Public District School Board Writing Partnership

Science

Course Profile

Chemistry

Grade 12
College Preparation
SCH4C

• *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.

Spring 2002

Acknowledgments

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Course Overview
Chemistry, SCH4C, Grade 12, College Preparation

Policy Document: *The Ontario Curriculum, Grades 11 and 12, Science, 2000.*
Prerequisite: Grade 10 Science, Academic or Applied, SNC2D or SNC2P

Course Description

This course introduces students to the concepts that form the basis of modern chemistry. Students will study qualitative analysis, quantitative relationships in chemical reactions, organic chemistry, electrochemistry, and chemistry as it relates to the quality of the environment. Students will employ a variety of laboratory techniques, develop skills in data collection and scientific analysis, and communicate scientific information using appropriate terminology. Emphasis will be placed on the role of chemistry in daily life and in the development of new technologies and products.

Course Notes

The Goals of Grade 12 Chemistry

SCH4C has three goals identified in *The Ontario Curriculum, Grades 11 and 12: Science, 2000,* (p. 6).

- 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 Tasks for the course were 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 Task. However, this is not the only possible clustering. The unit activities were then expanded following each overview chart. The suggested activities are intended to be neither restrictive nor prescriptive; instead the intent is to provide teachers with suggestions for course development. Teachers must adapt the profile to suit their circumstances and to match the students' needs while ensuring that all Learning Expectations of the curriculum are addressed fully.

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, SCH4C must adequately prepare those students who will opt for further study of the subject in college and similar post secondary institutions. Knowledge, Inquiry, Communication, and Making Connections expectations, along with the Learning Skills, including study skills and independent learning strategies, must be learned, practised, assessed, and evaluated at a standard that will enable students to assess realistically their aptitude and chances 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 the following recommendations regarding teaching approaches and curriculum expectations that are reflected in this Course Profile and should be evident in courses developed using it as a template. (pp. 8–10)

- 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 is given that precedes the strands. 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 called Science Investigative Skills (SIS). When developing detailed course plans, it is recommended that 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 SCH4C, using and/or adapting activities described in this profile, they should consider the following:

- SCH4C 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 technology, materials, and laboratory equipment is necessary to illuminate theoretical concepts and develop skills.
- Learning activities in this profile are set in a context that relates science to technology, society, and the environment.
- 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.

- Disposal of products of laboratory investigations must be carried out in a safe and environmentally responsible manner. The teacher must follow board policy with respect to disposal of hazardous waste.
- 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
- 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 with 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 teacher 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. The prerequisite for the course is either SNC2P or SNC2D; some students will display strengths in practical problem solving, while others will arrive with a more theoretical background. Students may also bring knowledge and skills from a variety of technical courses. 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 as an end in themselves and should not dominate the curriculum. It is important to emphasize key skills and concepts without obscuring them by expecting students to memorize a multitude of facts, equations, and formulae. 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. 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 and evaluation 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 Course 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 unstated assumptions.
- Practical applications and real world examples are key to the clustering of expectations in SCH4C. Throughout the course students are shown, or investigate on their own, how knowledge of chemistry concepts is applied. Career links, college course offerings, and school-to-work linkages, both in the local community and beyond, are also important considerations when implementing SCH4C.
- In this Course 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 made more open ended 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 have its safety confirmed by the teacher prior to performance. 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

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 n 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.

Note: 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 website prior to assigning them for student use.

The following references will be useful throughout the course:

Barton, Mary Lee and Deborah L. Jordan. *Teaching Reading in Science: A Supplement to Teaching Reading in the Content Areas Teacher's Manual*. Aurora: McRel, 2001. ISBN 1-893476-03-0

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

Donovan, et al. *Chemicals In Action.* Toronto: Holt, Rinehart & Winston, 1987. ISBN 0039219755

Harrison, et al. *Laboratory Manual, Chemistry a First Course*. Toronto: Addison Wesley Publishers, 1988. ISBN 0201178818

Morgan, Nina. *Chemistry in Action*. New York: Oxford University Press, 1995. ISBN 0195210867

