the incomplete combustion of graphite:



Extension

Students may

- Research possible bond energies for the C–H bond and propose reasons why they vary as they do.
- Research and identify a chemical reaction that is too dangerous to perform in their school's laboratory. Using Hess's law, determine the enthalpy change for the reaction.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 224-225

Chemistry: Newfoundland and Labrador (SR)

- pp. 616-621, 630-631

Teaching and Learning Strategies: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202.html>

- Determining Specific Heat Capacity of a Metal

Section Three:
Specific Curriculum Outcomes

Unit 4: Electrochemistry

Focus

Students use electrochemical applications in their everyday lives. By studying the design and function of various electrochemical technologies, students will better understand the progress, evolution, and uses of electrochemical cell technology.

Students will research technologies related to electrochemistry before studying oxidation and reduction reactions. They will be able to identify redox reactions, use oxidation numbers, and balance redox reactions. They will study applications of technology including the processes associated with various electrochemical cells, and they will also compare the internal structures of batteries. Students will study, understand, and compare the processes associated with electrochemical cells, and explain the production of electrical energy in a hydrogen fuel cell.

Problem solving and decision making skills will help to create an interest in the application of technology. Lab investigations related to writing and testing redox reactions and measuring voltage of galvanic cells are valuable to student learning. STSE connections include describing, designing, and evaluating scientific problems and solutions associated with electrochemistry.

Students studied the mole and electronegativity in Chemistry 2202. This unit will provide a more in-depth look into chemical reactions involving electron transfer. Solutions, ionization, and chemical equilibrium in Chemistry 3202 should be completed before beginning electrochemistry.

Outcomes Framework

GCO 1 (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.

- 78.0 distinguish between scientific questions and technological problems
- 79.0 describe and evaluate the design of technological solutions and the way they function, using scientific principles
- 80.0 analyze natural and technological systems to interpret and explain their structure and dynamics
- 81.0 evaluate the design of a technology and the way it functions on the basis of a variety of criteria that they have identified themselves
- 89.0 analyze why and how a particular technology was developed and improved over time

GCO 2 (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.

- 1.0 identify questions to investigate that arise from practical problems and issues
- 2.0 define and delimit problems to facilitate investigation
- 7.0 formulate operational definitions of major variables
- 10.0 carry out procedures controlling the major variables and adapting or extending procedures where required
- 15.0 select and use apparatus and materials safely
- 22.0 compare theoretical and empirical values and account for discrepancies
- 23.0 evaluate the relevance, reliability, and adequacy of data and data collection methods
- 25.0 construct and test a prototype of a device or system and troubleshoot problems as they arise
- 26.0 evaluate a personally designed and constructed device on the basis of criteria they have developed themselves
- 28.0 identify and evaluate potential applications of findings
- 32.0 evaluate individual and group processes used in planning, problem solving and decision making, and completing a task

GCO 3 (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.

- 82.0 define oxidation and reduction experimentally and theoretically
- 83.0 compare oxidation-reduction reactions with other kinds of reactions
- 84.0 write and balance half-reactions and net reactions for redox equations
- 85.0 illustrate and label the parts of electrochemical cells and explain how they work
- 86.0 compare galvanic and electrolytic cells in terms of energy efficiency, electron flow/transfer, and chemical change
- 87.0 predict whether oxidation-reduction reactions are spontaneous based on their reduction potentials
- 88.0 predict the voltage of various electrochemical cells
- 90.0 explain the processes of electrolysis and electroplating
- 91.0 explain how electrical energy is produced in a hydrogen fuel cell

GCO 4 (Attitude): 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.

Students are encouraged to

- project the personal, social, and environmental consequences of proposed action
- value the contributions to scientific and technological development made by women and men from many societies and cultural backgrounds
- want to take action for maintaining a sustainable environment

SCO Continuum

GCO 3: Knowledge		
Science 1206	Chemistry 2202	Chemistry 3202
<ul style="list-style-type: none"> • name and write formulas for some common ionic and molecular compounds, using the periodic table and a list of ions • represent chemical reactions and the conservation of mass using molecular models and balanced symbolic equations • classify chemical reactions based on type • classify substances as acids, bases, or salts, based on their characteristics, name, and formula 	<ul style="list-style-type: none"> • write and name the formulas of ionic and molecular compounds, following simple IUPAC rules • define molar mass and perform mole-mass interconversions for pure substances • explain the variations in the solubility of various pure substances, given the same solvent • use the solubility generalizations to predict the formation of precipitates • identify mole ratios of reactants and products from balanced chemical equations • perform stoichiometric calculations related to chemical equations • predict how the yield of a particular chemical process can be maximized • identify various stoichiometric applications • identify and describe the properties of molecular, ionic, and metallic substances • describe how intermolecular forces account for the properties of molecular compounds • illustrate and explain the formation of ionic and metallic bonds • explain the structural model of an ionic substance in terms of the various bonds that define it • describe how ionic bonding accounts for the properties of ionic compounds • relate the properties of a substance to its structural model of ionic compounds • describe how metallic bonding accounts for the properties of metals • relate the properties of a substance to its structural model • describe the process of dissolving, using concepts of intramolecular and intermolecular forces • classify ionic, molecular, and metallic substances according to their properties 	<ul style="list-style-type: none"> • define oxidation and reduction experimentally and theoretically • compare oxidation-reduction reactions with other kinds of reactions • write and balance half-reactions and net reactions for redox equations • illustrate and label the parts of electrochemical cells and explain how they work • compare galvanic and electrolytic cells in terms of energy efficiency, electron flow/transfer, and chemical change • predict whether oxidation-reduction reactions are spontaneous based on their reduction potentials • predict the voltage of various electrochemical cells • explain the processes of electrolysis and electroplating • explain how electrical energy is produced in a hydrogen fuel cell

Applications of Redox Reactions and Electrochemical Cells

Outcomes

Students will be expected to

1.0 identify questions to investigate that arise from practical problems and issues
[GCO 2]

32.0 evaluate individual and group processes used in planning, problem solving and decision making, and completing a task
[GCO 2]

78.0 distinguish between scientific questions and technological problems
[GCO 1]

79.0 describe and evaluate the design of technological solutions and the way they function, using scientific principles
[GCO 1]

80.0 analyze natural and technological systems to interpret and explain their structure and dynamics
[GCO 1]

81.0 evaluate the design of a technology and the way it functions on the basis of a variety of criteria that they have identified themselves
[GCO 1]

Focus for Learning

Students should research electrochemistry related technologies and issues that are relevant in their lives. They should have opportunities to analyze and interpret information, pose and answer questions, evaluate systems and designs, and propose solutions to problems.

