
Public District School Board Writing Partnership

Science

Course Profile

Chemistry

Grade 12

University Preparation

SCH4U

• *for teachers by teachers*

This sample course of study was prepared for teachers to use in meeting local classroom needs, as appropriate. This is not a mandated approach to the teaching of the course. It may be used in its entirety, in part, or adapted.

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Course Overview

Chemistry SCH4U, Grade 12, University Preparation

Policy Document: *The Ontario Curriculum, Grades 11 and 12, Science, 2000.*

Prerequisite: Chemistry SCH3U, Grade 11, University Preparation

Course Description

This course enables students to deepen their understanding of chemistry through the study of organic chemistry, energy changes and rates of reaction, chemical systems and equilibrium, electrochemistry, and atomic and molecular structure. Students will further develop problem-solving and laboratory skills as they investigate chemical processes, at the same time refining their ability to communicate scientific information. Emphasis will be placed on the importance of chemistry in daily life, and on evaluating the impact of chemical technology on the environment.

Course Notes

The Goals of Grade 12 Chemistry

Identified in *The Ontario Curriculum, Grades 11 and 12, Science, 2000* (p. 6): SCH4U has three goals:

- to relate science to technology, society, and the environment;
- to develop skills, strategies, and habits of mind required for scientific inquiry;
- to understand basic concepts of science.

The activities and assessment tasks in this profile reflect the importance of the three goals and have been developed around clusters of Specific Expectations. A design down approach was used in developing the overall course and individual units. The Final Assessment Task for the course was developed first, followed by the End-of-Unit Tasks. The Expectations in each unit were clustered into activities that connected together logically and provided the necessary background knowledge and skills to be applied in the completion of the End-of-Unit Tasks. However, this is by no means the only possible clustering. The unit activities were then expanded following each overview chart. Although this is a deviation from the suggested format, it is not intended to be either restrictive or prescriptive; instead its intent is to provide teachers with suggestions for course development. Teachers may adapt the profile to suit their circumstances and to match their students' needs while ensuring that all learning expectations of the course are addressed fully. Such adaptation may include selection of some but not all of the suggested experiments.

Scientific Literacy for All Students and Preparation for Further Study

The paramount task of science education is to equip all students with scientific literacy – the combination of knowledge, skills, and habits of mind that enable them to think creatively, reason logically, evaluate information critically, and communicate effectively. This is an essential base for making productive and ethical decisions, not only about scientific and technological issues but in all areas of life.

The Ontario Curriculum, Grades 11 and 12: Science, 2000 (p. 4) notes that “Achieving excellence in scientific literacy is not the same as becoming a science specialist.” The focus in Grade 12 chemistry is scientific literacy for all students, with preparation for further studies in chemistry and related disciplines for some students. The policy document goes on to note, “The newer aspects of the science curriculum – especially those that focus on science, technology, society, and the environment (STSE) – call for students to deal with the impacts of science on society and the environment, which includes both the natural environment and the workplace environment. This requirement brings in issues that relate to human values. Science can therefore not be viewed as merely a matter of “facts”; rather, it is a subject in which students learn to weigh the complex combinations of fact and value that developments in science and technology have given rise to in modern society.” (p. 4)

This perspective is consistent with the vision advanced in this profile. The challenge in delivering the course is to find ways to bring to the classroom an STSE focus from which the facts and chemistry-specific skills derive naturally.

At the same time, SCH4U must adequately prepare those students who will opt for further study of the subject in university and other postsecondary institutions. It is important to note that SCH4U is a university preparation course and not a copy of a first year university course in chemistry. Knowledge and skills must be learned, practised, assessed, and evaluated at a standard that enables students to realistically assess their aptitude and preparation for success in further studies in chemistry and possible employment in a related field.

Policy Requirements

The Ontario Curriculum, Grades 11 and 12, Science, 2000 contains recommendations regarding teaching approaches and curriculum expectations that are reflected in this profile and should be evident in courses developed using this profile as a sample.

- The expectations in science courses call for an active, experimental approach to learning, and require all students to participate regularly in laboratory activities;
- Where opportunity allows, students might be required, as part of their laboratory activities, to design and conduct research on a real scientific problem for which the results are unknown;
- Where possible, concepts should be introduced in the context of real-world problems and issues;
- In all courses, a list of expectations precedes each strand. These expectations describe skills that are considered to be essential for scientific investigation, e.g., skills in research, in the use of materials, and in the use of units of measurement, and skills required for investigating possible careers in the subject area. These skills apply to all areas of course content and *must be developed in all strands* of the course. Assessment of students' mastery of these skills must be included in the evaluation of students' achievement of the expectations for the course. These expectations are Science Investigative Skills (SIS). When developing detailed course plans, it is recommended teachers use these SIS Expectations as a primary guide. These skills serve as a lens through which all Expectations in the profile are interpreted.

Planning and Implementing Grade 12 Chemistry

As teachers organize and plan the delivery of Expectations of SCH4U, using and/or adapting activities described in this profile, they should consider the following:

- SCH4U requires a focus on inquiry skills. Through a variety of investigations, students describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others. They identify their assumptions, use critical and logical thinking, and consider alternative explanations. Direct experience with chemicals, materials, and laboratory equipment is necessary to illuminate theoretical concepts and develop skills.
- A number of activities in this profile have a research focus that requires accessing information beyond the laboratory or field trip. Students should be taught how to use all available sources of information – people, print, online sources, and other media, both within the school and in the community. They should also be given opportunities to use those skills, and to experience the challenges that invariably accompany the location and acquisition of valid information. However, care must be taken that student time is spent primarily on processing information rather than accessing information, so that the research does not become an end in itself.

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- The Expectations are central to all aspects of this profile. The context in which each unit is delivered, the skills and concepts developed, and the assessment tasks used must be interconnected, and linked to the Expectations. The assessment data accumulated throughout the course must be sufficient (in kind and number) to permit teachers to evaluate the consistent level of performance for each student in each of the four categories in the Achievement Chart for Science (*The Ontario Curriculum, Grades 11 and 12, Science, 2000* pp. 174–175).
 - Some of the expectations are given special emphasis in learning activities and are often revisited. These are expectations that are taught, assessed, evaluated, and where necessary, revisited using alternate instructional strategies.
 - Students interpret new information in terms of what they already know. They try to make sense of what is taught by trying to fit it into their experiences. A key concept is understood when students examine significant examples that represent the concept, then create a generalization from those personal experiences. The teachers must be aware of the experiences that students have had prior to Grade 12 and use them as the basis for new and more complex concepts. Students may also arrive with misconceptions from prior experience that will interfere with their ability to understand new concepts. Identifying misconceptions and revising them using concrete examples may be required at times. A number of diagnostic tools and activities are suggested throughout the profile.
 - Terminology, formulae, and algorithms should be viewed by students as tools for describing observations, solving problems, and communicating ideas, not isolated pieces of information. It is important to emphasize key skills and concepts without obscuring them by expecting students to memorize a multitude of facts, equations, and formulae. (For example, the nomenclature of inorganic and organic chemicals should be limited to what is helpful to understand key concepts.) Students could be encouraged to develop reference sheets of significant formulae, algorithms and concepts for use in class and on tests or examinations. When the size of the sheet is limited, e.g., to a single-sided sheet of paper, handwritten, preparation requires that students review their work, then identify and summarize critical information. Such reference sheets may be submitted for assessment and evaluation of Learning Skills. Teachers may also choose to supply a reference sheet for student use. Use of reference sheets allows teachers to move the focus of evaluation away from factual recall and toward higher-level thinking skills.
 - Assessment should focus on the application of terminology to explain concepts and phenomena, not on terms and definitions in isolation. It is essential that students understand the concept before acquiring the vocabulary.
 - This profile describes a chemistry course in which students are encouraged to ask their own questions and, in many cases, find their own answers by inquiry (experiment or research). Fundamental to the skill set of a scientifically literate person/citizen is the ability to ask incisive questions, to interpret the answers critically, and to identify un-stated assumptions.
 - In this profile, there is a reduced emphasis on traditional laboratory activities in which students are provided step-by-step instructions. Teacher demonstrations can be used in place of these activities and the time saved used for developing students' ability to devise and carry out true experimental inquiry. The teacher's role is to decide what knowledge and skills students must have to proceed safely and successfully in a laboratory setting. Many traditional laboratory exercises can be opened up by rewording statements into questions, and replacing detailed procedures with a teacher-led class discussion. This could be followed by a challenge, which requires students to devise a procedure and confirm with the teacher that safety factors have been adequately addressed before carrying it out. By making decisions regarding what data to collect and which format to use for reporting both data and results, students develop skills of inquiry and communication essential in science.

Resources

Resources are listed throughout the unit overviews and the full unit, wherever the writers felt it provided the most support for teachers. The URLs for the websites were verified by the writers prior to publication. Given the frequency with which these designations change, teachers should always verify the websites prior to assigning them for student use.

Units in this course profile make reference to the use of specific texts, magazines, films, videos, and websites. Teachers need to consult their board policies regarding use of any copyrighted materials. Before reproducing materials for student use from printed publications, teachers need to ensure that their board has a Cancopy licence and that this licence covers the resources they wish to use. Before screening videos/films with their students, teachers need to ensure that their board/ school has obtained the appropriate public performance videocassette licence from an authorized distributor, e.g., Audio Cine Films Inc. Teachers are reminded that much of the material on the Internet is protected by copyright. The copyright is usually owned by the person or organization that created the work. Reproduction of any work or substantial part of any work on the Internet is not allowed without the permission of the owner.

Rationale for the Unit Sequence of the Course Profile

The goal of this course is to lead students to develop independent learning strategies, such as making their own notes from a lesson, drawing connections across several strands of study, designing and conducting investigations for which they have generated their own question, and participating in seminars. This course has been organized around two themes. The first three units – Chemical Systems and Equilibrium, Energy Changes and Rates of Reaction, and Electrochemistry – are unified by the theme of chemical reactions. The last two units, Structure and Properties of Matter and Organic Chemistry, both involve the study of how the structure of matter affects chemical and physical properties. Introducing the course through the Chemical Systems and Equilibrium unit is a non-traditional approach. Courses generally begin with both a diagnostic assessment and a review of student knowledge and skills. Since the Equilibrium unit in SCH4U is a direct extension of the Solutions and Solubility unit of SCH3U, studying it first emphasizes the bridging between the courses and makes efficient use of the time spent reviewing SCH3U material. Secondly, the unit provides many opportunities to exercise appropriate lab safety and inquiry skills that set an appropriate tone early in the course. Thirdly, the unit's strong emphasis on wet-lab procedures stimulates students to generate ideas for the Final Assessment Task early in the course. The second unit, Energy Changes and Rates of Reactions is a continuation of the study of chemical reactions focusing on energy changes. It too is very experimentally based, and provides students with opportunities to generate ideas and practice skills required for the Final Assessment Task. The third unit is Electrochemistry, which examines the interconversion of electrical and chemical energy in chemical reactions. The fourth and fifth units of study are Structure and Properties of Matter and Organic Chemistry. The latter is an application of the skills and information acquired in the former. Also, since both these units are theory intensive, positioning them at the end of the course provides students with opportunities to exercise more independent learning strategies, e.g., taking notes from a lecture, participating in seminars.

Units: Titles and Times

* Unit 1	Chemical Systems and Equilibrium	30 hours
Unit 2	Energy Changes and Rates of Reaction	18 hours
Unit 3	Electrochemistry	18 hours
Unit 4	Structure and Properties of Matter	16 hours
Unit 5	Organic Chemistry	16 hours
Unit 6	Final Assessment Tasks	12 hours

* This unit is fully developed in this Course Profile.

Unit Overviews

Unit 1: Chemical Systems and Equilibrium

Time: 30 hours

Unit Description

In this unit, students increase their understanding of solutions to incorporate equilibrium systems. Students investigate the behaviour of different equilibrium systems, e.g., liquid-vapour, insoluble salts, weak acids and bases, and solve problems involving the law of chemical equilibrium. Le Chatelier's principle is used to predict how various factors affect a chemical system at equilibrium. Students explore the importance of equilibrium systems in their daily lives, e.g., how equilibrium systems optimize the production of industrial chemicals and the role they play in biological systems. Throughout the unit the teacher leads students to use more independent learning strategies, e.g., students generate their own notes and compare these with teacher expectations. In the End-of-Unit Task, students use their titration skills and their understanding of molar solubility and the common ion effect to determine an unknown concentration. Students also complete a written test.

Unit Overview Chart

Activity/Time	Learning Expectations	Assessment Categories
1.1 Introduction to Equilibrium Systems 10 h	CSV.01, CSV.02, CSV.03, CS1.01, CS1.02, CS1.03, CS1.07, CS2.01, CS2.02, CS2.03, CS2.06, CS3.01 SIS.01, SIS.02, SIS.03, SIS.07, SIS.08, SIS.09	Knowledge/Understanding Inquiry Communication Making Connections
1.2 Entropy 2.0 h	CSV.01, CS1.04, CS1.05	Knowledge/Understanding Communication
1.3 Solubility of Salts 6 h	CSV.01, CSV.02, CS1.06, CS1.07, CS2.01, CS2.03, CS2.04, CS2.05, CS2.06, CS3.02 SIS.01, SIS.02, SIS.03, SIS.08, SIS.09, SIS.10	Knowledge/Understanding Inquiry Communication Making Connections
1.4 Acid Base Equilibrium 6 h	CSV.01, CSV.02, CS1.07, CS1.08, CS2.01, CS2.03, CS2.06, CS2.07, CS2.08 SIS.01, SIS.02, SIS.03, SIS.09	Knowledge/Understanding Inquiry Communication Making Connections
1.5 Buffer Solutions 2.5 h	CSV.01, CSV.03, CS1.09, CS3.03 SIS.06	Knowledge/Understanding Inquiry Communication Making Connections
1.6 End-of-Unit Task 3.5 h	CSV.01, CSV.02, CSV.03 SIS.01, SIS.02, SIS.03	Knowledge/Understanding Inquiry Communication Making Connections

Unit 2: Energy Changes and Rates of Reaction

Time: 18 hours

Unit Description

This unit involves the study of energy transformations and kinetics of chemical changes. Energy changes for physical and chemical processes and rates of reaction are studied through experimental data and calculations. Research is done on the dependence of chemical technologies and processes on the energetics of chemical reactions. Students may complete a large quiz at the end of both the Energy Changes and the Rates of Reaction section. For the End-of-Unit Task, students design and conduct an experiment to investigate the energy production/absorption and the rate associated with a chemical reaction. A mid-term examination, if one is planned, may take place at the end of this unit.

Unit Overview Chart

Activity/Time	Learning Expectations	Assessment Categories
2.1 Enthalpy and Heats of Reaction 4.0 h	ECV.01, ECV.02, ECV.03, EC1.01, EC2.01, EC2.03, EC3.01, EC3.02 SIS.02, SIS.08, SIS.09, SIS.10	Knowledge/Understanding Inquiry Communication Making Connections
2.2 Hess's Law and Thermochemical Equations 3.0 h	ECV.01, ECV.02, EC1.02, EC2.01, EC2.02, EC2.04, EC2.05 SIS.03, SIS.08, SIS.09	Knowledge/Understanding Inquiry Communication
2.3 Rates of Reaction 5.0 h	ECV.01, ECV.02, ECV.03, EC1.03, EC2.01, EC2.06, EC3.03 SIS.01	Knowledge/Understanding Inquiry Communication Making Connections
2.4 Collision Theory 2.0 h	ECV.01, ECV.02, ECV.03, EC1.03, EC1.04, EC1.05, EC2.01, EC3.04 SIS.01, SIS.02, SIS.05	Knowledge/Understanding Inquiry Communication
2.5 Reaction Mechanism 1.0 h	ECV.01, ECV.02, EC1.06, EC2.01	Knowledge/Understanding Communication Making Connections
2.6 End-of-Unit Task: Controlling Reaction Rate 3.0 h	ECV.01, ECV.02, ECV.03 SIS.01, SIS.02, SIS.03	Knowledge/Understanding Inquiry Communication Making Connections

Suggested Activities

Enthalpy and Heats of Reaction

- 2.1.1 The teacher introduces key concepts related to heats of reactions pertinent to the lab activity (outlined below) such as: heats of reactions; calorimeters; specific heat capacity; and enthalpy. Students determine the heat of a reaction using a calorimeter, and use the data obtained to calculate the enthalpy change for a reaction, e.g., neutralization of NaOH with HCl. The teacher may use a checklist to assess the student's scientific investigative skills, e.g., use appropriate instruments effectively and accurately, and express the result to the appropriate number of significant digits.
- 2.1.2 Students discuss and compare their results from Activity 2.1.1. This is followed by a teacher-directed lesson on the energy transformations of a reaction, with emphasis on the use of appropriate scientific vocabulary, e.g., activated complex.