Richardson, C. and T. Chasteen. *A Laboratory Manual: Experience the Extraordinary Chemistry of Ordinary Things.* Toronto: John Wiley and Sons, 1995. ISBN 0471059390

Slater, A. and G. Rayner-Canham. *Microscale Chemistry, Laboratory Manua*l. Toronto: Addison Wesley, 1994. ISBN 0201602156

Smith, et al. ALCHEM *Chemistry: Science, Technology, Society*. Toronto: J.M. LeBel. Enterprises, 1990. ISBN 920008313

On-Line Magazines

Popular Science, Times Mirror Magazines – http://www.popsci.com

Discover Magazine, Disney Corp. – http:// www.discover.com

National Geographic – http://nationalgeographic.com

Scientific American – http://www.sciam.com

Rationale for the Unit Sequence of the Course Profile

This course is structured such that the first two units provide the students with skills and knowledge that can be applied in the remaining three units. Unit 1, Matter and Qualitative Analysis, is taught first because it introduces students to a systematic approach used in studying chemistry. Students are provided with an opportunity to learn and practise process and communication skills such as using flow charts to organize data and distinguishing between observations and inferences. Applying qualitative analyses to the study of science helps develop scientific literacy in students. Introducing this unit first enables students to demonstrate mature scientific approaches to investigating chemistry. The second unit of study, Chemical Calculations, again provides students with useful skills that require application throughout the remainder of the course. The three remaining units, Organic Chemistry, Electrochemistry and Chemistry in the Environment, can be interchanged depending on individual teacher preference, availability of supplies and weather considerations, e.g., the Chemistry in the Environment may be best placed as the fifth unit in semester two.

Units: Titles and Times

Unit 1	Matter and Qualitative Analysis	20 hours
* Unit 2	Chemical Calculations	20 hours
Unit 3	Organic Chemistry	20 hours
Unit 4	Electrochemistry	20 hours
Unit 5	Chemistry in the Environment	20 hours
Unit 6	Final Assessment Tasks	10 hours

* This unit is fully developed in this Course Profile.

Unit Overviews

Key to Abbreviations
K = Knowledge/Understanding
I = Inquiry
C = Communication
MC = Making Connections

Unit 1: Matter and Qualitative Analysis

Time: 20 hours

Unit Description
This unit serves to introduce students to the basic principles and techniques of qualitative analysis. Students design investigations and use flow charts to determine the identity of unknown compounds. The role of qualitative analysis in society is also examined. The End-of-Unit Task requires students to organize the information from the unit into a concept map or other graphic organizer. For each cluster that is created on the map, students research several connections to society, technology, and/or the environment.

Unit Overview Chart

Activity/ Time	Title/Focus	Learning Expectations	Assessment Categories
1.1 4 h	Qualitative Technique	MQV.01, MQV.02, MQV.03, MQ1.01, MQ2.01, MQ2.02, MQ3.01 SIS.01, SIS.02, SIS.03, SIS.06	Communication Inquiry
1.2 3 h	Understanding Bohr	MQV.01, MQV.02, MQ1.02, MQ1.03, MQ2.02, MQ2.05 SIS.01, SIS.03, SIS.09	Inquiry Communication Knowledge/Understanding Making Connections
1.3 5 h	Chemical Bonding	MQV.01, MQV.02, MQ1.02, MQ1.04, MQ1.05, MQ2.03 SIS.01, SIS.06	Communication Inquiry Knowledge/Understanding

Activity/ Time	Title/Focus	Learning Expectations	Assessment Categories
1.4 5 h	Identifying an Unknown	MQV.02, MQV.03, MQ2.04, MQ2.01, MQ3.02 SIS.01, SIS.02, SIS.03, SIS.04, SIS.06, SIS.09	Communication Inquiry Knowledge/Understanding Making Connections
1.5 3 h	End-of-Unit Task: Graphic Organizer	MQV.01, MQV.02, MQV.03 SIS.06	Inquiry Communication Knowledge/Understanding Making Connections

Suggested Activities

Qualitative Technique

1.1.1 Students observe several teacher demonstrations and take part in a variety of activities to fulfill the following purposes: a diagnostic tool for understanding chemistry concepts from Grade 9 and 10 Science (evidence of chemical change, pH scale, Bohr model, physical and chemical properties); a review of techniques and concepts from Grade 9 and 10 (use of molecular models, physical and chemical changes, word and chemical equations, use of acid/base indicators); an introduction to some of the concepts and activities in this course (separation techniques, displacement reactions); and an opportunity for students to record and explain observations. Students should then discuss their observations and explanations and the difference between inference, expected observation and true observation.