While some topics and issues may be addressed as independent tasks (e.g., research or project based), an attempt should be made to integrate skill outcomes throughout the unit in the form of discussion, case study, or inquiry, as specific topics arise.

Topics to address these outcomes may include but are not limited to those listed below:

- Breathalyzer technology
- Combustion reactions
- Corrosion and how can it be prevented
- Development of the electric cell and batteries
- Discovery of elements, electroplating, electrowinning, and electrorefining
- Electric and hybrid automobiles
- Free-radicals and antioxidants
- Fuel cells
- Metal purification and processing (e.g., hydrometallurgy and pyrometallurgy)
- Oxidation of fruit
- Reactions in cell respiration
- Safety issues associated with using lithium-ion batteries
- Vitamin C content in foods
- Water quality analysis

Students should be able to use an example to explain the importance of advances in electrochemistry. For example, the development of the electrochemical cell led to the discovery of electrolysis since the electrical energy produced could be used to cause non-spontaneous reactions to occur.

Students should explain the difference between scientific investigation and technological development. They should also be able to discuss examples.

Refer to the Integrated Skills unit for further elaboration on SCOs 1.0 and 32.0.

Attitude

Encourage students to

- project the personal, social, and environmental consequences of proposed action, and
- value the contributions to scientific and technological development made by women and men from many societies and cultural backgrounds. [GCO 4]

Applications of Redox Reactions and Electrochemical Cells

Sample Teaching and Assessment Strategies

Activation

Students may

- Brainstorm practical and natural examples of electrochemistry.

Connection

Students may

- Discuss answers to the following questions:
 - Why do automobiles in some locations rust more quickly than in other locations?
 - Why does fruit turn brown?
 - Why do lithium batteries explode?

Consolidation

Students may

- Research, in small groups, the environmental effects of different types of batteries. Analyze both the production and waste costs, then share research processes and findings with the class.
- Research the work of the Dalhousie University research chair in battery and fuel cell materials (Jeff Dahn). Share findings.
- Research and present findings on corrosion prevention using a sacrificial anode such as zinc on a metal (e.g., hull of a fishing vessel) or cathodic protection.

Extension

Students may

- Research a career in metallurgy, chemical engineering, or industrial areas of electrochemistry.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (Teacher Resource [TR])

- pp. 231-232, 242, 245, 248-250, 252-254

Chemistry: Newfoundland and Labrador (Student Resource [SR])

- pp. 639, 656, 662, 682-683, 696-702

Newfoundland and Labrador teacher Resource and Solutions Manual (Digital)

Suggested

Resource Links: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202/resource-links.html> (Sign-in to the K-12 PL Site is necessary)

- CurioCity Vanadium: From Stronger Steel to Energy Efficiency
- CurioCity: Battery Power on Lithium-ion Batteries

Oxidation and Reduction Reactions

Outcomes

Students will be expected to

82.0 define oxidation and reduction experimentally and theoretically [GCO 3]

Focus for Learning

Lewis dot diagrams were addressed in Chemistry 2202, Unit 2.

Students should define electrochemistry as the study of the relationship between electricity and chemical change.

Students should define redox reactions as those which involve a transfer of electrons. Equations for redox reactions are combinations of an oxidation half-reaction and a reduction half-reaction. Some of these reactions convert chemical energy to electrical energy while others convert electrical energy to chemical energy.

Students should be able to compare oxidation and reduction in terms of loss or gain of electrons. Given an equation, they should also be able to identify the substance being oxidized and the substance being reduced, the reducing agent, and the oxidizing agent. Given the net ionic equation for a redox reaction, students should be able to write oxidation and reduction half-reactions.

Teachers should demonstrate a simple electrochemical reaction, (e.g., place a strip of zinc metal in a CuSO_4 solution).

While this is not an outcome for Chemistry 3202, teachers should review, from Chemistry 2202, the transfer of electrons. This may be illustrated using Lewis dot diagrams to show formation of ionic compounds such as NaCl.



Sample Performance Indicators

- The following changes occurred. Label each change as oxidation or reduction:
 - Co became Co^{2+}
 - Cl_2 became 2Cl^-
 - Pb^{4+} became Pb^{2+}
- Consider the reaction below:

$$\text{Cu}^{2+}(\text{aq}) + \text{Zn}(\text{s}) \rightarrow \text{Cu}(\text{s}) + \text{Zn}^{2+}(\text{aq})$$
 - Write the oxidation and reduction half-reactions.
 - Identify the oxidizing agent and the reducing agent.

Oxidation and Reduction Reactions

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Introduce the topic of oxidation and reduction by questioning students' knowledge of corrosion and anti-corrosion (or other relevant examples).
- Link the historical meaning of reduction and oxidation to the field of metallurgy.
- Demonstrate corrosion of iron (rusting) and the factors that affect it. Use a series of test tubes containing steel nails and galvanized nails under different conditions (e.g., water and air, drying agent, water and oil, salt water).

Students may

- Discuss how, when a copper(II) solution reacts with solid zinc, copper metal forms on the surface of the zinc, zinc metal disappears, and the blue colour of the Cu^{2+} ions fades.

Connection

Students may

- Use mnemonics such as OIL (Oxidation Is Losing) and RIG (Reduction Is Gaining) or LEO the lion says GER, (Loss of Electrons is Oxidation and Gain of Electrons is Reduction) to help remember the meaning of oxidation and reduction.
- Carry out an investigation to test the factors that affect corrosion.

Extension

Students may

- Research how oxidants and antioxidants affect human health (e.g., aging and disease prevention).

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 239-241

Chemistry: Newfoundland and Labrador (SR)

- pp. 642-646

Suggested

Resource Links: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202/resource-links.html>

- Curiosity: Can Vegetables Conduct Electricity?
- Curiosity: Explore Antioxidants

Identifying Redox Reactions

Outcomes

Students will be expected to

83.0 compare oxidation-reduction reactions with other kinds of reactions [GCO 3]

Focus for Learning

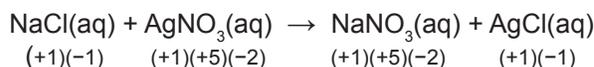
Given a compound, students should

- define and assign oxidation numbers for elements and monatomic ions,
- use oxidation number rules to find the oxidation numbers of the atoms in molecules or polyatomic ions, and
- identify changes in oxidation numbers in half-reactions and in redox equations.

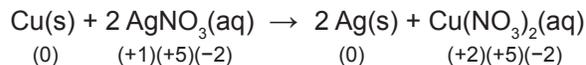
Given a reaction, students should

- define and assign oxidation numbers,
- determine whether a reaction is a redox reaction,
- identify oxidizing and reducing agents, and
- identify the species oxidized and the species reduced.