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- 2.1.3 Students participate in a seminar activity. They gather information from a variety of sources to: compare the energy changes resulting from physical change, chemical reactions and nuclear reactions (fission and fusion); compare conventional and alternative sources of energy with respect to efficiency and environmental impact. Working in smaller groups students discuss and record their findings.
- 2.1.4 Students research and describe examples of technologies that depend on exothermic and endothermic changes, e.g., hydrogen rocket fuel, hot and cold packs, and the primary reaction(s) involved in the processes. They also investigate careers related to the use and development of these technologies.

Assessment Lab Report – Abstract and Results (Knowledge/Understanding, Inquiry, Communication), Seminar (Knowledge/Understanding, Inquiry, Communication), Research (Inquiry, Making Connections)

Hess's Law and Thermochemical Equations

- 2.2.1 A teacher-directed lesson on: enthalpy of reaction; enthalpy of formation; thermochemical equations; energy changes as a ΔH value or as a heat term in the equation; the difference between heat and enthalpy; Hess's Law; and the application of Hess's Law to determine the net change in enthalpy. Students generate their own note.
- 2.2.2 Students work in small groups to solve problems calculating the heat of a reaction using tabulated enthalpies of formation and data obtained through experimentation.
- 2.2.3 Students choose a reaction, formulate a question, and design an experiment to measure the heat of reaction, e.g., reactions that can be combined to yield the ΔH of combustion of magnesium or the ΔH of reaction of calcium metal with cold water.

Assessment Problems (Knowledge/Understanding, Communication), Lab Report – Procedure and Analysis of Results, (Inquiry, Communication), Written Quiz (Knowledge/Understanding, Communication)

Rates of Reaction

- 2.3.1 The teacher demonstrates how reaction rates can be measured, e.g., observe volume of gas for metal and acid. Follow this up with a brainstorming activity on practical means of measuring various rates of reactions, including common environmental and industrial reactions.
- 2.3.2 Students work independently, using several graphs provided by the teacher and a textbook, to describe the rate of a reaction as a function of change in concentration of reactant or product with respect to time. They also express the rate of a reaction as a rate law equation. Students discuss their findings with the class.
- 2.3.3 Students work in small groups to: determine patterns in concentration changes for sets of reactants and products (given data); define first-order and second-order reactions; classify reactions into correct reaction-order categories; plot given data to observe any patterns for first and second order reactions; and explain the half-life of a reaction. Students generate their own note.
- 2.3.4 Students formulate a question and design an experiment to determine the rate of a reaction. The teacher may direct students to a list of possible reactions from which they can choose. An emphasis is placed on students defining the method used to determine the rate of the reaction.
- 2.3.5 The teacher conducts a class discussion about the results of Act 2.3.4 followed with a teacher-directed lesson on potential energy diagrams for molecules in a system, and the effect of temperature, concentration and catalysts on the number of reactive molecules.
- 2.3.6 Students gather information using a variety of sources to describe the use of catalysts in industry and in biochemical systems, and to explore related career opportunities.

Assessment Written quiz (Knowledge/Understanding, Making Connections), Lab Report – Procedure (Knowledge/Understanding, Inquiry, Communication)

Collision Theory

- 2.4.1 The teacher conducts a lesson on the collision theory followed by group work with model-kits to investigate and simulate particles engaging in a reaction, e.g., orientation and speed of collision. This is followed by a class discussion about the rates of several reactions, e.g., oxidation of metals, explosions, food decay, and catalytic converter reactions. The teacher describes how some reaction rates can be controlled. Students generate their own notes and compare them with peers.
- 2.4.2 Students solve problems using the collision theory and potential energy diagrams to explain how temperature, surface area, nature of reactants, catalysts and concentration control the rate of a chemical reaction.
- 2.4.3. Students select a reaction, e.g., iodine clock reaction, formulate a question, and design an experiment to control the rate at a given value by controlling various factors. Students may choose to design a control mechanism for the reaction used in Act 2.3.4.

Assessment Problem Worksheet (Knowledge/Understanding, Communication),
Lab Report – Procedure and Results (Inquiry, Communication)

Reaction Mechanism

- 2.5.1 The teacher conducts a lesson on reaction mechanisms of a variety of reactions, both simple and complex, emphasizing that most reactions occur as a series of elementary steps and that enthalpies of initial reactant and final product are independent of the reaction mechanism. Show potential energy diagrams for reaction mechanism.
- 2.5.2 Provide a worksheet with several problems analysing and predicting radical formation and reaction mechanisms from potential energy diagrams.

Assessment Problem Worksheet (Knowledge/Understanding, Communication),
Written Quiz based on Kinetics (Knowledge/Understanding, Making Connections)

End-of-Unit Task: Controlling Reaction Rate

- 2.6.1 Students formulate a question, design, and conduct an experiment to calculate the heat associated with a particular reaction and to demonstrate how the rate of the reaction can be controlled. There is also an opportunity to assess SIS expectations.
- 2.6.2 This stage of the unit is the unit test or mid-term examination. Ensure that some questions are designed to assess the Making Connections Expectations.

Assessment Lab Report (Inquiry, Connections),
Unit Test (Knowledge/Understanding, Making Connections)

Resources

Iodine Clock – www.ucdsb.on.ca/tiss/stretton/chem2/ratelab1.htm
– www.usoe.k12.ut.us/curr/science/sciber00/8th/matter/sciber/iodine.htm
Science Teachers' Resource Centre (Lapeer County Information Depot
– <http://chem.lapeer.org/Chem1Docs/Index.html>
World of Chemistry, TVO series, 1988 – Episode Molecules In Action

Unit 3: Electrochemistry

Time: 18 hours

Unit Description

In this unit, students demonstrate an understanding of fundamental concepts related to oxidation-reduction and the interconversion of chemical and electrical energy. Students build and explain the functioning of simple galvanic and electrolytic cells and use equations to describe these cells and solve quantitative problems related to electrolysis. Students describe some uses of batteries and fuel cells, explain the importance of electrochemical technology to the production and protection of metals and assess environmental and safety issues associated with these technologies. In the End-of-Unit Task students design and construct their own battery of a given voltage.

Unit Overview Chart

Activity/Time/Focus	Learning Expectations	Assessment Categories
3.1 Introduction to 2.0 h Electrochemistry	ELV.01, ELV.03, EL3.03 SIS.05, SIS.06, SIS.07	Knowledge/Understanding
3.2 Redox Reactions and Equations 3.0 h	ELV.01, ELV.02, EL1.01, EL2.01, EL2.02, EL2.03 SIS.05, SIS.06, SIS.07, SIS.08	Knowledge/Understanding Communication
3.3 Electrochemical Cells 4.5 h	ELV.01, ELV.02, ELV.03, EL1.02, EL1.03, EL1.04, EL1.06, EL2.01, EL2.02, EL2.04, EL2.05, EL3.01 SIS.01, SIS.02, SIS.03, SIS.04, SIS.08, SIS.09	Knowledge/Understanding Inquiry Communication Making Connections
3.4 Electrolytic Cells 4.5 h	ELV.01, ELV.02, ELV.03, EL1.02, EL1.05, EL2.01, EL2.04, EL2.06, EL2.07, EL3.02 SIS.01, SIS.02, SIS.03, SIS.04, SIS.05, SIS.06, SIS.07, SIS.08, SIS.09, SIS.10	Knowledge/Understanding Inquiry Communication Making Connections
3.5 End-of-Unit Task Design a Battery 4.0 h Written Test	ELV.01, ELV.02, ELV.03 SIS.01, SIS.02, SIS.03, SIS.04, SIS.05, SIS.06, SIS.07, SIS.08, SIS.09	Knowledge/Understanding Inquiry Communication Making Connections

Suggested Activities

Introduction to Electrochemistry

- 3.1.1 Introduce the End-of-Unit Task and remind students to make an appointment to conference with the teacher about the Final Assessment Task. Allow time for students to ask clarification questions.
- 3.1.2 Conduct discussion used to prepare students for the concepts they will need in this unit with questions such as: Do metals and electrolytic solutions conduct electricity in the same way? Explain. Why do some drivers in northern climates often take their car batteries inside on very cold nights? How can you tell that a nail has corroded? Is corrosion confined to the surface of a metal? Explain. How does corrosion affect the performance of the nail? If corrosion is a metal oxide, how might it be formed? How could you predict which of the following nails would corrode first: one made of iron, one made of aluminum or one made of stainless steel? What does it mean for something to be bonded? Are all bonds the same? What are batteries made of and how do they operate? Why is one battery marked 1.5V and another battery marked 9V? What is the purpose of sulfuric acid in a car battery? What effects might discarded batteries have on the environment?

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- 3.1.3 Students take part in a diagnostic assessment, e.g., short quiz, to assess understanding of the following concepts: electronegativity and periodic trends; formation and characteristics of ions; conductivity in metals and salt solutions; covalent bonding; balancing equations, replacement reactions, and activity series.
 - 3.1.4 The teacher could have several electrochemical cells prepared for a class discussion of the interconversion of chemical and electrical energy, such as: 1) an overhead demonstration of a redox reaction, e.g., zinc metal in a petri dish of copper sulfate solution showing the plating of copper metal; 2) a strip of zinc and a thermometer suspended in a copper sulfate solution to observe the heat energy released as the redox reaction occurs; and 3) a galvanic cell connected to a voltmeter or light bulb, e.g., copper and zinc electrodes immersed in sulfate solutions of their respective ions and separated by a porous barrier showing the production of electric energy instead of heat.
 - 3.1.5 The teacher introduces the Research Report. Students research and assess environmental, health, and safety issues involving electrochemistry, e.g., the corrosion of metal structures by oxidizing agents, industrial production of chlorine by electrolysis and its use in the purification of water, the use of antioxidants BHT (butylated hydroxytoluene) and BHA (butylhydroxyanisole) as food additives. This activity should be handed in at the end of the unit.

Assessment Diagnostic

Redox Reactions and Equations

- 3.2.1 Conduct lesson on redox reactions; assigning oxidation numbers; and balancing redox equations using changes in oxidation numbers. Introduce students to an easy mnemonic device such as OIL RIG.
- 3.2.2 Students investigate redox reactions and the activity series. They determine which metal ions are the best/poorest oxidizing agents and which metals are the strongest/weakest reducing agents, develop an activity series and identify other common oxidizing and reducing agents.
- 3.2.3 Conduct a lesson related to balancing redox equations using the half-cell method.
- 3.2.4 Students discuss and identify everyday redox reactions, e.g., discolouration of fruit, testing of urine for sugar, bioluminescence, rusting of iron, making of blueprints and cleaning of tarnished silverware.
- 3.2.5 Students develop a graphic organizer for this activity.

Assessment Graphic Organizer (Knowledge/Understanding, Communication),
Quiz (Knowledge/Understanding)

Electrochemical Cells

- 3.3.1 Conduct a lesson and demonstration using an electrochemical cell as a visual aid for introducing terminology, e.g., half-cells, voltage, current, electrodes, cell potential, potential difference. Students make their own notes, including a labelled diagram demonstrating the set up.
- 3.3.2 Create a problem-solving activity for students to determine: oxidation and reduction half-cell reactions; direction of current flow; electrode polarity; cell potential; ion movement in typical galvanic cells.
- 3.3.3 The teacher leads a lesson on: standard potential, reduction potential, calculating standard reduction potentials, predicting the spontaneity of redox reaction and overall cell potentials by studying a table of half-cell reduction potentials.
- 3.3.4 Through inquiry, students construct electrochemical cells, measure their cell potentials, and identify and describe the function of the components.
- 3.3.5 Students make their own notes, e.g., concept maps, graphic organizers, embedded notes, etc. from their textbook describing common electrochemical cells, e.g., lead-acid, nickel-cadmium, and evaluate their environmental and social impact, e.g., describe how advances in the hydrogen fuel cell have facilitated the introduction of electric cars. Students participate in peer assessment of their notes.

3.3.6 Students make their own notes from their textbook describing corrosion as an electrochemical process, and describing corrosion-inhibiting techniques, e.g., painting, galvanizing, cathodic protection. This activity could be assessed with a quiz.

Assessment Quizzes (Knowledge/Understanding, Inquiry, Making Connections),
Lab Report (Knowledge/Understanding, Inquiry, Communication),

Electrolytic Cells

3.4.1 The teacher sets up an electrolytic cell as a visual aid for this lesson, and discusses with students electrolysis, electrolysis of melted binary salts and of aqueous solutions. Emphasize that electrolytic reactions are non-spontaneous reactions that take place because of the addition of electrical energy to the system and that the system undergoes an increase in potential energy. Students make their own notes including a labelled diagram demonstrating the set up.

3.4.2 Students make their own notes from their textbook on: how electrolytic processes are involved in industrial processes, e.g., Inco Limited's Canadian electrolytic operation for refining copper; the electroplating of the Canadian dollar coin at the Sherrit Gordon plant in Fort Saskatchewan, Alberta; the production of chlorine and sodium at Dow Chemical in Fort Saskatchewan, Alberta; the production of aluminum, from imported bauxite ore.

3.4.3 Students make their own notes on the quantitative aspects of electrolysis, the inter-relationship of time, current, and the amount of substance produced or consumed in an electrolytic process (Faraday's Law). As a check for accuracy, students share the information from this and the previous lesson with their peers. Students direct clarification questions to the teacher.

3.4.4 Students solve quantitative problems related to electrolysis.

3.4.5 Students assemble an electrolytic cell, use equations to describe the cell, measure through experimentation the mass of metal deposited by electroplating and apply Faraday's law to relate the mass of metal deposited to the amount of charge passed. Students should account for the difference between theory and observation.

3.4.6 Students identify and describe science- and technology-based careers related to electrochemistry.

Assessment Quiz (Knowledge/Understanding, Inquiry, Making Connections),
Problems Worksheet (Inquiry), Lab Report (Inquiry, Communication),
Research (Inquiry, Communication, Making Connections)

End-of-Unit Task: Design a Battery

3.5.1 Students design a battery that produces 5.0V using standard lab materials.

3.5.2 Written Test

Assessment Battery Report (or other method) (Inquiry, Communication),
Unit Test (Knowledge/Understanding, Making Connections)

Resources

Electrochemistry, TVO Video Series, 1987.