1.1.2 Following a brainstorming session on the elements of procedure design and separation techniques, students propose a method and carry out an investigation to separate the parts of a mechanical mixture. Initial separation should involve physical techniques like filtration, use of magnetic properties, and sedimentation centrifugation. The separation of the remaining components involves chemical techniques, e.g., electrolysis. The procedure should be set up in a flow chart and should include proper disposal of materials.

1.1.3 Students are introduced to the End-of-Unit Task and encouraged to begin keeping records of the various methods of qualitative analyses as they are encountered throughout the unit.

Assessment Lab Flow Chart (C, I)

Understanding Bohr

1.2.1 The teacher leads a discussion on the nature of light and the electromagnetic spectrum. Demonstrate the use of the spectroscope and the discreet line spectra for elements. Students research applications of spectroscopy, e.g., eye lens research, cardiovascular disease research, magnetic resonance imaging, organic substance identification emphasizing related careers and current discoveries. Students record their findings in a one-page report.

1.2.2 Students carry out flame tests on several different compounds (some of the compounds should contain the same metals) and infer from their observations a method for identifying ions. Students may also use the spectroscope when observing the flame tests. They test their inferences by analysing unknown samples, some of which may contain two different metals. Students could record their findings on a Standard Results Sheet for evaluation and summarize their results in a Qualitative Analysis Log Book.

1.2.3 Following an introduction to the absorption spectra using several different gas samples, students observe and infer, and then attempt to identify unknown gas samples. Teachers may wish to distinguish between absorption spectra and emission spectra.

1.2.4 The teacher leads a lesson to review the Bohr model of the atom and Rutherford-Bohr diagrams, then extends these concepts to Lewis diagrams. Discuss the concept of quanta of energy and tie observations from activities to the Bohr model.

Assessment Research (I, C, MC), Lab Report – Standard Result Sheet (I, C), Written Quiz (K/U)

Chemical Bonding

1.3.1 The teacher leads a lesson on covalent bonding (a video on bonding would complement this lesson) with a review of basic nomenclature of common ionic and molecular compounds from Grade 10. Use Lewis structures to show common covalent molecules including diatomic gases. Students may build simple covalent structures using one of the following: atomic model kits; toothpicks and coloured jujubes or polystryrene balls.

1.3.2 The teacher conducts a lesson on the formation of ions, ionic bonds and the relationship between the charge on an ion and the number of electrons lost or gained. The use of Rutherford-Bohr diagrams for ions may be useful to illustrate these ideas. Introduce total and net ionic equations.

1.3.3 Students design investigations involving double displacement reactions and use the solubility rules to determine the products. Volumes should be on the order of drops. Products should be disposed of properly according to board policy.

1.3.4 The teacher conducts a lesson on total and net ionic equations. Students complete selected questions that involve determining net ionic equations for various double displacement reactions using the solubility rules for common ionic compounds.

Assessment Molecule Building (I, K/U), Lab Report (K/U, I, C)

Identifying an Unknown

1.4.1 Students perform a number of procedures used to identify anions and cations. Procedures, summarized as flow charts, and results are recorded in the Analytical Chemistry Log Book. Students should be made aware of safety concerns (handling and disposal) for all chosen chemicals. Proper safety equipment should be provided and its use explained.

1.4.2 Students are then presented with unknown sample(s). Students identify the unknown compounds (anions and cations) by using the information recorded in their Analytical Chemistry Log Books.

1.4.3 Students participate in a field trip to a local industry where understanding and application of the knowledge and/or skills presented in this unit are required. A guest speaker, or video may also be used, e.g., a forensic scientist using a sample of paint to identify a car make and model.