Students should be able to identify a redox reaction as one which involves changes in oxidation number.



– no change in oxidation number for any of the elements; therefore, not a redox reaction

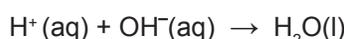
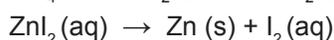
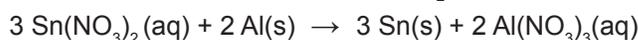
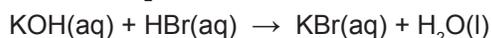
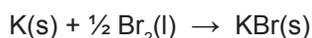


– change in oxidation number for copper and silver; therefore, a redox reaction

In the reaction above, Ag^+ ions (oxidation number = +1) have been reduced to Ag metal atoms (oxidation number = 0), Cu metal atoms (oxidation number = 0) have been oxidized to Cu^{2+} ions (oxidation number = +2). In this reaction, Cu(s) is the reducing agent and Ag^+NO_3 is the oxidizing agent.

Sample Performance Indicators

1. Determine the oxidation number for the specified atom in each example: Carbon in $\text{C}_6\text{H}_{12}\text{O}_6$; Sulfur in SO_4^{2-} ; Chromium in $\text{K}_2\text{Cr}_2\text{O}_7$.
2. Identify the redox reactions below. For each redox reaction, identify the species that is oxidized and the species that is reduced.



Identifying Redox Reactions

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Facilitate a brainstorming activity to identify different types of chemical reactions (completed in Science 1206 Chemistry unit). Ask students: How do you know it's a reaction?
- Discuss how many previously discussed reactions are redox reactions.

Connection

Students may

- Discuss why double replacement reactions are not redox reactions.
- Complete exit cards to indicate their understanding of what is, and what is not, an oxidation-reduction reaction.

Consolidation

Students may

- Develop a PowerPoint™, Prezi™, comic, or poster outlining how to identify an oxidation-reduction reaction.
- Consider each of the following unbalanced equations. Use oxidation numbers for each species to show the species that is oxidized and the species that is reduced. In each unbalanced equation below, identify the oxidizing agent, reducing agent, oxidation number of each species, and electrons transferred:



Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 239-241

Chemistry: Newfoundland and Labrador (SR)

- pp. 646-650

Identifying Redox Reactions

Outcomes

Students will be expected to

83.0 compare oxidation-reduction reactions with other kinds of reactions [GCO 3]

2.0 define and delimit problems to facilitate investigation [GCO 2]

15.0 select and use apparatus and materials safely [GCO 2]

23.0 evaluate the relevance, reliability, and adequacy of data and data collection methods [GCO 2]

28.0 identify and evaluate potential applications of findings [GCO 2]

Focus for Learning

Students should complete a lab investigation to test the spontaneity of redox reactions. They should use a variety of oxidizing and reducing agents. Students should make a list of spontaneous reactions and non-spontaneous reactions after performing chemical tests of various metals with solutions containing metallic ions.

Students should select at least three metals and corresponding nitrates. Due to safety concerns, they should be limited to the materials below:

- Al
- Cu
- Fe
- Mg
- Ni
- Sn
- Zn
- 0.1 mol/L solutions of the corresponding nitrates

After students tabulate their data, they should rank the metal ions in order from strongest to weakest oxidizing agents.

Effective organization of the results is required to analyze data obtained from this investigation. Once analysis has been completed, students should be able to generalize the relationship between the strength of the oxidizing agent and spontaneity of a reaction.

Refer to the Integrated Skills unit for further elaboration on SCOs 2.0, 15.0, 23.0, and 28.0. This investigation also provides an opportunity to address additional inquiry-related skill outcomes from the Integrated Skills unit (e.g., 1.0, 9.0, 10.0, 27.0).



Identifying Redox Reactions

Sample Teaching and Assessment Strategies

Activation

Teachers may

- View and discuss examples of spontaneous redox reactions such as apples turning brown when left exposed to air.
- Ask students:
 - What is a galvanized nail? Why are nails galvanized?
 - What colour was the roof of the Parliament Building when it was new? Why is it now green?
 - Why is the Statue of Liberty no longer copper colour?

Students may

- Brainstorm evidence of chemical reactions (e.g., colour change, bubbles).

Connection

Students may

- Consider and discuss the advantages and disadvantages of selecting different metals for specific applications (e.g., materials for an outside statue).
- Investigate how corrosion affects concrete structures (e.g., bridges).

Consolidation

Students may

- Predict whether the following reactions are possible:
 - Oxidation of bromide ion by chlorine
 - Oxidation of iron atoms by silver ions
 - Reduction of iodine by fluoride ion

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 243-244

Chemistry: Newfoundland and Labrador (SR)

- p. 657

Suggested

Resource Links: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202/resource-links.html>

- Statue of Liberty: The Green Hue of Liberty
- Electrochemistry: Redox Reactions (video)

Balancing Redox Reactions

Outcomes

Students will be expected to

84.0 write and balance half-reactions and net reactions for redox equations
[GCO 3]

Focus for Learning

Using half-reactions, students should balance redox reactions under neutral and acidic conditions. Students are not expected to balance under basic conditions.

Given an unbalanced, net ionic, or non-ionic equation, students should be able to complete the following:

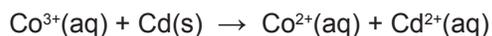
1. Write half-reactions identifying the reduction half-reaction and the oxidation half-reaction as well as the oxidizing agent and the reducing agent.
2. Balance the redox reaction.

Sample Performance Indicators

1. A copper strip is placed in a solution of zinc nitrate.
 - Write the non-ionic, total ionic, and net ionic equations.
 - Write the oxidation and reduction half-reactions.
 - State what is oxidized and reduced.
 - Identify the reducing agent and the oxidizing agent.
2. Under acidic conditions, balance the redox reaction below.



3. Consider the following unbalanced net ionic equation:



- Write oxidation and reduction half-reactions.
- Identify the oxidizing and reducing agents.
- Balance the redox equation.

Balancing Redox Reactions

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Introduce non-ionic, total ionic, and net ionic equations as they relate to redox reactions.

Students may

- Compare the non-ionic, total ionic, and net ionic equations to the writing of Brønsted-Lowry acid-base reactions from Unit 2, Acids and Bases.
- View a demonstration of the redox reaction between silver ions (from AgNO_3) and copper wire (i.e., the cleaned copper wire can be formed into a Christmas tree shape and immersed in a solution of $\text{AgNO}_3(\text{aq})$; silver metal 'flakes' will form on the wire, creating the appearance of snow on the tree).