Jaeger, Dave and Suzanne Weisker. *Holt Chemistry: Visualizing Matter Laboratory Experiments*. United States: Holt, Rinehart and Winston, Inc., 1996. ISBN 0-03-095284-0

Jenkins, Frank et al. *Nelson Chemistry*. Nelson Canada, 1993. ISBN 0-017-603863-9

Tocci, Salvatore and Claudia Viehland. *Holt Chemistry: Visualizing Matter*. United States: Holt, Rinehart and Winston, Inc., 1996. ISBN 0-03-000193-5

Tocci, Salvatore and Claudia Viehland. *Holt Chemistry: Visualizing Matter Study Guide*. United States: Holt, Rinehart and Winston, Inc., 1996. ISBN 0-03-095283-2

Toon, Ernest R., et al. *Foundations of Chemistry*. Holt, Rinehart and Winston of Canada, Limited, 1990. ISBN 0-03-922287-X

American Chemical Society

– http://chemistry.org/portal/Chemistry?PID=acsdisplay.html&DOC=vc2\1rp\1rp1_markers.html

Ernest B. Yeager Center for Electrochemical Sciences (YCES)

– <http://electrochem.cwru.edu/ed/dict.htm#e32>

– <http://www.geocities.com/CapeCanaveral/Lab/5875/>

– <http://www.geocities.com/CapeCanaveral/Lab/5875/>

– http://www.riverdeep.net/science/chemistry_explorer/ce_overviews/catn.ovw_ELC.jhtml

– <http://www.snowbirdsoftware.on.ca/>

World of Chemistry, TVO Video Series, 1988 – *World of Chemistry: The Busy Electron*

Unit 4: Structure and Properties of Matter

Time: 16 hours

Unit Description

This unit increases student understanding of the structure of the atom by exploring the quantum mechanical model. They describe products and contributions that have advanced the knowledge of atomic and molecular theory, write electronic configurations, and explain the relationship between the position of elements in the periodic table and their properties. Students investigate solids/liquids and explain how types of chemical bonding account for the properties of ionic, molecular, covalent network and metallic substances. Students predict molecular shape using the Valence Shell Electron Pair Repulsion model. The End-of-Unit Task consists of three parts. First, students analyse the properties of an unknown solid or liquid to determine the type of substance it is (ionic, molecular, covalent network or metallic) and explain their observations. Secondly, students use the Valence Shell Electron Pair Repulsion (VSEPR) theory to predict the shape and polarity of a molecule. Thirdly, students complete a written test.

Unit Overview Chart

Activity/Time/Focus	Learning Expectations	Assessment Categories
4.1 Development of the Model of the Atom 3.0 h	SPV.01, SPV.03, SP1.01, SP3.03	Inquiry Communication Making Connections
4.2 Quantum Mechanic Model 2.5 h	SPV.01, SPV.02, SPV.03, SP1.02, SP1.03, SP2.01, SP2.02, SP3.01 SIS.05, SIS.07	Knowledge/Understanding Inquiry Communication Making Connections
4.3 Intramolecular Forces of Attraction 3.0 h	SPV.01, SPV.02, SP1.04, SP2.01, SP2.05, SP2.06 SIS.01, SIS.02, SIS.03	Knowledge/Understanding Inquiry Communication
4.4 Predicting Shape 2.0 h	SPV.01, SPV.02, SP1.05, SP2.03, SP2.04 SIS.05	Knowledge/Understanding Communication
4.5 Applications 2.5 h	SPV.03, SP3.02 SIS.06	Inquiry Communication Making Connections
4.6 End-of-Unit Task: Testing a Substance 3.0 h	SPV.01, SPV.02, SPV.03 SIS.01, SIS.02, SIS.03, SIS.05	Knowledge/Understanding Inquiry Communication Making Connections

Suggested Activities

Development of the Model of the Atom

- 4.1.1 Assess and review student understanding of the development of the atom, covalent bonding, Lewis dot diagrams, and structural diagrams by means of a diagnostic quiz.
- 4.1.2 Students observe an atomic line spectrum using hydrogen gas and spectrometers. This is followed by a teacher-led discussion regarding the experimental observations and inferences made by Rutherford and Bohr in developing the planetary model of the hydrogen atom. Students generate their own notes.
- 4.1.3 Students participate in a seminar activity. They review information about advances in Canadian research on atomic and molecular theory, e.g., the work of R.J. LeRoy at the University of Waterloo in developing the mathematical technique for determining the radius of molecules, called the LeRoy Radius. Working in small groups, students discuss the implications of the recent contributions and make point form notes. Teachers may assess student Learning Skills.

Assessment Diagnostic Written Quiz, Notes (Inquiry, Communication, Making Connections)

Quantum Mechanics Model

- 4.2.1 The teacher directs a lesson describing the quantum mechanical model of the atom.
- 4.2.2 Students investigate individual contributions made to the quantum mechanical model, e.g., Planck, de Broglie, Einstein, Heisenberg, and Schrodinger and the principles (and rules) required to complete electronic configurations.
- 4.2.3 Students investigate elements to discover a relationship between elemental position on the periodic table and their electronic configurations and properties. They explain their findings to the class or to a group of peers.
- 4.2.4 Students formulate a scientific research question and prepare a visual display or a software presentation based on an application of principles relating to atomic and molecular structure in analytical chemistry and medical diagnosis, e.g., infrared spectroscopy, X-ray crystallography, nuclear medicine, CT scan, MRI.

Assessment Written Quiz (Knowledge/Understanding), Visual Display or Presentation (Knowledge/Understanding, Inquiry, Communication, Making Connections)

Intramolecular Forces of Attraction

- 4.3.1 Students complete an experiment and a lab worksheet to determine the physical properties associated with different types of substances (ionic, covalent network, molecular and metallic).
- 4.3.2 The teacher conducts a lesson explaining how the properties of a solid or liquid depend on the nature of the particles present and the types of forces between them. The lesson is accompanied by visual representations of the particles contained within the solids. Students generate their own notes.
- 4.3.3 Students are provided with an unknown substance and design an experiment to predict the type of solid formed based on its physical properties. The teacher may use a checklist to assess scientific investigation skills.

Assessment Lab Worksheet (Knowledge/Understanding, Inquiry, Communication),
Lab Report – Procedure and Results (Knowledge/Understanding, Inquiry, Communication)

Predicting Shape

- 4.4.1 The teacher demonstrates the Valence Shell Electron Pair Repulsion (VSEPR) model (using balloons or plasticine) and explains how the model can be used to predict molecular shape. Molecular shape is examined further, along with electronegativity values to predict the polarity of various substances.

- 4.4.2 Provide students with a list of molecular formulae. They determine the structural formula, predict the shape using the VSEPR model, build the molecule, and predict the polarity for each of the substances.

Assessment Worksheet (Knowledge/Understanding, Communication)

Applications

- 4.5.1 Students participate in a seminar activity. They work in small groups to research and describe a specialized material that has been recently created based on the structure of matter, chemical bonding, and other properties of matter, e.g., ceramic technologies, bullet-proof fabric, superconductors, silicon chips, epoxy resin, superglue. Each group presents their findings to the class. They may use an electronic presentation if available.

Assessment Presentation (Inquiry, Communication, Making Connections)

End-of-Unit Task: Testing a Substance

- 4.6.1 Provide students with an unknown solid. Students design and conduct tests to determine the type of solid based on physical properties. Students explain their findings. There is an opportunity to assess students' Learning Skills and Investigative Skills.
- 4.6.2 Students conference individually with the teacher who provides them with a molecular formula. Students complete the structural formula, predict the shape, build the molecule, and predict the polarity.
- 4.6.3 Assign a written test including questions to assess the student's ability to Make Connections.

Assessment Type of Solid (Inquiry, Communication),
Molecular Formula (Knowledge/Understanding, Inquiry, Communication),
Unit Test (Knowledge/Understanding, Making Connections)

Resources

Atomic Structure, TVO Video Series, 1987.

Chemistry Learning Centre – <http://learn.chem.vt.edu/tutorials/organic/index.html>

Atomic Structure Timeline – www.watertown.k12.wi.us/hs/teachers/buescher/atomtime.html

Atomic Structure II – www.syvum.com/cgi/online/serve.cgi/squizzes/chem/atomic2.tdf?0

Foundation Chemistry – www.rjclarkson.demon.co.uk/found/found2.htm

Unit 5: Organic Chemistry

Time: 16 hours

Unit Description

Students continue the explorations of organic substances that began in Grade 11. They distinguish among the different classes of organic substances including alcohols, aldehydes, ketones, carboxylic acids, esters, ethers, amines and amides, by name and by structural formula. Inquiry skills such as model building and wet laboratory procedures are used to gather data and information about the properties and types of reactions in order to predict and explain observations. Students investigate the production, uses and importance of polymers in our daily lives.

The End-of-Unit Task involves students assessing the risks and benefits associated with the development and application of synthetic organic products and using molecular model kits to predict and explain a reaction.

Unit Overview Chart

Activity/Time/Focus	Learning Expectations	Assessment Categories
5.1 Introduction 2.0 h	OCV.03, OC3.03, OC3.04	Inquiry Communication Making Connections

Activity/Time/Focus	Learning Expectations	Assessment Categories
5.2 Naming and Properties of Organic Substances 2.0 h	OCV.01, OCV.02, OC1.01, OC1.02, OC2.01, OC2.02, OC2.04 SIS.05	Knowledge/Understanding Communication
5.3 Chemical Reactions 3.5 h	OCV.01, OCV.02, OC1.03, OC2.03, OC2.05, OC2.06 SIS.01, SIS.02, SIS.03, SIS.08	Knowledge/Understanding Inquiry Communication
5.4 Polymer Chemistry 2.0 h	OCV.01, OCV.02, OCV.03, OC1.04, OC2.05, OC3.02 SIS.10	Knowledge/Understanding Inquiry Communication Making Connections
5.5 Organic Chemistry and Living Organisms 1.5 h	OCV.01, OC1.05	Knowledge/Understanding Communication
5.6 Consumer Reports 2.0 h	OCV.03, OC3.01 SIS.07	Knowledge/Understanding Inquiry Communication Making Connections
5.7 End-of-Unit Task: Risks and Benefits 3.0 h	OCV.01, OCV.02, OCV.03	Knowledge/Understanding Communication Making Connections

Suggested Activities

Introduction

5.1.1 Students work in groups of two or three. Each group collects information from a video, periodical, magazine or any other media source, pertaining to the use of organic chemistry to improve technical solutions for identified health, safety and environmental problems. Students make an informed decision about the risks and benefits associated with the use of the product and present their findings to the class. (Suggested topics: leaded versus unleaded gasoline, hydrocarbon propellants versus chlorofluorocarbons.)

Assessment Presentation (Inquiry, Communication, Making Connections)

Naming and Properties of Organic Substances

5.2.1 The teacher may use a diagnostic tool such as a worksheet or an informal question/answer period to assess the students' prior knowledge.

5.2.2 Students work independently (outside of class time) to name (using the IUPAC system), build models of and identify alcohols, aldehydes, ketones, carboxylic acids, esters, ethers, amines and amides. They become familiar with the non-systematic names for some common chemicals such as: acetone; isopropyl; alcohol; and acetic acid. Students may work on this prior to the start of the organic unit to promote their personal development as independent learners.

5.2.3 Students use a graphic organizer to research, predict and explain physical properties such as: solubility in water; solubility in oil; molecular polarity; odour; and melting and boiling points of alcohols, aldehydes, ketones, carboxylic acids, esters, ethers, amines and amides.

Assessment Diagnostic Worksheet (Knowledge/Understanding),
Assignment (Knowledge/Understanding, Communication),
Graphic Organizer (Knowledge/Understanding, Communication)

Chemical Reactions

- 5.3.1 The teacher conducts a lesson describing different types of chemical reactions, such as substitution, addition, elimination, oxidation, esterification, and hydrolysis. Students generate their own notes and review them with other students.
- 5.3.2 Students work in pairs. The teacher provides each pair with a list of reactants and the students build models to represent the reactants, predict the type of reaction and build and name the products. Students complete a model reaction for the teacher and submit a completed worksheet.
- 5.3.3 Students design and carry out a lab activity to synthesize an ester. They investigate the safe use and disposal of required reactants and products. This is a good opportunity for teachers to assess the student's scientific investigation skills, e.g., disposing and handling of organic materials, using appropriate personal protection.

Assessment Student-Generated Note (Knowledge/Understanding, Communication),
Reactions Worksheet (Knowledge/Understanding, Communication),
Lab Report – safety and results (Knowledge/Understanding, Inquiry, Communication)

Polymer Chemistry

- 5.4.1 The teacher demonstrates the production of a polymer, e.g., nylon, reviews the structure of the reactants, and encourages students to predict the chemical formula of the product. This is followed by a class discussion about the processes of addition and condensation polymerization. Students generate their own notes.
- 5.4.2 Students participate in a group (Jigsaw) activity. Each expert group concentrates on a different type of organic substance, e.g., plastics, pharmaceuticals, synthetic fibres, asphalt. They are responsible for writing a one-page handout demonstrating an understanding of how the substance is produced, the chemical formula of the substance, the uses and the importance in our lives. Students also explore careers related to the development of the product. The handout is shared with others.

Assessment Note (Knowledge/Understanding, Communication),
Quiz (Knowledge/Understanding, Communication, Making Connections),
Research Handout (Knowledge/Understanding, Inquiry, Communication)

Organic Chemistry and Living Organisms

- 5.5.1 The teacher describes the reactants and the reaction responsible for the production of fats. This leads to a class discussion describing the importance of organic compounds present in living organisms. Students investigate the structure, production, and importance of proteins, carbohydrates, and nucleic acids. Students generate their own notes.
- 5.5.2 Students complete a worksheet or selected questions based on organic compounds present in living organisms.

Assessment Worksheet/Questions (Knowledge/Understanding, Communication)

Consumer Reports

- 5.6.1 Students participate in a seminar activity. They research and review material concerning the validity of promoting consumer goods using terms such as organic, natural, and chemical. Working in smaller groups, students discuss their findings.
- 5.6.2 Students write a letter to a local newspaper informing the public about the validity of the use of the terms organic, natural, and chemical in the promotion of consumer goods.

Assessment Letter (Knowledge/Understanding, Inquiry, Communication, Making Connections)

End-of-Unit Task: Risks and Benefits

- 5.7.1 Students write a one-to-two page essay or present their findings in another way, such as a website or concept map, describing the importance of organic compounds in our daily lives. Students provide evidence with examples of substances used to improve current health, safety and environmental problems, and an analysis of the risks and benefits associated with the development and application of synthetic products.

5.7.2 Students conference individually with the teacher who provides them with the name(s) of organic reactants. They must complete the following: build molecular models to represent each reactant, predict the type of reaction, name and build a model to represent the product(s). The teachers may choose to provide students with the name(s) of the product(s) and ask students to predict the reactants and type of reaction. There is also an opportunity to assess students' Learning Skills.

5.7.3 Written Test.

Assessment Essay/Other (Inquiry, Communication, Making Connections),
Molecular Model Activity (Inquiry, Communication, Making Connections),
Unit Test (Knowledge/Understanding, Making Connections)

Resources

Chemistry Learning Centre – <http://learn.chem.vt.edu/tutorials/organic/index.html>

General, Organic and Biochem – <http://ull.chemistry.uakron.edu/genobc/>

Organic Chemistry Resources Worldwide – <http://www.organicworldwide.net/>

IUPAC Nomenclature – <http://www.acdlabs.com/iupac/nomenclature/>

The Canadian Society for Chemistry Organic Division – <http://publish.uwo.ca/~mworkent/orgdiv/>

Mansfield University – <http://www.mnsfld.edu/~bganong/102.html>

Organic Chemistry, TVO Video Series, 1987.

World of Chemistry, TVO Video Series, 1988 – *World of Chemistry: Carbon*.

Unit 6: Final Assessment Task

Time: 12 hours

Unit Description

This course has provided students with numerous and varied opportunities to demonstrate the full extent of their achievement of the curriculum expectations, across all four categories of knowledge and skills. Thirty per cent of the final grade will be based on a final evaluation in the form of a written examination and a Performance Task administered towards the end of the course. The Written Examination need not cover all four Achievement Chart categories if a portion of the expectations in a particular category are addressed through the Performance Task. The Performance Task requires students to design and conduct an experiment to investigate a self-generated question pertaining to information studied in one or more of the units in the course. Students will be expected to demonstrate a high degree of scientific literacy in communicating their planning activity and their results.