Assessment Lab Report – Flow Chart (C, I, K/U)

End-of-Unit Task: Graphic Organizer

1.5.1 Students organize the concepts and skills of the unit into a graphic organizer, e.g., a concept map, a web diagram, or a Venn diagram. To begin, all information may be listed in point-form notes as if studying for a test, then, the information should be clustered into appropriate groups. For each cluster, students find one or more connections to the world outside the classroom and include that in their organizer. The connections should focus on career links and college programmes. This approach to summarizing unit material allows students to learn/practise techniques that they could employ independently in later units of this course and as students at a college or other post-secondary institution.

1.5.2 Unit Test

Assessment Graphic Organizer; see Appendix A for rubric (C, I, K/U, MC), Unit Test (K/U, MC)

Resources

Structure of the Atom, a 6-part video series from TVO, provides information about the Bohr model.

Biomedical Applications of Spectroscopy
– http://www.pfeiffer.com/Corporate/Website/Objects/Products/0,9049,88571,00.html

Imaging Spectroscopy – http:// www.techexpo.com/WWW/opto-knowledge/IS_resources.html
Squier Group: Education: Physical Chemistry: Spectroscopy
– http:// www-wilson.ucsd.edu/education/pchem/spectroscopy/

Unit 2: Chemical Calculations

Time: 20 hours

Unit Description

This unit is designed to expand the basic skills and knowledge of qualitative analysis, encountered in Unit 1, to quantitative analysis, since this combination is required for ensuing units. Real-life examples are used wherever possible and skills are introduced in the context of technical careers to allow students to appreciate chemistry in a practical setting. The activities show a progression towards independent note taking and lab skills, with an emphasis on proper lab technique, accuracy of results and procedures, and standardized recording of data and results, as would be required in the pharmaceutical industry, and by the International Organization for Standardization (ISO) or Canadian Good Manufacturing Practices (CGMPs). The unit begins with a discussion on the importance of accurate quantitative chemistry in industrial settings, including Canadian industries, and an introduction to the mole concept. Mole quantities are applied to both theoretical (calculating and quantifying relationships in chemical equations) and experimental (preparing and reacting standard solutions) situations. The End-of-Unit-Task involves designing an experiment to determine the quantitative identity of a substance, in preparation for Unit 6 Final Assessment Tasks. It must be noted that this unit is mathematics-intensive as well as lab-intensive, with a focus on the skills required for quantitative analysis in industry, e.g., quality control lab. Students are therefore advised to review basic algebraic manipulations, calculations, and ratios. Teachers should adapt the complexity of chemical calculations to the degree required to address the expectations. If such equipment is available, this is also a good unit in which to introduce micro-chemistry, since this simulates many “real-life” labs and reduces waste and chemical pollution in the environment. Proper disposal of materials in an environmentally responsible manner must be emphasised.

Unit Overview Chart

Activity/ Time	Title/Focus	Learning Expectations	Assessment Categories
2.1 4 h	The Mole Concept	CCV.01, CCV.O2, CCV.03, CC1.01, CC2.02, CC2.03, CC2.05, CC3.01, CC3.02 SIS.01, SIS.02, SIS.03, SIS.04, SIS.05, SIS.06, SIS.07, SIS.08, SIS.09	Knowledge/ Understanding Inquiry Communication Making Connections
2.2 5 h	Calculating Concentrations	CCV.O2, CCV.03, CC2.01, CC2.02, CC2.05, CC2.06, CC2.08, CC3.01, CC3.02 SIS.01, SIS.02, SIS.03, SIS.04, SIS.05, SIS.07, SIS.08, SIS.09	Knowledge/ Understanding Inquiry Communication Making Connections
2.3 5 h	Stoichiometry and Percentage Yield	CCV.01, CCV.O2, CCV.03, CC1.02, CC1.03, CC2.01, CC2.02, CC2.05, CC2.06, CC2.07, CC2.08, CC3.02, CC3.03 SIS.05, SIS.07, SIS.08, SIS.09	Knowledge/ Understanding Inquiry Communication Making Connections
2.4 2 h	Percentage Composition	CCV.O2, CC2.04 SIS.01, SIS.02, SIS.03, SIS.04, SIS.05, SIS.07, SIS.08, SIS.09	Knowledge/ Understanding Making Connections