Connection

Students may

- List examples of redox reactions that might occur in their homes.
- Discuss electrochemical cell construction using lemons to illustrate that electron transfer frequently occurs in acidic environments. Brainstorm other acidic environments in which electron transfer occurs (e.g., car battery).
- Perform a titration of a redox reaction in order to quantify the concentration of a dissolved ion in a water sample.

Consolidation

Students may

- Balance the following redox equations using half-reactions:
 - $\text{Co}^{3+}(\text{aq}) + \text{Au}(\text{s}) \rightarrow \text{Co}^{2+}(\text{aq}) + \text{Au}^{3+}(\text{aq})$
 - $\text{Mg}(\text{s}) + \text{Cu}(\text{NO}_3)_2(\text{aq}) \rightarrow \text{Mg}(\text{NO}_3)_2(\text{aq}) + \text{Cu}(\text{s})$
 - a lead strip is placed in a solution of silver nitrate

Extension

Students may

- Find and view a video of the thermite reaction between iron(III) oxide by aluminum powder to form molten iron.

$$\text{Fe}_2\text{O}_3(\text{s}) + 2 \text{Al}(\text{s}) \rightarrow \text{Al}_2\text{O}_3(\text{s}) + 2 \text{Fe}(\text{l})$$

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 241-242

Chemistry: Newfoundland and Labrador (SR)

- pp. 644-645, 652-655

*Electrochemical Cells: Parts and Function***Outcomes**

Students will be expected to

79.0 describe and evaluate the design of technological solutions and the way they function, using scientific principles
[GCO 1]

85.0 illustrate and label the parts of electrochemical cells and explain how they work
[GCO 3]

86.0 compare galvanic and electrolytic cells in terms of energy efficiency, electron flow/transfer, and chemical change
[GCO 3]

7.0 formulate operational definitions of major variables
[GCO 2]

Focus for Learning

Electrochemical cells include galvanic (voltaic) cells, electrolytic cells, and fuel cells. Students should be able to define both galvanic (voltaic) cells and electrolytic cells and explain how they work.

Students should be able to

- illustrate and label a complete cell diagram for both half-cells when given either the redox equation or the cell notation;
- write balanced redox equations and cell notation from the cell diagram; and
- explain how the cell works (i.e., explain, in terms of electron transfer and ion migration, what occurs in each half-cell).

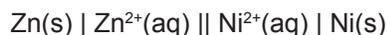
The cell illustration should include the following components:

- anode
- cathode
- direction of electron flow
- electrodes
- half-reactions that occur at the anode and cathode
- internal and external circuit
- migration of all ions
- power supply (if required)
- salt bridge/porous cup (if required)
- voltmeter (if required)

Students should use cell notation as a shorthand method of summarizing the oxidation and reduction half-reactions in an electrochemical cell.

For cell notation, the anode components are listed on the left and the cathode components are listed on the right. Double lines represent a salt bridge, a single line indicates the components are in different phases, and a comma indicates they are in the same phase. Students should include an inert electrode (Pt or C) if required.

anode | electrolyte || electrolyte | cathode



In the case where a physical barrier such as a salt bridge is not used, the notation has the following format where the double line, representing the barrier, is removed:

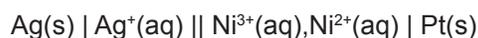
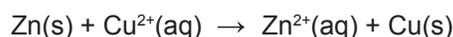
anode | electrolyte, electrolyte | cathode



Refer to the Integrated Skills unit for more information on SCO 7.0.

Sample Performance Indicator

Draw a fully labelled diagram for each of the following galvanic cells:



Electrochemical Cells: Parts and Function

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Demonstrate the use of a fruit or vegetable to supply the electrolyte for a galvanic cell (e.g., potato clock).
- Introduce galvanic cells through a demonstration by placing a piece of zinc metal in a solution of CuSO_4 . Discuss the history of the development of galvanic cells and batteries.

Connection

Students may

- Write a journal entry explaining how the flow of electrons in a flashlight produces light.
- Determine whether plastic coated paper clips could work as electrodes.

Consolidation

Students may

- Draw a concept map for the following terms: anode, cathode, anion, cation, salt bridge, internal circuit, external circuit, power supply.
- View online virtual labs and simulations that provide results of many different combinations of anode and cathode.
- Complete an investigation involving the building of cells (to test different cell designs).
- Report on a personally-designed electrochemical device. Include criteria, procedures, variables, and materials.
- Use common household materials to construct a galvanic cell (e.g., fruit or vegetable as electrolytes, and aluminum foil, nails, pencil lead/graphite as possible electrodes). Evaluate.

Extension

Students may

- Research the history of the development of the electrochemical cell. Include the contributions of Luigi Galvani and Alessandro Volta as well as those of Sir Humphrey Davy and Michael Faraday.
- Research the historical development of the electric car.
- Identify, evaluate, and discuss alternative applications for existing cells, such as using car batteries to power wheelchairs.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 245-250

Chemistry: Newfoundland and Labrador (SR)

- pp. 663-669, 677-684
- p. 666 (sample cell diagram)

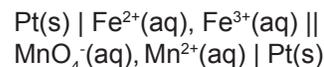
Suggested

Resource Links: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202/resource-links.html>

- Electrochemical Cell (interactive simulation)
- Electrolytic Cell (interactive simulation)
- Cell Types (video)
- Our Hydrogen Future (video)

Note

The cell notation on page 668 of the text should be



Electrochemical Cells: Cell Potential

Outcomes

Students will be expected to

86.0 compare galvanic and electrolytic cells in terms of energy efficiency, electron flow/transfer, and chemical change
[GCO 3]

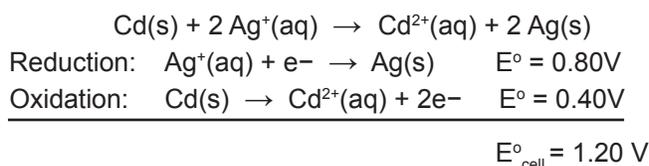
87.0 predict whether oxidation-reduction reactions are spontaneous based on their reduction potentials
[GCO 3]

88.0 predict the voltage of various electrochemical cells
[GCO 3]

Focus for Learning

Students should identify the standard hydrogen half-cell and explain its importance in ranking oxidizing and reducing agents. Teachers should emphasize that multiplying half-reactions to balance electrons has no effect on E° . Students should be able to calculate the overall E° for the cell using values from the Table of Standard Reduction Potentials of Half-Cells (SRP Table). For example, consider the following notation: $\text{Cd} \mid \text{Cd}^{2+} \parallel \text{Ag}^+ \mid \text{Ag}$

Teachers should reinforce that writing a balanced redox equation would require multiplying the reduction half-reaction by 2 to balance electrons. This would have no impact on the standard reduction potential for that half cell or E°_{cell} . Since the oxidation half-reaction is reversed, the sign of its E° must be changed.