Unit Overview Chart

Activity/Time/Focus	Learning Expectations	Assessment Categories
6.1 Performance Task 10.0 h	Any of V.01 and corresponding V.02 and V.03 SIS.01, SIS.02, SIS.03, SIS.04, SIS.04, SIS.05, SIS.06, SIS.07, SIS.08, SIS.09	Inquiry Communication
6.2 Written Examination 2.0 h	CSV.01, CSV.02, CSV.03, ECV.01, ECV.02, ECV.03, ELV.01, ELV.02, ELV.03, SPV.01, SPV.02, SPV.03, OCV.01, OCV.02, OCV.03 SIS.09, SIS.10	Knowledge/Understanding Making Connections

Suggested Activities

6.1 The goal of this portion of the Final Performance Task is to allow the university-bound student an opportunity to pursue an interest in chemistry outside the regular curriculum and to demonstrate their knowledge and expertise by engaging in a series of tasks: research; investigation; hypothesizing; verifying; organizing; and presenting. The specific objectives of this unit are to: act as a vehicle for the exploration of some genuine interest; provide experience in independent thinking; give students the opportunity to demonstrate excellence in research and presentation; provide motivated students with an opportunity to work on an enriching and challenging project.

The role of the teacher is to: provide access to a choice of suitable project topics and supply suitable resources where necessary; provide ongoing support and maintain overall control of the project; ensure that all safety and waste disposal requirements are met; evaluate the process forms, final report and peer evaluation forms.

The role of the student is to: choose a suitable topic; do the background research necessary to ensure that the investigation proceeds to completion; schedule the lab work necessary and ensure that it is done under the proper supervision and conditions; maintain a record of their time spent on activities in a log; maintain the agreed-upon schedule to completion; prepare and submit the process forms, final reports and peer evaluations forms on time and in an acceptable format. Probably the single most difficult part of the Performance Task for students is the choice of a good research question; refer to Planning Notes for Activity 1.1 and Activity 1.1.2.

Students' search for a Performance Task question should begin with an inventory of personal interests and related chemical/scientific topics as early in the course as possible. Since all research begins with a question, students should be given the opportunity to ask their own research question and follow through with an experimental investigation. It should also be pointed out that a Performance Task that follows the true "Scientific Method" is deemed superior to one that only follows a pre-written procedure.

The following items could be included in the experimental design proposal and discussed with the teacher in a student-teacher conference:

- identification of the dependent, independent and controlled variables;
- a labelled diagram of the experimental set up;
- a list of all required chemicals, their required concentrations/masses;
- a list of all required equipment;
- a detailed, step-by-step procedure that indicates how the dependent variable will be measured and how the controlled variables will be kept constant;
- an outline of the observations/data tables;
- a description of how the observations/data will be analysed;
- possible sources of error and ways to minimize error;
- safety concerns and waste disposal.

The importance of lab work in the Performance Task cannot be overstated; the results of experimental work are necessary in order to write the scientific lab report. There is also an opportunity to evaluate student Learning Skills and Investigative Skills.

6.2 Written Examination

Assessment Inquiry Activity (Inquiry, Communication, Making Connections),
Final Exam (Knowledge/Understanding, Making Connections)

Resources

Science Teachers' Resource Center Lapeer County Information Depot

– <http://chem.lapeer.org/Chem1Docs/Index.html>

Rubric design (Salina High School South)

– <http://www.usd305.com/south/teachers/pitts/projects/projectpaper.html>

Teaching/Learning Strategies

Need for Variety and Balance

Since the overriding aims of this course are to develop scientific literacy in all students and to prepare students for science courses at university, teachers should use a wide variety of instructional strategies to provide learning opportunities that accommodate a range of learning styles and interests.

In planning activities for chemistry class, ensure that your students have:

- opportunities to work individually, in pairs and small groups, and in large groups;
- direct instruction as well as opportunities for open-ended exploration;
- opportunities to develop concepts themselves from observed data;
- tasks in which they define some of the parameters (such as scope or procedure);
- opportunities to acquire knowledge and apply that knowledge in a variety of contexts;
- opportunities to communicate using standard formats (such as lab reports) as well as opportunities to choose and develop the format;
- opportunities to develop skills that would assist them in being successful at university: note taking during a lecture, examination preparation, multiple choice test taking, in-depth, independent research, report writing, and time management.

Students need to be informed in advance of methods of assessment and evaluation. From the beginning, students should understand the nature and scope of the course's final assessment tasks and how the completion of the End-of-Unit Tasks assists them in gaining the skills and knowledge necessary for its successful completion. Expectations are presented in such a way as to prepare students for the End-of-Unit Tasks. Assessment and evaluation then become an integral part of the teaching/learning strategies.

Skills are Developed through Experience and Refined with Practice

Lesson design should evolve during the course. Initially lessons could centre around the familiar guided discovery approach, but the final unit(s) of the course could be organized around a lecture, laboratory, tutorial and seminar format. Early experiences with the use of the lecture format should include assessment opportunities. The adequacy of recorded notes may be assessed by the teacher, peers or self, using a checklist; they may also be assessed by the teacher by means of an open-note quiz.

Seminars can be used to enhance class discussions of science issues as they relate to technology and the environment. An article, selected by the teacher or students, could be assigned for pre-reading prior to the seminar. A quiz could be used to assess whether the article had been read before involving the class in a teacher or student-led discussion. Teacher-led discussions could occur near the start of the course with student-led discussions taking place later in the course.

Many of the Learning Expectations describe Inquiry Skills. Students should be given repeated opportunities to carry out genuine inquiries in which they are responsible for defining one or more of the components of the inquiry: the topic or question, the methodology, the mode of presentation, the criteria of success. In this chemistry course students should have multiple opportunities to practise a variety of inquiry styles, including the following:

- **Research:** accessing information that has already been previously gathered, selecting the relevant details, analysing that information for patterns and meaning, and communicating their findings or conclusion. This will require instruction and practice in techniques for effective use of library/resource centre resources, searching the Internet and interviewing experts.
- **Experimentation:** developing questions, identifying controls and variables, designing the experimental procedure, observing and measuring, analysing the data for patterns and meaning, and communicating conclusions. This may occur in laboratories or the field. Ensure that laboratory techniques and safety procedures are taught and assessed.

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- **Design/Innovation:** applying knowledge to define a problem or challenge, setting criteria for a satisfactory solution, devising and executing a procedure, and assessing the result.

Every inquiry should be driven by a clear question that is manageable and has relevance to the students. Students should be given instruction and repeated practice in:

- identifying and refining good inquiry questions;
- developing testable hypotheses;
- setting the parameters of the solutions;
- assessing results.

All forms of inquiry as well as other activities throughout the course develop **Communication Skills**. Although the traditional written report is one form of communication, students need to describe what they do and what they learn in other formats as well – such as poster presentations, computer presentations, video, music. Through various formats of co-operative learning, they discuss, debate, and reflect on their own thinking and learning.

In addition to key chemical concepts, every learning activity should identify a technique or skills that will be taught or reinforced and assessed. Over the length of the course, all skills required to meet the Overall Expectations should be practised repeatedly in a variety of contexts.

Initially, the teacher may assign specific review exercises from a textbook or other resource. Later students could simply be told to complete the questions that they feel are necessary to ensure their own understanding of the concepts.

Use of Computer Technology

Computer applications should be included in activities whenever they enhance student learning by enabling them to complete work more efficiently or to complete work that otherwise could not be done. A wide variety of software tools should be used to record and display information. Examples include word-processing, e.g., reports, spreadsheets; class data from measurements taken in the laboratory; graphics; flow charts; concept maps; diagrams of investigations; databases; gathering small groups or individual's observations into class sets; collecting data from replicated experiments, and electronic presentation. Probeware should be used to collect data (e.g., to permit replications of experiments where complex procedures would limit students to single experiments). Simulations may substitute for experiences but should not be used to replace direct experiences that are safe, ethical, and available. The portability of calculator-based laboratory systems makes them useful for work outside the classroom. Online communication between teacher and students could occur throughout the course. Homework assignments and answers could be posted, along with reminders about upcoming assignment deadlines and evaluation dates. Sample exam questions could be included and links made to pertinent sites, covering a variety of STSE topic. Online tutorials could be arranged and one of the later units in the course could be presented online. Many of these experiences will mirror what students will encounter at university.

Group Work Considerations

A number of group activities are described in this profile. These allow students opportunities to practise and be assessed and evaluated for Teamwork, one of the five Learning Skills. Teamwork is often identified as a key employability skill. Initiative, Organization, and Work Habits/Homework, three other Learning Skills, can be practised, assessed, and evaluated.

However, when group assignments are used to evaluate the achievement of course Expectations, the teacher must ensure that this is done on an individual basis. This can be accomplished in a number of ways:

- Arrange individual teacher/student conferences. Student responses to a series of questions can be used to evaluate Knowledge, Communication Skills, and Making Connections most easily, but can also be used for inquiry.
- On a regular basis, collect and evaluate work journals or log books, where students describe their role and responsibility in completion of an activity.
- Students use reflection journals to describe their learnings related to a certain activity; teachers then evaluate them for knowledge and making connections.
- Work logs and reflection journals can be in formats other than pencil and paper. Some students might produce more complete and detailed answers by using a tape recorder or a concept map. This would allow different learning styles to be addressed.
- Students could pool their experimental or research results, and produce an independent, individual final product that would be evaluated.
- Students could contract for different aspects of research or communication for a group project. This is another opportunity to address individual learning styles. When evaluating the group presentation, the teacher should be aware of individual responsibilities.
Use quizzes to evaluate specific Knowledge or Making Connections Expectations gained through a group activity.
- Teacher observation, using a checklist, and on-the-spot questioning can be used to assess and evaluate expectation achievement on an individual basis.
- Acquisition of technical skills could be evaluated in another, individual situation by means of a summative, practical skills test.

Self- and peer assessment of individual performances within a group setting are appropriate and useful to assist students in becoming self-monitoring. However, such assessments are not to be the basis for evaluation; evaluation is the sole responsibility of the teacher.

Making Connections

The knowledge expectations of this course have intrinsic worth as useful information, but they also serve as vehicles for developing other expectations:

- acquisition of knowledge through inquiry develops inquiry skills;
- connecting chemical concepts to social and environmental issues develops the necessary habits of mind for making connections;
- applying scientific knowledge to practical problems makes connections to technology; considering how scientific knowledge is acquired brings understanding of the role that technology plays in scientific discovery.

During their study of chemistry, students should 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.

Assessment & Evaluation of Student Achievement

Seventy per cent of the grade will be based on assessments and evaluations conducted throughout the course. Thirty per cent of the grade will be based on a final evaluation in the form of an examination, performance, essay, and/or other methods of evaluation.

Assessment is a process of gathering information and providing descriptive feedback about student learning. Evaluation is the process of judging work and assigning a value, based on established criteria.

The purpose of assessment is to improve student learning. This means that judgements of student performance must be criterion-referenced so that feedback can be given that includes clearly expressed next steps for improvement. Tools of varying complexity can facilitate this.

- For assessing/evaluating a test or quiz, a marking scheme is used.
- Where completion or non-completion is the issue, a checklist is sufficient.
- Where quality of performance is easily identifiable, a rating scale can be used.
- For more complex tasks, the criteria may be incorporated into a rubric where levels of performance for each criterion are stated in language that can be understood by students.

Teacher developed rubrics should be task-specific.

Marking schemes, checklists, rating scales and rubrics become powerful tools for improving learning when students understand the criteria and levels of performance before they undertake the task.

Discussion of the criteria for success should be part of every learning task. Wherever possible, students should be involved in the development of the rating scale or rubric (identifying criteria and setting levels of achievement in terms they understand).

Assessment must be embedded within the instructional process throughout each unit rather than being an isolated event at the end. Often, the learning and assessment tasks are the same, with formative assessment provided throughout the activity. In every case, the desired demonstration of learning is articulated at the beginning and the learning activity is planned to make that demonstration possible.

When planning learning activities for chemistry, this process of beginning with the end in mind helps to focus on the Expectations and to reduce the inclination to expand what is taught beyond what is required by the guideline.

Assessment, Evaluation and Reporting are tied to the Learning Expectations and Achievement Chart for Science (*The Ontario Curriculum, Grades 11 and 12: Science, 2000*, pp 174 - 75). Every learning activity and its assessment should produce data allowing the teacher to make judgements about performance in one or more of the Achievement Categories: Knowledge/Understanding, Inquiry, Communications and Making Connections. Within each unit and across the course, the teachers must collect sufficient data (in kind and number) to make valid judgements about students' performances in all categories.

In the end, the evaluation of the assessment data is expressed as a percentage based on Achievement Chart levels. Evaluation must be based on individual student performance relative to the criteria. Final evaluations should reflect the teacher's informed, professional judgement of each student's most consistent level of performance in each category of the Achievement Chart. Added weight should be given to more recent performances.

Teachers need to use a wide and balanced range of assessment strategies to accommodate the varied learning styles of all students, to meet the needs of students with special needs, and to encompass a broadened range of knowledge and skills expectations. Teachers will consult individual IEPs for specific direction on accommodation for individuals.

Teachers should provide opportunities for students to demonstrate learning at all levels of the Achievement Chart. Strategies include:

- diagnostic, formative and summative assessments;
- performance tasks and pencil-and-paper instruments (Both are needed to assess the full range of expectations);
- teacher assessment and student (self and peer) assessment. With clearly articulated criteria, students become partners in the assessment process;
- individual and group assessment. (When students are engaged in group tasks it is appropriate to consider group interaction as an indicator of each student's learning skills. However, assessment must focus primarily on each student's individual demonstration of the learning expectations.)

The Final 30% Examination

Students of SCH4U need to be properly prepared success in university science courses. Study skills, including chunking of content, use of different graphic organizers, and preparation of study sheets, should be integrated into a number of lessons. Multiple-choice questions should be used as one of a variety of ways of evaluating a wide range of expectations. Students should experience all types of questions throughout the course and be taught strategies for answering them.

Students would benefit from more than one opportunity to complete an examination. Should a mid-term examination be administered, an opportunity for feedback and reflection should be provided.

The Final 30% Evaluation design must allow for evaluation to occur within all four categories.

Examination questions should be equally distributed across the course units, and consideration should be given to a range of question types, such as multiple choice, short and extended answer, laboratory-based and higher-order questions. The written examination could stress Knowledge/Understanding and Making Connections while the Performance Task could focus on Inquiry and Communication Skills. There must be a balance of data from the four categories on the Achievement Level Chart, spread over both the Written Examination and the Performance Task.

Accommodations

Students with special needs, whether identified formally or not, need additional supports to succeed in Grade 12 Chemistry to their full potential. Teachers should consult individual student IEPs for specific direction on accommodation for individuals. The following are examples of accommodations and aids that may be helpful in a general way. Where there are specific accommodations required in an activity, the suggestions are noted within the activity.

- Check the IEPs of identified students for specific modifications in teaching methodologies and evaluation.
- Ensure that peer helpers are available when students are working in small groups.
- Provide handout sheets with sample calculations and specific skill instructions.
- Help students create data charts into which they record information.
- Advise special education staff in advance when students who require their support are working on major assignments.
- Advise ESL/ESD staff in advance when significant written work is required.
- Have students keep a science dictionary of terms using pictures and first language words.
- Permit the use of a translation dictionary on assessments.
- Record key words on the board when students are expected to make their own notes.
- Allow students to report verbally to a scribe (teacher or student) who can then help in note making.
- Utilize student strengths by permitting them a wide range of options for recording and reporting their work, e.g., drawings, diagrams, flow charts, concept maps.
- Extend timelines to give students more time to process language and put their thoughts into words.
- Give readings in advance to students or provide a selection of materials at different reading levels.
- Provide extended timelines in situations where students do not have access to computers outside of school.
- Provide additional time on assessments for dictionary use and processing language.
- Provide resources with appropriate reading level when research is required.