Activity/ Time	Title/Focus	Learning Expectations	Assessment Categories
2.5 4 h	End-of-Unit Task: Concentration of a Non-standard Solution	CCV.01, CCV.O2, CC1.02, CC1.01, CC2.01, CC2.02, CC2.03, CC2.04, CC2.05, CC2.08 SIS.01, SIS.02, SIS.03, SIS.04, SIS.05, SIS.07, SIS.08	Knowledge/ Understanding Inquiry Communication Making Connections

Unit 3: Organic Chemistry

Time: 20 hours

Unit Description

Students develop their understanding of organic substances by examining the characteristics of the carbon atom then identifying functional group structures that define common families, e.g., alkenes, alkynes, alcohols, aldehydes, ketones, acids, esters, amines, and finally examining some reactions common to groups of organic substances. Through experimentation and qualitative and quantitative analysis students examine distillation, physical and chemical properties of common organic compounds and key chemical reactions, such as combustion of hydrocarbons and condensation polymerization. The End-of-Unit Task involves students designing and completing a laboratory investigation to identify an unknown liquid from a mixture. Students distil the liquid from a fermentation mixture and determine physical and chemical properties to help identify the unknown.

Unit Overview Chart

Activity/ Time	Title/Focus	Learning Expectations	Assessment Categories
3.1 3 h	Safety and Awareness	OCV.03, OC3.03, OC3.04 SIS.01, SIS.09	Knowledge/Understanding Inquiry Communication Making Connections
3.2 2 h	Distillation	OCV.01, OCV.02, OCV.03, MQV.02, OC1.05, OC2.02, OC3.02 SIS.01, SIS.05	Knowledge/Understanding Inquiry Communication Making Connections
3.3 4.5 h	Organic Families	OCV.01, OCV.02, OC1.01, OC1.02, OC1.03, OC2.01, OC2.03, OC2.04 SIS.01, SIS.02, SIS.03	Knowledge/Understanding Inquiry Communication
3.4 4.5 h	Reactions	OCV.01, OCV.02, OC1.04, OC2.01, OC2.05, OC2.06, CC1.02 SIS.01, SIS.02, SIS.03	Knowledge/Understanding Inquiry Communication
3.5 3 h	Applications	OCV.03, OC3.01, OC3.05 SIS.05, SIS.06	Knowledge/Understanding Inquiry Communication Making Connections
3.6 3 h	End-of-Unit Task: Unknown Liquid	OCV.01, OCV.02, OCV.03, MQV.02, CCV.01 SIS.01, SIS.02, SIS.03	Knowledge/Understanding Inquiry Communication Making Connections

Suggested Activities

Safety and Awareness

3.1.1 The teacher directs a lesson identifying industries (and associated careers) using organic solvents and explaining the dangers associated with their use. Student awareness is increased regarding the combustibility and toxicity of organic solvents. An emphasis is placed on the necessary precautions taken when dealing with these substances. Safety should be related to student use.

3.1.2 Students identify issues associated with the increasing use of plastics such as: depletion of fossil fuels; appropriate waste disposal; short-and-long term environmental impacts; and related careers. Students suggest possible alternatives to plastic products, e.g., paper bags instead of plastic for yard wastes; a caterer using glassware in place of plastic cups; aluminium foil in place of plastic food wrap; cardboard boxes in place of plastic grocery bags; cloth in place of disposable diapers. Products suggested by students are compared based on flexibility of use, durability, cost to manufacture, cost and method of disposal, biodegradability, etc. As students would likely search for most of their information on the Internet, this would be a good time to consider issues such as bias and website reliability.

Assessment Checklist – Safe Handling of Organic Substances (K/U), Plastic Alternatives (I, C, MC)

Distillation

3.2.1 Students participate in a class discussion where the teacher encourages them to generate questions about the production of useful fuels. This leads to a discussion about the principles of distillation and the role of distillation and cracking to produce useful fuels from crude oil.