Students should identify a given reaction as spontaneous (positive E°_{cell}) or non-spontaneous (negative E°_{cell}). They should determine the type of electrochemical cell from the sign of the cell potential (positive E°_{cell} = galvanic or negative E°_{cell} = electrolytic).

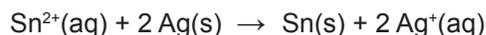
Students should compare galvanic and electrolytic cells based on

- conversion of energy,
- direction of ion movement,
- electron flow,
- reaction occurring at the anode,
- reaction occurring at the cathode,
- requirement for a salt bridge, and
- spontaneity of reaction.

Students should note that every time energy is changed from one form to another, some energy is lost as heat. To reverse the reaction in a galvanic cell, a voltage of opposite polarity and greater magnitude than the voltage produced by the spontaneous reaction must be applied in order to overcome energy loss. For example, the $\text{Zn} \mid \text{Zn}^{2+} \parallel \text{Cu}^{2+} \mid \text{Cu}$ cell produces 1.10 V. If a voltage greater than 1.10 V (minimum voltage) is applied to this cell, the reverse of the spontaneous reaction will occur.

Sample Performance Indicator

Calculate the standard cell potential, E°_{cell} , for the following reactions and indicate if the reaction is spontaneous or non-spontaneous:



Electrochemical Cells: Cell Potential

Sample Teaching and Assessment Strategies

Activation

Students may

- Answer the question: What voltage must be applied to charge a 12 V car battery? Explain, based on efficiency.

Connection

Students may

- Brainstorm possible practical applications of electrochemical cells.

Consolidation

Students may

- Construct a table outlining similarities and differences between galvanic and electrolytic cells. Comparisons may be based on energy efficiency, direction of electron flow, direction of ion movement, energy conversions, and spontaneity.
- Determine the minimum voltage required to produce each of the following chemical reactions:
 1. $\text{Zn}^{2+} + 2 \text{Ag} \rightarrow \text{Zn} + 2 \text{Ag}^+$
 2. $\text{Co}^{2+} + \text{Cd}^{2+} \rightarrow \text{Co}^{3+} + \text{Cd}$
 3. $\text{Al}^{3+} + \text{Cu} \rightarrow \text{Cu}^{2+} + \text{Al}$

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 247-250

Chemistry: Newfoundland and Labrador (SR)

- pp. 670-675, 677-683
 - p. 678 (Table 1: Comparison of Galvanic and Electrolytic Cells)

Suggested

Resource Links: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202/resource-links.html>

- CurioCity: Battery Power
- CurioCity: Making Electricity From Bacteria
- Battery Research Prize (article)
- Table of Standard Reduction Potentials of Half-Cells

*Electrochemical Cells: Reactions***Outcomes**

Students will be expected to

87.0 predict whether oxidation-reduction reactions are spontaneous based on their reduction potentials [GCO 3]

88.0 predict the voltage of various electrochemical cells [GCO 3]

10.0 carry out procedures controlling the major variables and adapting or extending procedures where required [GCO 2]

22.0 compare theoretical and empirical values and account for discrepancies [GCO 2]

25.0 construct and test a prototype of a device or system and troubleshoot problems as they arise [GCO 2]

26.0 evaluate a personally designed and constructed device on the basis of criteria they have developed themselves [GCO 2]

Focus for Learning

Students should complete a lab investigation on galvanic cells including measuring voltages of various half-cell combinations. Students can compare results obtained in the lab with the accepted tabulated values found in the SRP Table.

Students should work in groups to construct possible cell combinations. Some suggested materials are listed below:

- Al
- Cu
- Fe
- Mg
- Ni
- Sn
- Zn
- 0.1 mol/L solutions of the corresponding nitrates

Voltage measurements should be shared with the class and compared to calculated theoretical voltages.

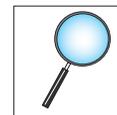
Students should be able to use an SRP Table to

- calculate cell voltage,
- rank the strength of oxidizing and reducing agents, and
- write and balance equations for redox reactions.

Students should be able to explain

- half-cell voltage,
- standard half-cell,
- cell voltage, E° ,
- spontaneous reaction, and
- non-spontaneous reaction.

Refer to the Integrated Skills unit for further elaboration on SCOs 10.0, 22.0, 25.0, and 26.0. This investigation also provides an opportunity to address additional inquiry-related skill outcomes from the Integrated Skills unit (e.g., 7.0, 8.0, 21.0, 23.0).



Electrochemical Cells: Reactions

Sample Teaching and Assessment Strategies**Connection**

Students may

- Discuss the difference between a battery and a cell.
- Explain differences between theoretical and measured values.
- Compare (theoretically) the reaction of copper with nitric acid to the reaction of copper with hydrochloric acid to determine which reaction is spontaneous.
- Discuss how the relative positions of SOA and SRA can be used to create a cell with the greatest voltage.

Extension

Students may

- Research why some reactions are spontaneous and some are not (entropy and enthalpy).
- Investigate the factors affecting the corrosion of iron.

Resources and Notes**Authorized**

Chemistry: Newfoundland and Labrador (TR)

- pp. 254-258

Chemistry: Newfoundland and Labrador (SR)

- pp. 704-705

Electrochemical Cells: Comparison

Outcomes

Students will be expected to

89.0 analyze why and how a particular technology was developed and improved over time
[GCO 1]

Focus for Learning

Teachers should remind students that changes or advancements in technology are the result of new demands. This is true in the area of new battery development which has occurred in response to demands of new technology such as mobile devices and automobiles. Students should identify different types of batteries as primary or secondary and be able to identify common examples of each, including those below:

- Alkaline
- Button
- Dry cell
- Lead storage
- Li-ion
- Li-ion polymer
- Ni-Cd

Students are not required to know the particular half-cell reactions for each battery.

Attitude

Encourage students to want to take action for maintaining a sustainable environment. [GCO 4]

Electrochemical Cells: Comparison

Sample Teaching and Assessment Strategies**Activation**

Students may

- Brainstorm a list of devices which use alkaline batteries versus those that use rechargeable batteries.

Connection

Students may

- Create and administer a survey to determine the types of batteries found in household electronics, tools, and/or vehicles.
- Keep a record (for a specified period of time) of all items they use that are powered by batteries. Record the device used and the number and the type of batteries it contains. Share with the class and discuss.