Resources

Units in this Course Profile make reference to the use of specific texts, magazines, films, videos, and websites. The teachers need to consult their board policies regarding use of any copyrighted materials. Before reproducing materials for student use from printed publications, teachers need to ensure that their board has a Cancopy licence and that this licence covers the resources they wish to use. Before screening videos/films with their students, teachers need to ensure that their board/school has obtained the appropriate public performance videocassette licence from an authorized distributor, e.g., Audio Cine Films Inc. The teachers are reminded that much of the material on the Internet is protected by copyright. The copyright is usually owned by the person or organization that created the work. Reproduction of any work or substantial part of any work from the Internet is not allowed without the permission of the owner.

Bennet, Barrie and Carol Rolheiser. *Beyond Monet - The Artful Science of Instructional Integration*. Toronto: Bookation, Inc., 2001. ISBN 0-9695388-3-9

Brady, James et al. *Chemistry: Matter and Its Changes*. Etobicoke, John Wiley & Sons, 2000. ISBN 0470831049

Hebden, James A. *Chemistry: Theory and Problems Book Two*. McGraw Hill, Toronto, 1980. ISBN 0070778612

Rayner-Canham et al. *Chemistry: A Second Course*. Addison Wesley, Don Mills, 1989. ISBN 0201178850

The URLs for the websites were verified by the writers prior to publication. Given the frequency with which these designations change, teachers should always verify the websites prior to assigning them for student use.

Internet Public Library – <http://www.ipl.org>

American Association for the Advancement of Science – <http://www.aaas.org/>

Canadian government and research sites related to science and engineering
– <http://www.nserc.ca/relate.htm>

CBC Educational Resources – <http://www.cbc.ca/insidecbc/educational/>

Education Network of Ontario – <http://www.enoreo.on.ca/>

Education Resources on the web (Canadian site)

– <http://www.educ.uvic.ca/depts/snsc/pages/weblinks/weblinks.htm>

Gateway to Educational Materials – <http://www.thegateway.org/>

Midwest Mathematics and Science Consortium (MSC) – <http://www.ncrel.org/msc/msc.htm>

National Science Foundation (USA) – <http://www.nsf.gov/>

National Staff Development Council – issues of implementation – <http://www.nsd.org/>

Online Resources for Assessment – <http://www.rmcdenver.com/useguide/assessme/online.htm>

Ontario Ministry of Education (EDU) – curriculum documents page

– <http://www.edu.gov.on.ca/eng/document/curricul/curricul.html>

Regional Education Laboratories in the USA – focus on educational research

– <http://www.sedl.org/RELS.html>

Science Teachers Association of Ontario (STAO) links to science sites

– <http://www.stao.org/hotlinks.htm>

Science Toys – <http://www.scitoys.com/>

STAR Centre for Academic Renewal (Texas) – <http://www.starcenter.org/>

USA National Academy of Sciences – <http://www.nas.edu/>

OSS Policy Considerations

Students can apply and refine the skills, knowledge, and habits of mind they acquire in SCH4U through Cooperative Education, work experience and service placements within the community.

A work site placement must be directly connected to the Expectations of SCH4U if it is to contribute to a student's perspective of future careers or educational opportunities. The wording in the document *Cooperative Education and Other Forms of Experiential Learning (Ontario, Ministry of Education, 2000)* provides clear direction, and should be the focus of the personalized learning plans for students.

“The personalized learning plan *must* include the following: the Curriculum Expectations of the related course that describe the knowledge and skills the student will *extend and refine* through application and practice at the workplace” (p. 23, emphasis added). The placement is not intended to introduce the student to the Expectations, but should connect closely enough that significant Expectations are clearly extended and refined in a workplace setting. Both workplace and community experiences may offer unique opportunities for students to achieve a major goal of SCH4U: “To relate science to technology, society, and the environment,” and to gain experience in the Science Investigative Skills defined at the beginning of the course description in the guideline. The personalized placement learning plan of a student who has an Individual Education Plan (IEP) must be developed with direct reference to the IEP.

Coded Expectations, Chemistry, Grade 12, University, SCH4U

Scientific Investigation Skills

- SIS.01** - demonstrate an understanding of safe laboratory practices by selecting and applying appropriate techniques for handling, storing, and disposing of laboratory materials (e.g., safely disposing of organic solutions; correctly interpreting Workplace Hazardous Materials Information System [WHMIS] symbols), and using appropriate personal protection (e.g., wearing safety goggles);
- SIS.02** - select appropriate instruments and use them effectively and accurately in collecting observations and data (e.g., use a calorimeter in heat transfer experiments);
- SIS.03** - demonstrate the skills required to plan and carry out investigations using laboratory equipment safely, effectively, and accurately (e.g., select and use apparatus safely in an experiment to determine the mass of a metal deposited by electroplating);
- SIS.04** - demonstrate a knowledge of emergency laboratory procedures;
- SIS.05** - select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate scientific ideas, plans, and experimental results (e.g., use the Valence Shell Electron Pair Repulsion [VSEPR] model to predict the shapes of molecules);
- SIS.06** - compile and interpret data or other information gathered from print, laboratory, and electronic sources, including Internet sites, to research a topic, solve a problem, or support an opinion (e.g., research the uses of the most commonly synthesized organic compounds);
- SIS.07** - communicate the procedures and results of investigations for specific purposes by displaying evidence and information, either in writing or using a computer, in various forms, including flow charts, tables, graphs, and laboratory reports (e.g., construct visual models that explain intermolecular and intramolecular forces);
- SIS.08** - express the result of any calculation involving experimental data to the appropriate number of decimal places or significant figures;
- SIS.09** - select and use appropriate SI units;
- SIS.10** - identify and describe science- and technology-based careers related to the subject area under study (e.g., describe careers related to thermochemistry, such as chemical engineering).

Organic Chemistry

Overall Expectations

- OCV.01** · demonstrate an understanding of the structure of various organic compounds, and of chemical reactions involving these compounds;
- OCV.02** · investigate various organic compounds through research and experimentation, predict the products of organic reactions, and name and represent the structures of organic compounds using the IUPAC system and molecular models;
- OCV.03** · evaluate the impact of organic compounds on our standard of living and the environment.

Specific Expectations

Understanding Basic Concepts

- OC1.01** – distinguish among the different classes of organic compounds, including alcohols, aldehydes, ketones, carboxylic acids, esters, ethers, amines, and amides, by name and by structural formula;
- OC1.02** – describe some physical properties of the classes of organic compounds in terms of solubility in different solvents, molecular polarity, odour, and melting and boiling points;
- OC1.03** – describe different types of organic reactions, such as substitution, addition, elimination, oxidation, esterification, and hydrolysis;

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- OC1.04** – demonstrate an understanding of the processes of addition and condensation polymerization;
OC1.05 – describe a variety of organic compounds present in living organisms, and explain their importance to those organisms (e.g., proteins, carbohydrates, fats, nucleic acids).

Developing Skills of Inquiry and Communication

- OC2.01** – use appropriate scientific vocabulary to communicate ideas related to organic chemistry (e.g., *functional group, polymer*);
OC2.02 – use the IUPAC system to name and write appropriate structures for the different classes of organic compounds, including alcohols, aldehydes, ketones, carboxylic acids, esters, ethers, amines, amides, and simple aromatic compounds;
OC2.03 – build molecular models of a variety of aliphatic, cyclic, and aromatic organic compounds;
OC2.04 – identify some nonsystematic names for organic compounds (e.g., *acetone, isopropyl alcohol, acetic acid*);
OC2.05 – predict and correctly name the products of organic reactions, including substitution, addition, elimination, esterification, hydrolysis, oxidation, and polymerization reactions (e.g., preparation of an ester, oxidation of alcohols with permanganate);
OC2.06 – carry out laboratory procedures to synthesize organic compounds (e.g., preparation of an ester, polymerization).

Relating Science to Technology, Society, and the Environment

- OC3.01** – present informed opinions on the validity of the use of the terms organic, natural, and chemical in the promotion of consumer goods;
OC3.02 – describe the variety and importance of organic compounds in our lives (e.g., plastics, synthetic fibres, pharmaceutical products);
OC3.03 – analyse the risks and benefits of the development and application of synthetic products (e.g., polystyrene, aspartame, pesticides, solvents);
OC3.04 – provide examples of the use of organic chemistry to improve technical solutions to existing or newly identified health, safety, and environmental problems (e.g., leaded versus unleaded gasoline; hydrocarbon propellants versus chlorofluorocarbons [CFCs]).

Energy Changes and Rates of Reaction

Overall Expectations

- ECV.01** · demonstrate an understanding of the energy transformations and kinetics of chemical changes;
ECV.02 · determine energy changes for physical and chemical processes and rates of reaction, using experimental data and calculations;
ECV.03 · demonstrate an understanding of the dependence of chemical technologies and processes on the energetics of chemical reactions.

Specific Expectations

Understanding Basic Concepts

- EC1.01** – compare the energy changes resulting from physical change, chemical reactions, and nuclear reactions (fission and fusion);
EC1.02 – explain Hess’s law, using examples;
EC1.03 – describe, with the aid of a graph, the rate of reaction as a function of the change of concentration of a reactant or product with respect to time; express the rate of reaction as a rate law equation (first- or second-order reactions only); and explain the concept of half-life for a reaction;
EC1.04 – explain, using collision theory and potential energy diagrams, how factors such as temperature, surface area, nature of reactants, catalysts, and concentration control the rate of chemical reactions;

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- EC1.05** – analyse simple potential energy diagrams of chemical reactions (e.g., potential energy diagrams showing the relative energies of reactants, products, and activated complex);
- EC1.06** – demonstrate understanding that most reactions occur as a series of elementary steps in a reaction mechanism.

Developing Skills of Inquiry and Communication

- EC2.01** – use appropriate scientific vocabulary to communicate ideas related to the energetics of chemical reactions (e.g., *enthalpy*, *activated complex*);
- EC2.02** – write thermochemical equations, expressing the energy change as an ΔH value or as a heat term in the equation;
- EC2.03** – determine heat of reaction using a calorimeter, and use the data obtained to calculate the enthalpy change for a reaction (e.g., neutralization of sodium hydroxide and hydrochloric acid);
- EC2.04** – apply Hess's law to solve problems, including problems that involve data obtained through experimentation (e.g., measure heats of reaction that can be combined to yield the ΔH of combustion of magnesium);
- EC2.05** – calculate heat of reaction using tabulated enthalpies of formation;
- EC2.06** – determine through experimentation a rate of reaction (e.g., of hydrogen peroxide decomposition), and measure the effect on it of temperature, concentration, and catalysis.

Relating Science to Technology, Society, and the Environment

- EC3.01** – compare conventional and alternative sources of energy with respect to efficiency and environmental impact (e.g., burning fossil fuels, solar energy, nuclear fission);
- EC3.02** – describe examples of technologies that depend on exothermic or endothermic changes (e.g., hydrogen rocket fuel, hot and cold packs);
- EC3.03** – describe the use of catalysts in industry (e.g., catalytic converters) and in biochemical systems (e.g., enzymes) on the basis of information gathered from print and electronic sources;
- EC3.04** – describe examples of slow chemical reactions (e.g., rusting), rapid reactions (e.g., explosions), and reactions whose rates can be controlled (e.g., food decay, catalytic decomposition of automobile exhaust).

Chemical Systems and Equilibrium

Overall Expectations

- CSV.01** · demonstrate an understanding of the concept of chemical equilibrium, Le Châtelier's principle, and solution equilibria;
- CSV.02** · investigate the behaviour of different equilibrium systems, and solve problems involving the law of chemical equilibrium;
- CSV.03** · explain the importance of chemical equilibrium in various systems, including ecological, biological, and technological systems.

Specific Expectations

Understanding Basic Concepts

- CS1.01** – illustrate the concept of dynamic equilibrium with reference to systems such as liquid-vapour equilibrium, weak electrolytes in solution, and chemical reactions;
- CS1.02** – demonstrate an understanding of the law of chemical equilibrium as it applies to the concentrations of the reactants and products at equilibrium;
- CS1.03** – demonstrate an understanding of how Le Châtelier's principle can predict the direction in which a system at equilibrium will shift when volume, pressure, concentration, or temperature is changed;
- CS1.04** – identify, in qualitative terms, entropy changes associated with chemical and physical processes;

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- CS1.05** – describe the tendency of reactions to achieve minimum energy and maximum entropy;
CS1.06 – describe, using the concept of equilibrium, the behaviour of ionic solutes in solutions that are unsaturated, saturated, and supersaturated;
CS1.07 – define constant expressions, such as K_{sp} , K_w , K_a , and K_b ;
CS1.08 – compare strong and weak acids and bases using the concept of equilibrium;
CS1.09 – describe the characteristics and components of a buffer solution.

Developing Skills of Inquiry and Communication

- CS2.01** – use appropriate vocabulary to communicate ideas, procedures, and results related to chemical systems and equilibrium (e.g., *homogeneous*, *common ion*, K_a value);
CS2.02 – apply Le Châtelier’s principle to predict how various factors affect a chemical system at equilibrium, and confirm their predictions through experimentation;
CS2.03 – carry out experiments to determine equilibrium constants (e.g., K_{eq} for iron [III] thiocyanate, K_{sp} for calcium hydroxide, K_a for acetic acid);
CS2.04 – calculate the molar solubility of a pure substance in water or in a solution of a common ion, given the solubility product constant (K_{sp}), and vice versa;
CS2.05 – predict the formation of precipitates by using the solubility product constant;
CS2.06 – solve equilibrium problems involving concentrations of reactants and products and the following quantities: K_{eq} , K_{sp} , K_a , K_b , pH, pOH;
CS2.07 – predict, in qualitative terms, whether a solution of a specific salt will be acidic, basic, or neutral;
CS2.08 – solve problems involving acid-base titration data and the pH at the equivalence point.

Relating Science to Technology, Society, and the Environment

- CS3.01** – explain how equilibrium principles may be applied to optimize the production of industrial chemicals (e.g., production of sulfuric acid, ammonia);
CS3.02 – identify effects of solubility on biological systems (e.g., kidney stones, dissolved gases in the circulatory system of divers, the use of barium sulfate in medical diagnosis);
CS3.03 – explain how buffering action affects our daily lives, using examples (e.g., the components in blood that help it to maintain a constant pH level; buffered medications).

Electrochemistry

Overall Expectations

- ELV.01** · demonstrate an understanding of fundamental concepts related to oxidation-reduction and the interconversion of chemical and electrical energy;
ELV.02 · build and explain the functioning of simple galvanic and electrolytic cells; use equations to describe these cells; and solve quantitative problems related to electrolysis;
ELV.03 · describe some uses of batteries and fuel cells; explain the importance of electrochemical technology to the production and protection of metals; and assess environmental and safety issues associated with these technologies.

Specific Expectations

Understanding Basic Concepts

- EL1.01** – demonstrate an understanding of oxidation and reduction in terms of the loss and the gain of electrons or change in oxidation number;
EL1.02 – identify and describe the functioning of the components in galvanic and electrolytic cells;
EL1.03 – describe electrochemical cells in terms of oxidation and reduction half-cells whose voltages can be used to determine overall cell potential;

EL1.04 – describe the function of the hydrogen half-cell as a reference in assigning reduction potential values;

EL1.05 – demonstrate an understanding of the interrelationship of time, current, and the amount of substance produced or consumed in an electrolytic process (Faraday’s law);

EL1.06 – explain corrosion as an electrochemical process, and describe corrosion-inhibiting techniques (e.g., painting, galvanizing, cathodic protection).