3.2.2 Students design an experiment to separate a mixture of liquids by distillation. They use a flowchart to describe the procedure used. An emphasis is placed on the safe handling and disposal of organic substances. Students keep a sample of the separated liquids for examination later in the unit. Students add information about distillation to their Analytical Chemistry Log Books for use in completing the Final Assessment Task. Science Investigative Skills could be assessed with a checklist.

Assessment Lab report (I, C), Written Quiz (K/U, MC)

Organic Families

3.3.1 The teacher directs a lesson (using model kits) to illustrate characteristics specific to the carbon atom, including its ability to bond to itself to form long chains.

3.3.2 Students investigate functional group structures that define common families using one or more of the following: textbook, workbook, Internet, software program or molecular model kits. They name and draw Lewis structures of representative molecules from each group, e.g., alkenes, alkynes, alcohols, aldehydes, ketones, acids, esters, and amines.

3.3.3 Students design an experiment to determine the chemical and physical properties of organic substances, e.g., combustibility, conductivity, odour, solubility. The teacher provides the students with a variety of organic substances such as alcohols, carboxylic acids and esters to test. The teacher must check board policy regarding organic substances allowed for student use. Students must follow safe procedures and work in a fume hood. Students identify the substance collected in Activity 3.2.2. A Standard Results Sheet could be used to record data. An emphasis is placed on the students' ability to collect data and identify trends in their observations.

3.3.4 Students work in small groups to discuss results from Act 3.3.3. This is followed with a teacher-directed lesson on the general properties of molecules containing oxygen and nitrogen. Students predict the properties of organic substances using terms such as electronegativity, covalent bond and polar molecules.

Assessment Worksheet – Groups of Organic Substances (K/U),
Lab Report Flow Chart and Standard Results Sheet (I, C)

Reactions

3.4.1 Students investigate organic reactions through experimentation. Some suggestions are: identify some of the products of the combustion of a hydrocarbon and an alcohol, and write balanced chemical equations to represent the combustion reaction; synthesize a condensation product (oil of wintergreen); demonstrate the production of a synthesis polymer (polyvinyl); and synthesize a common organic product (aspirin). **Note:** A fume hood is required for these activities. Some reactants involve particular hazards. The teacher may wish to demonstrate these. The teacher may assess the students' Science Investigative Skills using a checklist.

3.4.2 Students complete a worksheet based on chemical reactions. They predict products, and describe, using structural formulae, typical organic reactions such as addition, combustion, and addition polymerization. They also demonstrate an understanding of how coefficients in balanced chemical equations, quantity in moles, mass, and number of particles are related.

Assessment Lab - Results (K/U, C), Lab Quiz (I), Chemical Reaction Worksheet (K/U)

Applications

3.5.1 Students gather information from the Internet, books, periodicals, or any other source to explore how organic chemistry has led to the development of a specific product, e.g., polyester, nylon, artificial heart valve, indoor/outdoor carpet, teflon. They investigate how it is produced (including reactants and reaction type); its uses; environmental impacts; possible alternatives; the cost of manufacturing; and the molecular structure of the compound. Students prepare a visual display or an electronic presentation, e.g., electronic slide presentation, webpage to share the information. Students assess each other's work using guidelines provided by or agreed upon by the teacher.

Assessment Visual Display or Presentation (K/U, I, C, MC)

End-of-Unit Task: Unknown Liquid

3.6.1 Students are provided with a mixture containing an unknown liquid. They design and complete an experiment to isolate and identify the unknown liquid, using information from their Analytical Chemistry Log Book. The teacher prepares a fermented mixture by adding yeast, sugar, and warm water to a large bottle containing 500 mL of molasses and 2500 mL of warm water. Students distil the ethanol from the fermentation mixture and determine properties of the purified alcohol. Students use qualitative analysis, e.g., flow chart to describe the procedure used, and quantitative analysis, e.g., determine the moles of product produced.

3.6.2 Students then complete a Unit Test.

Assessment Lab Report (I, C, MC), Unit Test (K/U, MC)

Resources

– http://www.ameliaww.com/fpin/use_safety.htm

Contents of common organic substances and necessary precautions.

Investigating plastics – site suggestions:

– http://www.plasticsresource.com

– http://www.plastics.org/

– http://www.grc.nasa.gov/WWW/K-12/Summer_Training/Magnificat/Polymer_Project.html

Polymer chemistry.