Consolidation

Students may

- Research the environmental effects of different types of batteries. Analyze both the production and waste costs. Share their research process and findings with the class. This task may be expanded to include electronic wastes in general.

Extension

Students may

- Research and share an overview of current battery technology such as those used in hybrid automobiles.

Resources and Notes**Authorized**

Chemistry: Newfoundland and Labrador (TR)

- pp. 251-252

Chemistry: Newfoundland and Labrador (SR)

- pp. 690-694

Electrochemical Cells: Processes

Outcomes

Students will be expected to

90.0 explain the processes of electrolysis and electroplating [GCO 3]

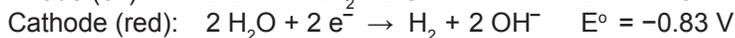
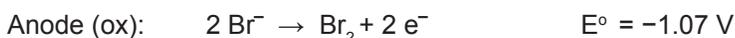
Focus for Learning

With reference to the electrolysis of water, molten salts, and aqueous solutions, students should be able to explain how the process of electrolysis works. They should be able to predict the most likely half-reactions to occur at the anode and the cathode of an electrolytic cell. Steps for predicting the most likely redox reactions are below:

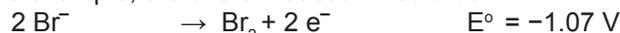
- List the species present.
- Identify the strongest oxidizing agent and write its half-reaction.
- Identify the strongest reducing agent and write its half-reaction.
- Write the balanced overall reaction.
- Determine the voltage.

To determine the products of the electrolysis of aqueous sodium bromide, complete the following steps:

1. List all species present: $\text{Na}^+(\text{aq})$, $\text{Br}^-(\text{aq})$, $\text{H}_2\text{O}(\text{l})$.
2. Identify all possible anodes (reducing agents): $\text{Br}^-(\text{aq})$ and $\text{H}_2\text{O}(\text{l})$.
3. Identify all possible cathodes (oxidizing agents): $\text{Na}^+(\text{aq})$ and $\text{H}_2\text{O}(\text{l})$.
4. Use the SRP Table to choose the strongest reducing agent (SRA) and the strongest oxidizing agent (SOA): SRA = $\text{Br}^-(\text{aq})$ and SOA = $\text{H}_2(\text{l})$



From the example, the overall reaction would be



E° values for half-reactions are taken from the SRP Table.

Students should perform stoichiometry calculations related to electroplating using Faraday's law of electrolysis, $Q = n_e F$, and $Q = It$.

$$n = \text{moles electrons (e}^-) = \frac{\text{current} \times \text{time}}{\text{Faraday's Constant}} = \frac{I \times t}{F}$$

Students should use stoichiometry and the appropriate half-reaction to calculate one of the following: molar amount of product, mass of product or current required, or time elapsed while electroplating.

Sample Performance Indicators

1. Predict the products for the electrolysis of 1.0 mol/L solution of lithium iodide. Include anode and cathode half-reactions and calculate the minimum cell potential.
2. Calculate the mass of zinc plated onto the cathode of an electrolytic cell by a current of 750 mA in 3.25 h.

Electrochemical Cells: Processes

Sample Teaching and Assessment Strategies

Activation

Teachers may

- Demonstrate both electrolysis and electroplating.
- Review the concept of mole ratios. Discuss the relationship between the number of moles of electrons transferred and number of moles of metal reduced at the cathode.

Connection

Students may

- Brainstorm and/or research industrial applications of Faraday's law (e.g., painting cars, galvanizing nails, silver plating, and chrome plating). Discuss.

Consolidation

Students may

- Determine the current required to produce 109 g of solid magnesium from a magnesium chloride solution (in 4.00 hours).
- Use a current of 1.55 A. Determine the number of minutes it takes to plate 0.925 g of silver onto the cathode of an electrolytic cell.
- Calculate the charge on the iridium ion if a current of 0.200 A is passed through a solution of iridium bromide for 1.00 h, resulting in the deposition of 0.478 g of iridium at the cathode.
- Calculate the moles of Mg produced when a current of 60.0 A is passed through a magnesium chloride solution for 4.00 hours.

Extension

Students may

- Research the use of electrolysis in soil remediation.
- Research the development of the electrolytic cell and how it has led to
 - discovery of several elements (Davy),
 - development of electroplating (Faraday),
 - purification of impure metals (Voisey's Bay),
 - electrowinning, and
 - electrorefining.

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 248-250

Chemistry: Newfoundland and Labrador (SR)

- pp. 677-683, 685-688, 704-707

Suggested

Resource Links: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202/resource-links.html>

- Centre for Distance Learning and Innovation (chemistry videos)
- Batteries Using Redox Reactions to Create Electricity (simulation)
- Electrolysis of Water (demonstration)

Hydrogen Fuel Cell

Outcomes

Students will be expected to

91.0 explain how electrical energy is produced in a hydrogen fuel cell [GCO 3]

Focus for Learning

Teachers should explain that fuel cells are electrochemical cells in which the cell reaction is identical to the combustion of hydrogen fuel where the chemical energy of the fuel is converted to electricity instead of heat energy.

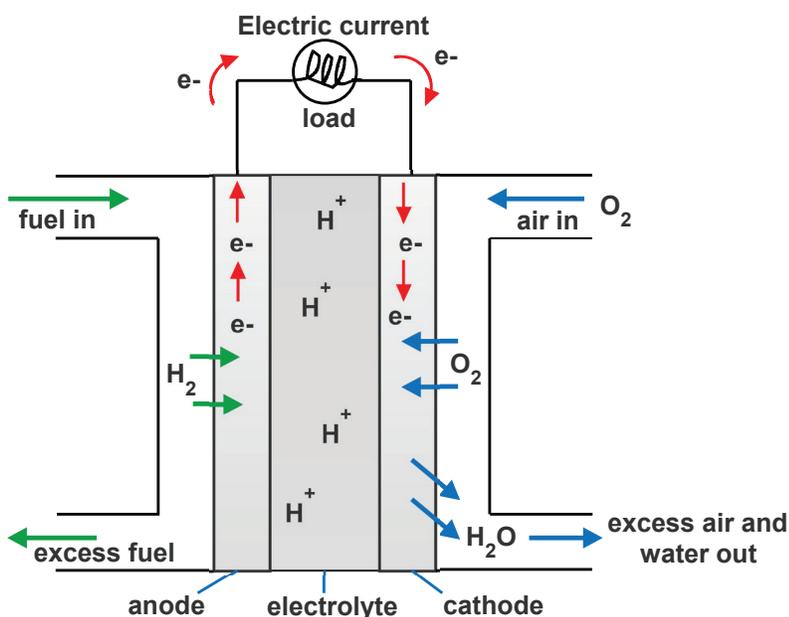
Students should be able to write half-reactions and the overall reaction for a hydrogen fuel cell. Students should research the advantages and disadvantages of hydrogen fuel cells to include the following:

Advantages

- The emission product (H_2O) is not harmful to the environment.
- In terms of efficiency, a hydrogen fuel cell converts approximately 65–80% of its chemical energy into the kinetic energy of the car, whereas a typical combustion engine converts only about 25%.
- It is a lightweight fuel source.