Developing Skills of Inquiry and Communication

EL2.01 – use appropriate scientific vocabulary to communicate ideas related to electrochemistry (e.g., *half-reaction, electrochemical cell, reducing agent, redox reaction, oxidation number*);

EL2.02 – demonstrate oxidation-reduction reactions through experiments, and analyse these reactions (e.g., compare the reactivity of some metals by arranging them in order of their ease of oxidation, which can be determined through observation of their ability to displace other metals from compounds; investigate the reactivity of oxidizing agents such as oxygen and various acids);

EL2.03 – write balanced chemical equations for oxidation-reduction systems, including half-cell reactions;

EL2.04 – determine oxidation and reduction half-cell reactions, direction of current flow, electrode polarity, cell potential, and ion movement in typical galvanic and electrolytic cells, including those assembled in the laboratory;

EL2.05 – predict the spontaneity of redox reactions and overall cell potentials by studying a table of half-cell reduction potentials;

EL2.06 – solve problems based on Faraday’s law;

EL2.07 – measure through experimentation the mass of metal deposited by electroplating (e.g., copper from copper II sulfate), and apply Faraday’s law to relate the mass of metal deposited to the amount of charge passed.

Relating Science to Technology, Society, and the Environment

EL3.01 – describe examples of common galvanic cells (e.g., lead-acid, nickel-cadmium) and evaluate their environmental and social impact (e.g., describe how advances in the hydrogen fuel cell have facilitated the introduction of electric cars);

EL3.02 – explain how electrolytic processes are involved in industrial processes (e.g., refining of metals, production of chlorine);

EL3.03 – research and assess environmental, health, and safety issues involving electrochemistry (e.g., the corrosion of metal structures by oxidizing agents; industrial production of chlorine by electrolysis and its use in the purification of water).

Structure and Properties

Overall Expectations

SPV.01 · demonstrate an understanding of quantum mechanical theory, and explain how types of chemical bonding account for the properties of ionic, molecular, covalent network, and metallic substances;

SPV.02 · investigate and compare the properties of solids and liquids, and use bonding theory to predict the shape of simple molecules;

SPV.03 · describe products and technologies whose development has depended on understanding molecular structure, and technologies that have advanced the knowledge of atomic and molecular theory.

Specific Expectations

Understanding Basic Concepts

- SP1.01** – explain the experimental observations and inferences made by Rutherford and Bohr in developing the planetary model of the hydrogen atom;
- SP1.02** – describe the quantum mechanical model of the atom (e.g., orbitals, electron probability density) and the contributions of individuals to this model (e.g., those of Planck, de Broglie, Einstein, Heisenberg, and Schrödinger);
- SP1.03** – list characteristics of the *s*, *p*, *d*, and *f* blocks of elements, and explain the relationship between position of elements in the periodic table, their properties, and their electron configurations;
- SP1.04** – explain how the properties of a solid or liquid (e.g., hardness, electrical conductivity, surface tension) depend on the nature of the particles present and the types of forces between them (e.g., covalent bonds, Van der Waals forces, dipole forces, and metallic bonds);
- SP1.05** – explain how the Valence Shell Electron Pair Repulsion (VSEPR) model can be used to predict molecular shape.

Developing Skills of Inquiry and Communication

- SP2.01** – use appropriate scientific vocabulary to communicate ideas related to structure and bonding (e.g., *orbital*, *absorption spectrum*, *quantum*, *photon*, *dipole*);
- SP2.02** – write electron configurations for elements in the periodic table, using the Pauli exclusion principle and Hund's rule;
- SP2.03** – predict molecular shape for simple molecules and ions, using the VSEPR model;
- SP2.04** – predict the polarity of various substances, using molecular shape and the electronegativity values of the elements of the substances;
- SP2.05** – predict the type of solid (ionic, molecular, covalent network, or metallic) formed by a substance, and describe its properties;
- SP2.06** – conduct experiments to observe and analyse the physical properties of different substances, and to determine the type of bonding present.

Relating Science to Technology, Society, and the Environment

- SP3.01** – describe some applications of principles relating to atomic and molecular structure in analytical chemistry and medical diagnosis (e.g., infrared spectroscopy, X-ray crystallography, nuclear medicine, medical applications of spectroscopy);
- SP3.02** – describe some specialized new materials that have been created on the basis of the findings of research on the structure of matter, chemical bonding, and other properties of matter (e.g., bulletproof fabric, superconductors, superglue);
- SP3.03** – describe advances in Canadian research on atomic and molecular theory (e.g., the work of Richard Bader at McMaster University in developing electron-density maps for small molecules; the work of R.J. LeRoy at the University of Waterloo in developing the mathematical technique for determining the radius of molecules called the LeRoy Radius).

Unit 1: Chemical Systems and Equilibrium

Time: 30 hours

Unit Description

In this unit, students increase their understanding of solutions to incorporate equilibrium systems. Students investigate the behaviour of different equilibrium systems, e.g., liquid-vapour, insoluble salts, weak acids and bases, and solve problems involving the law of chemical equilibrium. Le Chatelier's principle is used to predict how various factors affect a chemical system at equilibrium. Students explore the importance of equilibrium systems in their daily lives, e.g., how they optimize the production of industrial chemicals and the role they play in biological systems. Throughout the unit, the increased encouragement and emphasis is placed on independent learning strategies, e.g., students generate their own notes and compare them with teacher expectations. In the End-of-Unit Task, students use their titration skills and their understanding of molar solubility and the common ion effect to determine an unknown concentration. Students also complete a written test.

Unit Synopsis Chart

Activity/ Time	Learning Expectations	Assessment Categories	Task/Focus
1.1 An Introduction to Equilibrium Systems 10 h	CSV.01, CSV.02, CSV.03, CS1.01, CS1.02, CS1.03, CS1.07, CS2.01, CS2.02, CS2.03, CS2.06, CS3.01 SIS.01, SIS.02, SIS.03, SIS.07, SIS.08, SIS.09	Knowledge/ Understanding Inquiry Communication Making Connections	Diagnostic carousel activity; teacher-led discussions; student-designed investigations and reporting; graphical analysis; seminar on practical applications of Le Chatelier's principle; applications of problem-solving equilibrium systems.
1.2 Entropy 2 h	CSV.01, CS1.04, CS1.05	Knowledge/ Understanding Communication	Teacher demonstration; teacher-led discussion; independent note taking; environmental application.
1.3 Solubility of Salts 6 h	CSV.01, CSV.02, CS1.06, CS1.07, CS2.01, CS2.03, CS2.04, CS2.05, CS2.06, CS3.02 SIS.01, SIS.02, SIS.03, SIS.08, SIS.09, SIS.10	Knowledge/ Understanding Inquiry Making Connections Communication	Teacher-directed lesson; student laboratory exercise; problem solving applications; practical applications of solubility.
1.4 Acid Base Equilibrium 6 h	CSV.01, CSV.02, CS1.07, CS1.08, CS2.01, CS2.03, CS2.06, CS2.07, CS2.08 SIS.01, SIS.02, SIS.03, SIS.09	Knowledge/ Understanding Inquiry Communication Making Connections	Teacher-directed lesson; student-designed titration experiment; independent note taking; problem solving.
1.5 Buffer Solutions 2.5 h	CSV.01, CSV.03, CS1.09, CS3.03 SIS.06	Knowledge/ Understanding Inquiry Making Connections Communication	Teacher demonstration; research and seminar on how buffering action impacts daily life.

1.6 End-of-Unit Task and Written Test 3.5 h	CSV.01, CSV.02, CSV.03 SIS.01, SIS.02, SIS.03	Knowledge/ Understanding Inquiry Making Connections Communication	Students design, conduct and report on an equilibrium experiment; written test.
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Unit Planning Notes

Some of the planning notes below relate to the content of the unit while others are suggested to help establish routines in this first unit of the course.

- Follow all board policies/procedures for the safe handling and disposal of chemicals and ensure proper laboratory safety (goggles, gloves, ventilation) for all lab activities.
- Provide reminder, hints, and personal reflection time on a continual basis for students to generate possible research questions/ideas for the Final Assessment Task.
- Promote independent learning skills by encouraging students to accept increasing responsibility for their work, e.g., check posted solutions, generate and compare lesson/text notes, formulate scientific questions and participate in peer assessment.
- It may be appropriate to use a lecture for content delivery occasionally to help better prepare students for university teaching strategies.
- If possible, book class time in the library/resource centre and/or the computer lab.
- This unit is rich in problem-solving opportunities. Careful planning will be essential. Consult with math teachers regarding problem-solving background and possible additional/supporting activities; if needed, arrange for possible sharing of the graphing calculators.
- Collect exemplars of student work, e.g., notes, lab reports, Final Assessment Report, etc. for future reference.
- Prepare solutions required for the End-of-Unit Task, e.g., $\text{Ca}(\text{OH})_2$ and $\text{Ca}(\text{OH})_2$ with a dissolved calcium salt such as $\text{Ca}(\text{NO}_3)_2$ at least one week prior to the activity.
- This unit has a larger proportion of laboratory explorations to better prepare students for the Final Assessment Task.
- Self- and peer assessment can be used as a valuable component of the assessment for many of the activities, especially when accompanied by clear criteria; evaluation and assignment of marks remain the responsibility of the teacher.

Unit Resources

Jaeger, Dave and Suzanne Weisker. *Holt Chemistry: Visualizing Matter Laboratory Experiments*. United States: Holt, Rinehart and Winston, Inc., 1996. ISBN 0-03-095284-0

Jenkins, Frank, et al. *Nelson Chemistry*. Nelson Canada, 1993. ISBN 0-017-603863-9

Slater, Alan and Geoff Rayner-Canham. *Microscale Chemistry Laboratory Manual*. Don Mills, ON. Addison-Wesley Publishers Ltd., 1994. Teacher's Edition ISBN 0-201-60216-4 and Student's Edition ISBN 0-201-60215-6

Tocci, Salvatore and Claudia Viehland. *Holt Chemistry: Visualizing Matter*. United States: Holt, Rinehart and Winston, Inc., 1996. ISBN 0-03-000193-5

Tocci, Salvatore and Claudia Viehland. *Holt Chemistry: Visualizing Matter Study Guide*. United States: Holt, Rinehart and Winston, Inc., 1996. ISBN 0-03-095283-2

Toon, Ernest R., et al. *Foundations of Chemistry*. Canada: Holt, Rinehart and Winston of Canada, Limited, 1990. ISBN 0-03-922287-X

BioChemLinks – <http://biochemlinks.com>.

Lab safety, teaching science, science-related careers Curriculum Services Canada

Ontario Curriculum Centre – <http://www.curriculum.org>

Grade 10 Academic Science Profile Note-Taking Styles

Science Teachers' Resource Center (Lapeer County Information Depot)

– <http://chem.lapeer.org/Chem1Docs/Index.html>

The Squier Group – <http://www-wilson.ucsd.edu/education/gchem/equilibrium/>

Clearinghouse For Science, Mathematics, and Environmental Education – <http://www.ericse.org/>

Mansfield University – <http://www.mnsfld.edu/~bganong/102.html>

Wilton Highschool Chemistry – <http://www.chemistrycoach.com/>

Chemistry Learning Center – <http://learn.chem.vt.edu/tutorials/organic/index.html>

American Chemical Society

– http://chemistry.org/portal/Chemistry?PID=acsdisplay.html&DOC=vc2\1rp\rp1_markers.html

– <http://www.sasked.gov.sk.ca/docs/chemistry/mission2mars/> – equilibrium activities

Activity 1.1: An Introduction to Equilibrium Systems

Time: 10.0 hours

Description

This activity introduces students to the concept of dynamic equilibrium. They carry out an experiment to determine the equilibrium constant for a system, followed by solving equilibrium problems involving concentrations of reactants and products and K_{eq} . There is an opportunity to incorporate the use of available technology, e.g., graphing calculators and spectrophotometers. Students develop an understanding of Le Chatelier's principle and use it to predict the direction in which a system at equilibrium will shift when volume, pressure, concentration, or temperature is changed, and to investigate how it may be applied to optimize the production of industrial chemicals. Students review the expectations for senior formal laboratory writing, in preparation for the End-of-Unit and Final Performance Task.

Strand(s) & Learning Expectations

Strand(s): Chemical Systems and Equilibrium

Learning Expectations

CSV.01 - demonstrate an understanding of the concept of chemical equilibrium, Le Chatelier's principle, and solution equilibria;

CSV.02 - investigate the behaviour of different equilibrium systems, and solve problems involving the law of chemical equilibrium;

CSV.03 - explain the importance of chemical equilibrium in various systems, including ecological, biological, and technological systems;

CS1.01 - illustrate the concept of dynamic equilibrium with reference to systems such as liquid-vapour equilibrium, weak electrolytes in solution, and chemical reactions;

CS1.02 - demonstrate an understanding of the law of chemical equilibrium as it applies to the concentrations of the reactants and products at equilibrium;

CS1.03 - demonstrate an understanding of how Le Châtelier's principle can predict the direction in which a system at equilibrium will shift when volume, pressure, concentration, or temperature is changed;

CS1.07 - define constant expressions; such as K_{sp} , K_w , K_a , and K_b ;

CS2.01 - use appropriate vocabulary to communicate ideas, procedures, and results related to chemical systems and equilibrium;

CS2.02 - apply Le Chatelier's principle to predict how various factors affect a chemical system at equilibrium, and confirm their predictions through experimentation;

CS2.03 - carry out experiments to determine equilibrium constants;

CS2.06 - solve equilibrium problems involving concentrations of reactants and products and K_{eq} ;

CS3.01 - explain how equilibrium principles may be applied to optimize the production of industrial chemicals;

SIS.01 - demonstrate an understanding of safe laboratory practices by selecting and applying appropriate techniques for handling, storing, and disposing of laboratory materials, and using appropriate personal protection;

SIS.02 - select appropriate instruments and use them effectively and accurately in collecting observations and data;

SIS.03 - demonstrate the skills required to plan and carry out investigations using laboratory equipment safely, effectively, and accurately;

SIS.04 - demonstrate a knowledge of emergency laboratory procedures;

SIS.05 - select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate scientific ideas, plans, and experimental results;

SIS.07 - communicate the procedures and results of investigations for specific purposes by displaying evidence and information, either in writing or using a computer, in various forms, including flow charts, tables, graphs, and laboratory reports;

SIS.08 - express the result of any calculation involving experimental data to the appropriate number of decimal places or significant figures;

SIS.09 - select and use appropriate SI units.

Prior Knowledge & Skills

- Understanding of the Solutions and Solubility unit from SCH3U
- Ability to solve quadratic equations

Planning Notes

- Review and follow all board regulations for the safe handling and disposal of chemicals, e.g., nitric acid. Teachers should consult (WHMIS) Material Safety Data Sheets for appropriate treatment of sensitivities to substances being used in the laboratory.
- Gather samples of relevant versus irrelevant or testable versus not testable research questions.
- Prepare a diagnostic quiz based on information from SCH3U if desired for this unit.
- Based on the outcome of the diagnostic assessment the teacher may wish to develop independent study packages to help strengthen student background knowledge.
- Gather and prepare materials required for the following Activities: 1.1.3 - straws of different diameter, 50 mL graduated cylinders; 1.1.4 - iodine and bromine tubes, sodium chloride, acetic acid, calcium carbonate; 1.1.6 - hydrated cobalt chloride, chromate/dichromate solutions etc.; 1.1.8 - pipettes, volumetric flasks, spectrophotometers if available, $Fe(NO_3)_3$, KSCN, nitric acid.
- Suggested Note-Taking Styles are provided in the Grade 10 Academic Profile Teacher Support Material - page 3.
- Prepare questions (and solutions) that incorporate practical applications and career components for the following Activities: 1.1.7 and 1.1.9.
- Prepare lesson notes for Activity 1.1.5.
- Plan such that the entire first period may be used to stimulate student interest, e.g., Act 1.1.1 Carousel Activity.