Disadvantages

- $\text{H}_2(\text{g})$ does not exist naturally on Earth, and is normally produced from the oxidation of hydrocarbon fuels (this process requires a source of energy).
- $\text{H}_2(\text{g})$ is highly explosive and is therefore difficult to store and transport in large quantities.



Sample Performance Indicator

Sketch a diagram of a hydrogen fuel cell. Write the two half-reactions occurring at the anode and cathode, give the overall reaction, and calculate the E° cell.

Hydrogen Fuel Cell

Sample Teaching and Assessment Strategies

Activation

Students may

- Discuss possible sources of clean energy.

Connection

Students may

- Compare the uses of different fuel sources for transportation.
- Research and discuss the use of hydrogen fuel cell technology in the building of automobiles.

Consolidation

Students may

- Research
 - alternate fuel cell types, and/or
 - NASA's use of hydrogen as a fuel.
- Describe how electrical energy is produced in a hydrogen fuel cell.

Extension

Students may

- Research local examples of hydrogen fuel cell technology (e.g., Ramea's wind-hydrogen-diesel-electricity energy system).

Resources and Notes

Authorized

Chemistry: Newfoundland and Labrador (TR)

- pp. 250-253

Chemistry: Newfoundland and Labrador (SR)

- pp. 639, 693-694

Suggested

Resource Links: <https://www.k12pl.nl.ca/curr/10-12/science/science-courses/chemistry-3202/resource-links.html>

- Centre for Distance Learning and Innovation (chemistry videos)
- Hydrogen: The Element That Destroyed The Hindenburg Could Power your Car
- NASA: Hydrogen Technology

Appendix A: Scientific Conventions

Scientific Conventions

Scientific information should be communicated according to accepted scientific conventions. These conventions include significant figures, formulas, units, and data (graphs, diagrams, tables). The Department of Education and Early Childhood Development follows the conventions below for public exams.

Significant Figures

Any number used in a calculation should contain only figures that are considered reliable; otherwise, time and effort are wasted. Figures that are considered reliable are called significant figures. Scientific calculations generally involve numbers representing actual measurements. In a measurement, significant figures in a number consist of:

Figures (digits) definitely known + one estimated figure (digit)

They are often expressed as “all of the digits known for certain plus one that is uncertain”.

Significant Figure Rules

1. All non-zero digits are significant.
2. Zero rules
 - Trailing zeros (i.e., at the end to the right) of a measurement may or may not be significant:
 - If it represents a measured quantity, it is significant (e.g., 25.0 cm - the zero is significant; the decimal is clearly indicated).
 - If immediately to the left of the decimal, it is not significant (e.g., 250 cm or 2500 cm - zeros are not significant; both have 2 significant digits as there is uncertainty whether zeros are measured values).
 - If the trailing zeros in 250 cm and 2500 cm are significant, the measurements must be written in scientific notation (e.g., 2.50×10^2 cm or 2.500×10^3 cm - zeros are significant).
Note: Scientific notation is not part of the K-12 mathematics program.
 - A zero, between two non-zero digits in a measurement, is significant (e.g., 9.04 cm - the zero is significant).
 - Leading zeros (i.e., at the beginning to the left) are never significant (i.e., they do not represent a measured quantity), they merely locate the decimal point (e.g., 0.46 cm and 0.07 kg - the zeros are not significant).

3. Rounding with Significant Figures

In reporting a calculated measured quantity, rounding an answer to the correct number of significant figures is important if the calculated measurement is to have any meaning. The rules for rounding are listed below.

- If the figure to be dropped is less than 5, eliminate it:
 - rounding 39.949 L to three significant figures results in 39.9 L
 - rounding 40.0 g to two significant figures results in 4.0×10^1 g
- If the figure to be dropped is greater than or equal to 5, eliminate it and raise the preceding figure by 1:
 - rounding 39.949 L to four significant figures results in 39.95 L
 - rounding 39.949 L to two significant figures results in 4.0×10^1 L

4. Multiplying and Dividing with Significant Figures

In determining the number of significant figures in a measurement that is calculated by multiplying or dividing, the measurement with the least number of significant figures should be identified. The final calculated measurement should contain the same number of significant figures as the measurement with the least number of significant figures.

$$2.1 \text{ cm} \times 3.24 \text{ cm} = 6.8 \text{ cm}^2$$

Since 2.1 cm contains two significant figures and 3.24 contains three significant figures, the calculated measurement should contain no more than two significant figures.

5. Adding and Subtracting with Significant Figures

In determining the number of significant figures when adding or subtracting, the final calculation should be rounded to the same precision as the least precise measurement.

$$42.56 \text{ g} + 39.460 \text{ g} + 4.1 \text{ g} = 86.1 \text{ g}$$

Since 4.1 g has only one decimal place, the calculated measurement must be rounded to one decimal place.

6. Performing a Series of Calculations with Mixed Operations

When a series of calculations is performed, it is important to remember that multiplication/division and addition/subtraction are governed by separate significant figure rules. Rounding only occurs at the last step.

When calculations involve both of these types of operations, the rules must be followed in the same order as the operations. Rounding still only occurs at the last step of the calculation.

$$\frac{(0.428 + 0.0804)}{0.009800}$$

The addition is first, $0.428 + 0.0804 = 0.5084$. Following the rules for addition/subtraction, the answer should have three significant figures, but rounding is the last step. Therefore, 0.5084 is used in the next step, $0.5084 \div 0.009800 = 51.87755$. Following the rules for multiplication/division, the answer should have four significant figures (but rounding is the last step). The sum of the numerator has three significant figures, and the denominator has four, so the final answer is rounded to three significant figures, 51.9.

In problems requiring multiple calculations (e.g., calculating final velocity and then using that value to calculate time), it is recommended that rounding only occur in the final calculation. Also, to improve accuracy and consistency, an extra digit should be carried in all intermediate calculations. Students may find it helpful to write the extra digit as a subscript (e.g., 39.5_4 [3 significant figures + 1 extra]).