Teaching/Learning Strategies

1.1.1 Student Activity: Students rotate through a carousel of activities to help the teacher assess prior knowledge and prepare a review of concepts and skills required for this unit.

Teacher Facilitation: The teacher prepares a carousel of activities including hands-on and pen-and-paper activities, based on material covered in SCH3U, e.g., binary nomenclature; mole calculations; concentration calculations; solubility rules; processes involved in dissolving compounds; identifying ionic and covalent compounds; titration skills and net ionic equations; formulae of various acids and bases; Bronsted-Lowry and Arrhenius definitions of acids and bases; writing equations for dissociation of acids and bases; operational definition of pH; saturated/unsaturated/super-saturated solution. Depending on the outcomes of the diagnostic activity, the teacher may wish to offer support material to be completed independently.

1.1.2 Student Activity: Students are introduced to the assessment and evaluation strategies for the course, including the midterm examination (if planned) to take place after the second unit and the nature of the End-of-Unit Task. The End-of-Unit Task (Act 1.6) requires students to use their knowledge of K_{sp} and the common ion effect to design and conduct an experiment. The Final Assessment Task provides senior students with the opportunity to demonstrate their Knowledge and Inquiry, Communication and Making Connections skills at a pre-university level. Students formulate their own research question, keep a log of their time, design and conduct the experiment, and communicate their research in a formal lab report. Students review a rubric and format for a senior level formal laboratory report. In preparation for the Final Assessment Task, students complete a T-chart comparing relevant versus irrelevant, or testable versus not testable research questions. Time is allowed for students to ask clarification questions.

Teacher Facilitation: The teacher reviews the four categories in the Achievement Chart, and emphasizes the importance of independent inquiry skills for the End-of-Unit Task. Assist students with the comparison chart by providing some criteria for an appropriate research question. It is important to guide students to generate a research question for the Final Assessment Task, preferably by the end of the second unit. Their question should relate to or extend upon the topics of study in the course. Be prepared to provide hints to generate appropriate research questions throughout the course. The teacher prepares a handout outlining the format for a formal laboratory report and a corresponding rubric. Suggestions for creating the rubric are found in the Appendix. The teacher recommends that students keep the rubric and format outline accessible in their notes.

1.1.3 Student Activity: Students work with a partner to construct a physical analogue for an equilibrium system. Each student gathers a 50 mL graduated cylinder and a straw (both straws should be identical). One student labels the graduated cylinder 'Reactant' and adds 50 mL of water. The other student labels the cylinder 'Product' and leaves it empty. Both students place the straw in the graduated cylinder until the bottom of the straw touches the bottom of the cylinder. They then transfer water from their graduated cylinders simultaneously, using one index finger to retain water in the straw. There will be no water transferred from the Product to Reactant containers during the first trial. Students record the volumes of the Reactant and Product after each trial and plot the data as a line graph (plot the Reactant and Product volumes on the same graph). Students formulate questions, design a procedure, and conduct a lab investigating how changing various factors may impact the physical analogue of the equilibrium system that they created. They then analyse and compare the graphical data.

Teacher Facilitation: The teacher provides instructions for the first part of the activity and encourages students to formulate questions investigating how changing various factors may impact the equilibrium system, e.g., starting with equal volumes of Reactant and Product, using straws with different diameters, using two straws in one direction only, etc. Graphing calculators could be used if available. The teacher uses the class results to introduce and explain the concept of equilibrium and to discuss factors that may prevent a reaction from reaching completion.

1.1.4 Student Activity: Students review the criteria for the Observation section of a formal lab report. They then design their own observation chart and collect data while investigating dynamic equilibrium at various lab stations. Students assess one another's observation charts.

Teacher Facilitation: As part of the progression towards producing independent learners, the teacher discusses expectations for an efficient observation chart with the students, by referring to a rubric or other recording tool. The teacher then sets up a variety of lab stations investigating chemical and physical equilibrium systems, e.g., $\text{Cr}_2\text{O}_7^{2-}$ and CrO_4^{2-} , N_2O_4 and NO_2 , equilibrium of soluble salt in solvent (NaCl in water), slightly soluble salt in solvent (CaCO_3 in water), liquid-vapour equilibrium (bromine tubes), solid-vapour equilibrium (iodine tubes), weak electrolytes in solution.

1.1.5 Student Activity: Students participate in a class discussion about various Note-Taking Styles, e.g., graphic organizers, point form, paragraph form, embedded notes. They generate their own notes based on a teacher-directed lesson about equilibrium and compare them with the teacher's notes.

Teacher Facilitation: The teacher may wish to direct students to the Grade 10 Academic Profile Teacher Support Material – page 3 on Note Taking Styles and participate in a brief discussion. The teacher directs a lesson on dynamic equilibrium systems including equilibrium constant expressions, and the differences among between K_{eq} , K_{p} and K_{c} . The teacher may post lecture notes as a reference and learning tool for students. Collect exemplars from students for future reference material.

1.1.6 Student Activity: Students review the assessment for the Procedure and Result sections of a formal lab report prior to the activity. They investigate Le Chatelier's principle by designing and conducting a lab to analyse the effect of changing various factors, e.g., temperature, concentration, volume and pressure, on different chemical equilibrium systems. Students participate in a discussion about Le Chatelier's Principle.

Teacher Facilitation: The teacher reviews requirements for a Formal Laboratory Report and ensures required materials are available for the experiments, e.g., hydrated cobalt chloride to observe the impact of temperature changes; chromate/dichromate to observe the impact of pH changes, etc. The teacher leads a discussion to summarize student results and reviews Le Chatelier's principle.

1.1.7 Student Activity: Students complete problems based on Le Chatelier's Principle. They research the application of Le Chatelier's Principle to optimize production of industrial chemicals, e.g., ammonia, sulphuric acid. Working in small groups, students discuss their findings.

Teacher Facilitation: The teacher assigns problems incorporating practical applications of Le Chatelier's Principle and possible career connections. Solutions to the problems are posted and students are given an opportunity to ask questions. The teacher may wish to book time in the library and/or computer room to assist students with their research.

1.1.8 Student Activity: Students vary the equilibrium concentrations of a chemical system to qualitatively investigate the effect on chemical equilibrium and to quantitatively determine the equilibrium constant of the system. They compare their results with each other and expected values.

Teacher Facilitation: There is an opportunity for the teacher to incorporate technology into this activity, i.e., Spectrophotometric Determination of the Equilibrium Constant (see Resources).

1.1.9 Student Activity: Students participate in a class discussion about the results of Act. 1.1.8. They discuss possible sources of error. Students solve equilibrium problems involving reactant/product concentrations and equilibrium constants.

Teacher Facilitation: The teacher leads the class in a discussion about Act.1.1.8 and encourages students to formulate ideas about possible sources or error. The teacher provides students with sample solutions to K_{eq} problems. Assign questions involving concentrations of reactants and products and equilibrium constants. The teacher may encourage the use of graphing calculators and the quadratic equation to analyse K_{eq} equations. Solutions should be posted for students to self-assess. The teacher may collect some problems for evaluation or provide a quiz.

Assessment & Evaluation of Student Achievement

A question-answer sheet and a checklist assessing skills could accompany the diagnostic activity to determine the students' incoming abilities. The teacher could assess one or two categories for each of the four experiments, e.g., Act 1.1.3 - Designing a Procedure and Tables and Figures, Act 1.1.4 - Observations, Act 1.1.6 - Procedure and Results, Act 1.1.8 - Discussion. Peer- and self-assessment could be used for self-generated notes. This activity provides an opportunity to assess and give feedback to students on their note-taking abilities and inquiry skills including laboratory writing skills, which they may apply in the Final Assessment Task. This activity provides many opportunities to assess the students' Scientific Investigative Skills to help set the tone early in the course. Solutions to selected problems may be evaluated; evaluation of a quiz would serve the same purpose.

Reports (Inquiry, Communication, Making Connections)

Problem Set or Quiz (Knowledge/Understanding, Making Connections, Communication)

Accommodations

- Allow increased time for the completion of problems or reduce the number of questions as appropriate for some students.
- Establish a glossary of terms that might be found in notes, texts, and problems.
- Include diagrams with problems.
- Alternative note-taking methods such as using a tape recorder can be used.

Resources

– <http://129.93.84.115/Chemistry/DoChem/DoChem115.html>

Le Chatelier's Principle

– <http://chem.lapeer.org/Chem2Docs/KeqLab.html>

Spectrophotometric determination of equilibrium constant

– <http://www.cvgs.k12.va.us/research/paper/question.htm>

Criteria for a relevant research question

Activity 1.2: Entropy

Time: 2.0 hours

Description

This activity introduces students to changes in entropy associated with chemical and physical processes and the tendency of reactions to achieve minimum energy and maximum entropy. Students investigate the role entropy plays in the spread and elimination of pollutants such as PCBs. They peer assess and check self-generated notes against the teacher's to help develop confidence in their abilities to work independently.

Strand(s) & Learning Expectations

Strand(s): Chemical Systems and Equilibrium

Learning Expectations

CS1.04 - identify, in qualitative terms, entropy changes associated with chemical and physical processes;

CS1.05 - describe the tendency of reactions to achieve minimum energy and maximum entropy.

Prior Knowledge & Skills

- Understanding of physical/chemical changes and endothermic/exothermic reactions.

Planning Notes

- Prepare lesson notes on entropy.
- Prepare a rubric for peer assessment of entropy notes.
- The teacher may wish to gather and prepare materials required for Activity 1.2.1- NaHCO_3 , bunsen burner, ice, concentrated H_2SO_4 .
- The teacher should follow all board regulations for the safe handling and disposal of chemicals, e.g., sulphuric acid.

Teaching/Learning Strategies

1.2.1 Student Activity: Students generate their own notes from a teacher demonstration and teacher directed lesson on entropy. Students peer-assess their notes in class and may compare with teacher notes outside of class time. They complete assigned reading and questions.

Teacher Facilitation: Use a demonstration to identify entropy changes associated with physical and chemical processes, e.g., compare the entropies of the solid, liquid, and gaseous states of a substance, concentrated sulphuric acid in water, decomposition of sodium bicarbonate and provide students with an opportunity to formulate and ask questions. Direct a lesson to emphasize that reactions have a tendency to achieve minimum energy and maximum entropy and that entropy is the driving force behind endothermic reactions. Assign problems incorporating environmental issues, e.g., the difficulty associated with eliminating a pollutant such as PCB because of the enormous energy requirement and generation of disorder.

Assessment & Evaluation of Student Achievement

This activity is an opportunity for peer assessment; in addition, provide feedback to students on their note-taking skills.

Notes (Knowledge/Understanding, Communication)

Accommodations

- Continue to add terms to glossary.
- Display posters of different note-taking styles, with a description of pluses and minuses for each method.
- Use a tape recorder for note taking.

Resources

Science Teachers' Resource Centre Lapeer County Information Depot
– <http://learn.chem.vt.edu/tutorials/>

Activity 1.3: Solubility of Salts

Time: 6.0 hours

Description

Students perform an experiment to determine the K_{sp} value of a slightly soluble salt. Students solve a variety of problems involving K_{sp} including predicting the formation of precipitates and determining the molar solubility of a pure substance in a solution of a common ion. The application and effects of solubility in a variety of contexts are discussed. Students generate their own notes and check posted solutions.

Strand(s) & Learning Expectations

Strand(s): Chemical Systems and Equilibrium

Learning Expectations

CS2.01 - use appropriate vocabulary to communicate ideas, procedures, and results related to chemical systems and equilibrium (e.g., *homogeneous*, *common ion*, K_a value);

CS2.03 - carry out experiments to determine equilibrium constants (e.g., K_{eq} for iron [III] thiocyanate, K_{sp} for calcium hydroxide, K_a for acetic acid);

CS2.04 - calculate the molar solubility of a pure substance in water or in a solution of a common ion, given the solubility product constant (K_{sp}), and vice versa;

CS2.05 - predict the formation of precipitates by using the solubility product constant;

CS2.06 - solve equilibrium problems involving concentrations of reactants and products and the following quantities: K_{eq} , K_{sp} , K_a , K_b , pH, pOH;

CS3.02 - identify effects of solubility on biological systems (e.g., kidney stones, dissolved gases in the circulatory system of divers, the use of barium sulfate in medical diagnosis);

SIS.01 - demonstrate an understanding of safe laboratory practices by selecting and applying appropriate techniques for handling, storing, and disposing of laboratory materials, and using appropriate personal protection;

SIS.02 - select appropriate instruments and use them effectively and accurately in collecting observations and data;

SIS.03 - demonstrate the skills required to plan and carry out investigations using laboratory equipment safely, effectively, and accurately;

SIS.08 - express the result of any calculation involving experimental data to the appropriate number of decimal places or significant figures;

SIS.09 - select and use appropriate SI units;

SIS.10 - identify and describe science-and technology-based careers related to the subject area under study.

Prior Knowledge & Skills

- Quantities in Chemical Reactions and Solutions and Solubility from SCH3U.

Planning Notes

- Review and follow all local Board regulations for the safe handling and disposal of chemicals.
- Gather materials for the following Activities: 1.3.2-silver acetate or lead(II) chloride needs to be prepared several days in advance of the activity; 1.3.4-ammonium hydroxide, ammonium chloride and phenolphthalein and a petri dish.
- Have students prepare Act 1.3.2 24 hours in advance of making quantitative observations to ensure that all the silver or lead(II) ions have had the opportunity to react.
- Due to toxic nature of lead(II) chloride, it is suggested that calcium hydroxide be used.
- Gather and prepare questions (and solutions) that incorporate practical applications and career components for the following Activities: 1.3.3 and 1.3.4.
- Take proper safety precautions when using concentrated stock solutions.
- Prepare notes on the applications of solubility product constants.

Teacher/Learning Strategies

Act 1.3.1 Student Activity: Students generate their own notes from a lesson on the equilibrium constant for slightly soluble ionic substances and its applications in the environment, society and industry. They investigate possible related careers. Students set up their lab for Act. 1.3.2 and, based on the lab procedure provided by the teacher, prepare their own observation tables. Students assess each other's lesson notes outside class time.

Teacher Facilitation: To provide a context for learning the solubility product constant, the teacher refers to applications of equilibrium solubility such as kidney stones, dissolved gases in the circulatory system of divers, the use of barium sulfate in medical diagnosis, the formation of stalactites and stalagmites as found in the Bonnechere Caves in Ontario, hard water and water softeners, refining nickel, developing camera film, and the massive deposits of limestone and gypsum as oceans dry up. A more detailed treatment of these applications can occur in Act 1.3.5 once students have mastered the concept of K_{sp} and the common ion effect. Based on the results of the diagnostic quiz in Act 1.1.2, the teacher uses the students' prior knowledge of unsaturated, saturated and supersaturated solutions and links it to chemical equilibrium systems. Students will apply this knowledge in Act 1.3.2 to determine an actual K_{sp} value. The teacher provides students with the lab procedure for Act 1.3.2.

1.3.2 Student Activity: Students conduct a lab to quantitatively determine the K_{sp} value for a relatively insoluble salt, e.g., silver acetate by displacement with copper wire, lead(II) chloride with a strip of zinc metal.

Teacher Facilitation: The teacher could set up the analysis section of this lab to lead students step-by-step to arrive at the expression and value for the K_{sp} of silver acetate or lead(II) chloride. The teacher may quickly check students' observation tables.

1.3.3 Student Activity: Students solve K_{sp} questions.

Teacher Facilitation: The teacher should choose K_{sp} problems involving concentration, including molar solubility of pure substances in water. Problems could be collected for evaluation.