7. Calculating with Exact Numbers

Sometimes numbers used in a calculation are exact rather than approximate. This is true when using defined quantities, including many conversion factors, and when using pure numbers. Pure or defined numbers do not affect the accuracy of a calculation. You may think of them as having an infinite number of significant figures. Calculating with exact numbers is important when dealing with conversions or calculating molar ratios in chemistry.

8. Scientific Constants

Treat scientific constants as significant digits because they are rounded values (i.e., actual measured or defined values have many decimal places [e.g., the speed of light constant, 3.00×10^8 m/s, is a rounded value based on the defined value, 299 792 458 m/s]).

9. Significant Figures in Logarithms

When determining the number of significant figures from a logarithm function, only the digits to the right of the decimal should be counted as significant figures.

- What is the pH of a sample of orange juice that has 2.5×10^{-4} mol/L hydronium ions?
The measurement 2.5×10^{-4} mol/L has two significant figures. The power of ten indicates where the decimal is located (i.e. 0.00025). The pH of the sample is $-\log(2.5 \times 10^{-4}) = 3.602\ 059$. The digit to the left of the decimal is derived from the power of ten, therefore, it is not significant. Only two digits to the right of the decimal are significant. The answer should be recorded as 3.60.
- What is the hydronium ion concentration of orange juice with pH = 2.25?
The pH value, 2.25, has two significant figures. The hydronium ion concentration is equal to the antilogs of -2.25. This value is 0.0056234 mol/L, which, when rounded to two significant figures, becomes 0.0056 mol/L or 5.6×10^{-3} mol/L.

Formulas and Units

A constructed response question that requires numerical calculations often uses formulas or equations as the starting point to its solution. Proper use of formulas and units in science indicates a thorough understanding of the logic to solve a problem. For any solution that requires the mathematical manipulation of a formula, the formula should be stated at the beginning, followed by workings that clearly indicate the mathematical computations necessary to find the solution.

For most cases in science, a SI unit follows a measured value because it describes the value. Three exceptions to this are pH, equilibrium constants, and index of refraction. The final answer of a solution for a constructed response question that requires the mathematical manipulation of a formula always has a unit with the value. The workings of a solution that lead to the final answer do not have to show units.

Data

Data is generally presented in the form of graphs, tables, and drawings. When these formats are used several scientific conventions should be followed.

Graphs

Graphs represent relationships between numerical information in a pictorial form. Two kinds of graphs are commonly used in science courses in Newfoundland and Labrador:

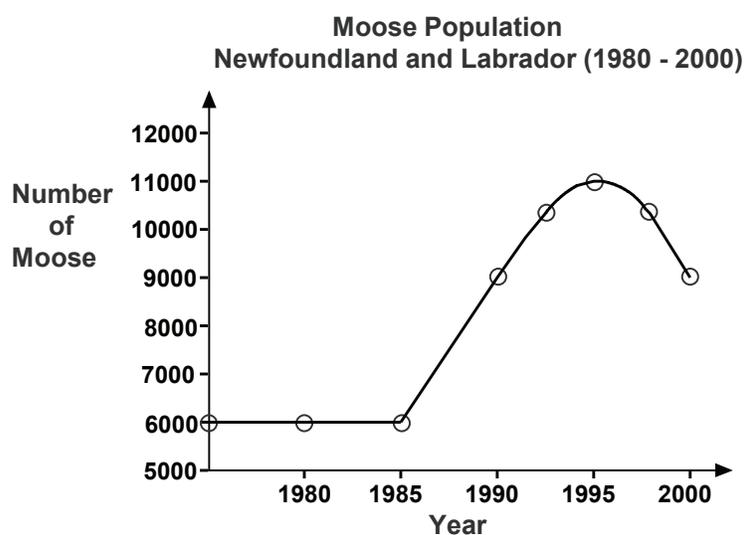
- Line graph
 - used to display the relationship between continuous data
 - demonstrates a progression of values or shows how one variable changes in relation to another variable (e.g., growth of a child with age)

Note: When equations are graphed, a line or curve of best-fit must be drawn.

- Bar graph
 - used to display discrete or discontinuous data
 - consists of parallel bars whose lengths are proportional to quantities given in a set of data. The items compared are plotted along the horizontal axis and appropriate measurement is plotted along the vertical axis (e.g., populations of different types of protists in a lake).

Graphing Rules:

1. The graph must have a title. The title represents the relationship between the two variables.
2. The independent variable is on the horizontal x-axis.
3. The dependent variable is on the vertical y-axis.
4. Each axis is specifically labelled with units (if applicable) according to the variable it represents and values are provided with equal increments. The scale does not have to be the same on both axes, but the scales must accommodate the ranges of the two variables (i.e., the graph line or series of bars must fill $\geq 75\%$ of the available space).
Note: It is not necessary that both axes start at zero. See example below.
5. When data are plotted, a circle should be placed around each point to indicate a degree of error. The graph may show exact numbers or a general relationship. A best-fit line or curve must be used in line and scatter graphs.
6. A legend may be used to identify individual lines on a multi-line graph.

**Tables**

Tables represent numerical or textual information in an organized format. They show how different variables are related to one another by clearly labelling data in a horizontal or vertical format. As with graphs, tables must have a title that represents the relationship between the variables.

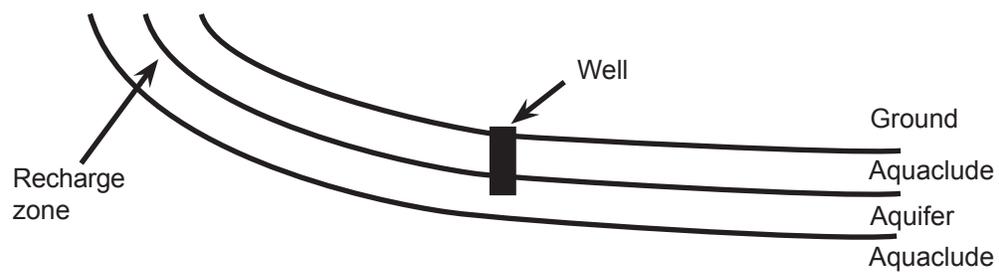
Moose Populations in Newfoundland and Labrador (1980 – 2000)

Year	Number of Moose
1980	5789
1985	6057
1990	8823
1995	11 156
2000	9315

Drawings

Biological drawings that indicate a scale are not required. Diagrams, however, may often be used to aid explanations. These should be clear and properly labelled to indicate important aspects of the diagram.

Geological Conditions Necessary for an Artesian Well



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