1.3.4 Student Activity: Students take notes on the common ion effect, precipitation reactions, predicting precipitate formation using K_{sp} data and applications from a teacher-directed lesson. Students solve problems involving common ion effect and compare their answers to posted solutions.

Teacher Facilitation: The teacher could do a quick demonstration of common ion effect such as how an excess of ammonium ions reduces the concentration of hydroxide ions. To do so place a petri dish on an overhead projector, and fill it halfway with 1mol/L ammonium hydroxide. Add two drops of phenolphthalein. The solution should be red. Stir a little solid ammonium chloride into the solution; the red colour will disappear. The ammonium ions suppress the ionization of the ammonium hydroxide. An example of a practical use of equilibrium constants is in the use of barium sulfate as an X-ray contrast medium. Doctors must make certain that almost no poisonous barium ions are present to dissolve in a person's body fluids. Knowing the solubility product constant for barium sulfate, calculations are made to determine the amount of barium sulfate needed for the procedure. To ensure that the concentration of barium ions will not exceed the safety level, a soluble salt such as sodium sulfate, which contributes sulfate ions, is added to increase the sulfate ion concentration and reduce the barium ion concentration. Because sulfate ion is present in both barium sulfate and sodium sulfate, sulfate is the common ion present in both substances dissolved in the solution. Some students will have trouble grasping the concept of the common ion effect. First, remind them that because the solubility of barium sulfate is very low, it is not involved in the equation for the solubility product constant. It follows that the product of the two ion concentrations is equal to the constant, K_{sp} . A constant value cannot change, so if one of the concentrations rises, the other must drop. By means of this principle, the common ion effect can be used to increase or decrease the concentration of a chosen ion.

1.3.5 Student Activity: Students can generate their own notes from a more detailed lesson on the practical applications of solubility equilibrium.

Teacher Facilitation: The teacher prepares lesson notes for those applications mentioned in Activity 1.3.1. The teacher administers a quiz based on Solubility Equilibrium.

Assessment & Evaluation of Student Achievement

A lab report (emphasizing the abstract) for the experiment would be appropriate. Short quiz questions on a variety of K_{sp} problems should be used to determine the students' abilities and/or a problem set could be collected.

Report (Inquiry, Communication, Making Connections)

Quiz (Knowledge/Understanding, Making Connections, Communication)

Problem Set (Knowledge/Understanding, Making Connections, Communication)

Accommodations

- Use alternative note-taking methods such as a tape recorder.
- Reduce the number of repetitive problems.
- Add terms to glossary.
- Organize problems according to type and provide model solutions for each type.

Resources

Newton, David. *Chemistry Problems*. Portland, Maine: J. Weston Walch, Publisher, 1977.

World of Chemistry, TVO Video Series, 1988 – *World of Chemistry: Driving Forces*

Activity 1.4: Acid Base Equilibrium

Time: 6.0 hours

Description

Students are introduced to the key concept of dissociation constants as a measure of the relative strength of weak acids and bases. They conduct experiments to find the K_a of a weak acid and the pH of salts of weak acids and bases. Students are provided with an opportunity to practise preparing solutions and using titration skills that may be applied in the End-of-Unit and Final Assessment Tasks. They solve a variety of problems involving acid-base equilibrium and titration data.

Strand(s) & Learning Expectations

Strand(s): Chemical Systems and Equilibrium

Learning Expectations

CS2.01 - use appropriate vocabulary to communicate ideas, procedures, and results related to chemical systems and equilibrium;

CS2.03 - carry out experiments to determine equilibrium constants (e.g., K_{eq} for iron [III] thiocyanate, K_{sp} for calcium hydroxide, K_a for acetic acid);

CS2.06 - solve equilibrium problems involving concentrations of reactants and products and the following quantities: K_{eq} , K_{sp} , K_a , K_b , pH, pOH;

CS2.07 - predict, in qualitative terms, whether a solution of a specific salt will be acidic, basic, or neutral;

CS2.08 - solve problems involving acid-base titration data and the pH at the equivalence point;

SIS.01 - demonstrate an understanding of safe laboratory practices by selecting and applying appropriate techniques for handling, storing, and disposing of laboratory materials, and using appropriate personal protection;

SIS.02 - select appropriate instruments and use them effectively and accurately in collecting observations and data;

SIS.03 - demonstrate the skills required to plan and carry out investigations using laboratory equipment safely, effectively, and accurately;

SIS.09 - select and use appropriate SI units.

Prior Knowledge & Skills

- Properties of acids and bases
- Bronsted-Lowry and Arrhenius definitions of acids and bases
- The difference between strong and weak acids and bases in terms of degree of dissociation
- The operational definition of pH
- Writing equations for dissociation of acids and bases
- Basic titration skills

Planning Notes

- Gather and prepare materials for the following Activities: 1.4.1 – solutions of strong and weak acids and bases, pH meters/probes/paper; 1.4.3 – a number of salts, distilled water and pH meters/probes/paper and a fill-in-the blank worksheet; 1.4.5 – concentrated acid and base solutions, pH meters/probes/paper, indicators and titration apparatus; 1.6 – End-of-Unit Task solutions of $\text{Ca}(\text{OH})_2$ and $\text{Ca}(\text{OH})_2$ with dissolved calcium salt.
- Prepare a rubric to assess the Abstract and Discussion sections of a senior-level formal lab report. Some suggested criterion statements are provided in the Appendix.
- Prepare a peer-assessment checklist for titration skills for use in Act 1.4.5.
- Gather and prepare questions (and solutions) that incorporate practical applications and career components for the following Activities: 1.4.2, 1.4.3, and 1.4.6.
- Take proper safety precautions when using concentrated stock solutions.
- Follow all board regulations for the safe handling and disposal of chemicals.

Teacher/Learning Strategies

1.4.1 Student Activity: Students could generate their own notes to distinguish between strong and weak acids and bases using the concept of equilibrium. Through a teacher-directed lesson, they are introduced to the equilibrium constants K_a , K_b and K_w .

Teacher Facilitation: Based on the results of the diagnostic quiz in Act 1.1.2, the teacher uses students' prior knowledge to explain how dissociation constants are a measure of the relative strength of weak acids and bases. The teacher may wish to do a demonstration as a visual aid using pH meters/probes/paper and a variety of solutions of acids and bases to compare strong and weak acids and bases using the concept of equilibrium. This leads to a discussion on equilibrium constants. Remind students that they worked with equilibrium constants in Act 1.1.9 and that the acid/base/water dissociation constants are set up the same way.

1.4.2 Student Activity. Students solve problems calculating pH, $[\text{H}_3\text{O}^+]$, pOH, $[\text{OH}^-]$, K_a , K_b , and K_w .

Teacher Facilitation: Direct a lesson to provide sample questions and solutions for problems calculating pH, $[\text{H}_3\text{O}^+]$, pOH, $[\text{OH}^-]$, K_a , K_b , and K_w . Post answers for the problem set and provide students with an opportunity to ask questions pertaining to the problems. Suggest that experiments to determine equilibrium constants, K_b , K_a for weak acids and bases at various temperatures would be a straightforward Final Assessment Task project.

1.4.3 Student Activity: Students prepare aqueous solutions of several salts and measure the pH of the solutions. Students record their results and then apply their knowledge to homework questions. Students compare their answers to posted solutions.

Teacher Facilitation: In order to encourage students to make connections, the teacher can extend the topic of salt hydrolysis with a discussion of the practical application of antacids to relieve acid indigestion. Excess stomach acid must be treated with a basic solution in order for neutralization to occur. The teacher could bring in some common antacids to determine their active ingredient, and ask students to show by equations how these particular substances can act as bases. Post answers for the problems and provide students with an opportunity to ask questions pertaining to the problems.

1.4.4 Student Activity: Under teacher guidance, students practise and participate in peer assessment of titration skills including appropriate use and care of burettes. They prepare their own dilutions of an acetic acid solution of known concentration. They then design and conduct a titration to confirm the pH of the solution of acetic acid they have prepared and to calculate K_a .

Teacher Facilitation: The teacher prepares a solution of acetic acid of known concentration for use in the dilutions and a standard base solution for titration.

1.4.5 Student Activity: Students participate in a class discussion about Act 1.4.4. Students work together to solve problems focussing on the use of titration curves for strong and weak acids and bases to determine the pH of the equivalence point. Students complete a written quiz based on Act 1.4 – Acid Base Equilibrium.

Teacher Facilitation: The teacher discusses the results and conclusion from Act 1.4.4. Post answers for the problems and provide students with an opportunity to ask questions pertaining to the problems. Error analysis can also be discussed here. The teacher administers a quiz based on Acid Base Equilibrium.

Assessment & Evaluation of Student Achievement

A laboratory report for the experiment emphasizing the Introduction and Discussion would be appropriate. The teacher could use a rubric as an assessment tool. Students should participate in peer assessment of titration skills. Post or discuss answers to the problems on acid base equilibrium and salt hydrolysis in order to provide feedback to the students. Use a written quiz based on acid base equilibrium to determine the students' skills.

Report (Inquiry, Communication, Making Connections)

Quiz and/or Problem Set (Knowledge/Understanding, Making Connections, Communication)

Accommodations

- Use alternative note-taking methods such as a tape recorder.
- Allow sufficient time for the completion of problems and for students to perform titrations until results are replicated.
- Set up a buddy system for students during problem-solving sessions.
- Include illustrations to show proper technique for using the equipment found in this unit.

Resources

Acids and Bases, TVO video series, 1987.

Chem tutor – <http://www.chemtutor.com/acid.htm#buffmat>
- Acid/base and titration activities

World of Chemistry, TVO Video Series, 1988 – *World of Chemistry: Proton of Chemistry*

Activity 1.5: Buffer Solutions

Time: 2.5 hours

Description

Students make observations and collect data from a teacher demonstration to help formulate a definition of a buffer system. They enhance their understanding of the characteristics and components of a buffer solution by completing an assigned reading and questions. Students participate in a seminar activity to research and report on how buffering action affects our daily lives.

Strand(s) & Learning Expectations

Strand(s): Chemical Systems and Equilibrium

Learning Expectations

CSV.01 - demonstrate an understanding of the concept of chemical equilibrium, Le Chatelier's principle, and solution equilibria;

CSV.03 - explain the importance of chemical equilibrium in various systems, including ecological, biological, and technological systems;

CS1.09 - describe the characteristics and components of a buffer solution;

CS3.03 - explain how buffering action affects our daily lives, using examples;

SIS.06 - compile and interpret data or other information gathered from print, laboratory, and electronic sources, including Internet sites, to research a topic, solve a problem, or support an opinion.

Prior Knowledge & Skills

- Identify and explain properties of acids, bases, and solutions from SCH3U and SNC2D.

Planning Notes

- Follow all board regulations for the safe handling and disposal of chemicals.
- Gather and prepare materials required for Act. 1.5.1: acetic acid, sodium acetate, concentrated acid, concentrated base, pH probe(s) if available.
- Book time in the resource centre and/or computer room.
- Gather and prepare questions about buffer systems that incorporate practical applications.

Teaching/Learning Strategies

1.5.1 Student Activity: Students design their own observation chart and collect data from a teacher demonstration illustrating the components and basic characteristics of a buffer system. They generate a definition of a buffer system and hypothesize how it works. Students enhance their understanding by completing an assigned reading and questions.

Teacher Facilitation: The teacher prepares solutions of a sodium acetate/acetic acid buffer system (6×50 mL) and use a pH probe or an indicator to demonstrate the effect of adding small volumes of concentrated acid and base. Remind students to think about the common ion effect and how weak acids function. Direct students to do additional reading and answer assigned questions. Post answers for the problems and provide students with an opportunity to ask questions.

1.5.2 Student Activity: Students research/review material on how buffering action affects our daily lives, e.g., acidosis/alkalosis, buffered medications. Working in small groups they further their understanding by discussing their findings.

Teacher Facilitation: The teacher may book time in the resource centre and/or computer room. Facilitate peer assessment of group work.

Assessment & Evaluation of Student Achievement

A short quiz could be used to ensure that students understand the characteristics and components of a buffer system. It would be appropriate to have students participate in peer assessment of group work skills.

Quiz (Knowledge/Understanding, Making Connections)

Research and/or Report (Inquiry, Communication, Making Connections)

Accommodations

- Have a range of reading materials for answering assigned questions.
- Continue the use of a glossary.

Resources

Chem tutor – <http://www.chemtutor.com/acid.htm#buffmat> - Buffer activities

Activity 1.6: End-of-Unit Task and Written Test

Time: 3.5 hours

Description

This activity is composed of two distinct parts. The first part provides students with an opportunity to combine knowledge and skills acquired throughout the unit to investigate a system at equilibrium. Students design a procedure, make their own solutions, perform a titration, collect and analyse data and communicate their results in a formal laboratory report. The second part is a written test used to assess students' knowledge and abilities to make connections.

Strand(s) & Learning Expectations

Strand(s): Chemical Systems and Equilibrium

Learning Expectations

CSV.01 - demonstrate an understanding of the concept of chemical equilibrium, Le Chatelier's principle, and solution equilibria;

CSV.02 - investigate the behaviour of different equilibrium systems, and solve problems involving the law of chemical equilibrium;

CSV.03 - explain the importance of chemical equilibrium in various systems, including ecological, biological, and technological systems;

SIS.01 - demonstrate an understanding of safe laboratory practices by selecting and applying appropriate techniques for handling, storing, and disposing of laboratory materials, and using appropriate personal protection;

SIS.02 - select appropriate instruments and use them effectively and accurately in collecting observations and data;

SIS.03 - demonstrate the skills required to plan and carry out investigations using laboratory equipment safely, effectively, and accurately.

Prior Knowledge & Skills

- Students should be familiar with standardizing acids and bases with titration, the common ion effect, K_{eq} , K_{sp} and K_a and quantitatively determining K_{eq} and K_{sp} .

Planning Notes

- Prepare the following solutions at least one week in advance: Ca(OH)_2 and Ca(OH)_2 with dissolved calcium salt such as $\text{Ca(NO}_3)_2$.
- Take proper safety precautions when using concentrated stock solutions.
- Follow all board regulations for the safe handling and disposal of chemicals.
- Ensure appropriate materials are available: titration apparatus, filter paper, indicators, thermometers, concentrated hydrochloric acid.
- Prepare a written test that assesses students' knowledge and ability to make connections.

Teaching/Learning Strategies

1.6.1 Student Activity: Students use their knowledge of K_{sp} to design and conduct an experiment to determine the solubility product constant for a semi-soluble salt, such as Ca(OH)_2 . Students should then use their knowledge of the common ion effect to determine the additional calcium ion concentration in an equilibrium system, e.g., Ca(OH)_2 containing dissolved calcium salt. This activity provides students with an opportunity to link skills and knowledge used throughout the unit, such as, using appropriate safety procedures, applying Le Chatelier's principle, and performing a titration.

Teacher Facilitation: Prepare two solutions, Ca(OH)_2 and Ca(OH)_2 with dissolved calcium salt, at least one week prior to use. Review the evaluation scheme with the class. Encourage students to consider using methods or techniques to maximize accuracy, e.g., filtering the Ca(OH)_2 solutions, using three trials etc. Ca(OH)_2 is corrosive. Remind students to handle and dispose of chemicals safely. The teacher may also allot time during the activity to assess the students' practical skills.

1.6.2 Student Activity: Students complete a written test.

Teacher Facilitation: The teacher generates a test focussing on Knowledge and Making Connections.

Assessment & Evaluation of Student Achievement

A formal laboratory report for the experiment would be appropriate, since it helps prepare the student for the Final Assessment Task. A written test including a variety of types of questions could be used to assess the student's knowledge and ability to make connections.

Report (Inquiry, Communication, Making Connections)

Unit Test (Knowledge/Understanding, Making Connections)

Accommodations

- Provide identified students with extra time for the written test.
- See Accommodations in the Course Overview.