Nalepa, R., R.L. Whitman, and E.E. Zinck. *Chemistry Today Second Edition Laboratory Manual.* Scarborough, Ontario: Prentice-Hall Canada Inc., 1982. ISBN 0-13-129551-9 - End-of-Unit Task for Unit 3 Organic Chemisty

Carbon Chemistry, video, Classroom Video, Burnaby B.C.

Organic Chemistry, a 6-part video series from TVO

The Plastics Industry in Canada, a resource package published by the Society of the Plastics Industry of Canada, 1992.

Unit 4: Electrochemistry

Time: 20 hours

Unit Description

This unit begins with a review of some of the basic principles and practices of current electricity from the Grade 9 Science course. Students then study reactions involving electron transfer and applications of these redox reactions in galvanic and electrolytic cells. The issue of corrosion is examined in terms of the reactions involved and preventative measures. The End-of-Unit Task requires students to design and construct an electrochemical cell, and justify their choice of materials.

Unit Overview Chart

Activity/ Time	Title/Focus	Learning Expectations	Assessment Categories
4.1 2.5 h	The Flow of Electricity	ELV.02, EL2.02, EL2.03 SIS.02, SIS.05	Knowledge/Understanding
4.2 6 h	Reactions	ELV.01, ELV.02, EL1.01, EL2.04, EL2.05, EL2.07 SIS.05, SIS.06	Communication Inquiry Knowledge/Understanding Making Connections
4.3 3.5 h	Cells	ELV.01, ELV.02, ELV.03, EL1.01, EL2.01, EL2.02, EL2.06, EL3.01, EL3.02 SIS.01, SIS.03, SIS.06, SIS.09	Inquiry Knowledge/Understanding
4.4 5 h	Corrosion	ELV.01, ELV.02, ELV.03, EL1.02, EL1.03, EL2.01, EL2.08, EL3.03, EL3.04 SIS.01, SIS.03, SIS.05	Communication Inquiry Knowledge/Understanding Making Connections
4.5 3 h	End-of-Unit Task – Cell Construction	ELV.01, ELV.02, ELV.03 SIS.01, SIS.03, SIS.06	Communication Inquiry Knowledge/Understanding Making Connections

Suggested Activities

The Flow of Electricity

4.1.1 Students brainstorm or participate in a graffiti activity to assess prior knowledge on electricity, circuits, current, conductors, safety, and other concepts covered in Grade 9 Science. This introduction is followed with an activity involving basic circuit construction (using wires, cells and voltmeters) and related measurements.

4.1.2 Students test various substances, e.g., metals, acids, bases, salt solutions, and covalent substances with a conductivity tester for electrical conductivity and classify these substances as conductors or non-conductors of electricity.

4.1.3 The End-of-Unit Task is introduced and time is allowed for students to ask clarification questions regarding the task or its assessment.

Assessment Diagnostic (K/U)

Reactions

4.2.1 Students observe models or demonstrations illustrating the components of various examples of electrochemical cells. The models are used to introduce vocabulary such as anode, cathode, electrode, electrolyte, oxidation, and reduction. The teacher conducts a lesson to cover both galvanic and electrolytic cells, describing the chemical reactions (oxidation and reduction) involved in generating the electrical flow.

4.2.2 As a follow up (may continue to use the models/demonstration apparatus from Activity 4.2.1), the role of the different metals used for the electrodes in cells is discussed. Students design and conduct experiments to discover which metal elements will displace metals in solutions (single displacement reactions). Results are summarized in a chart. The teacher approves the design before allowing students to proceed.

4.2.3 A class discussion around the results of the metal displacement activity ensues followed by a teacher-directed lesson on half-cell reactions, direction of electron flow and direction of ion movement in electrochemical cells. The activity series should be introduced and students should use this information to completely describe a variety of electrochemical cells (anode, cathode, ion migration, direction of electron flow, half-cell reactions).

4.2.4 Students use the activity series to predict the results of displacement reactions among different metals and metallic salts and test their predictions by conducting investigations. The metals should be ranked in order based on their oxidizing or reducing strength.

4.2.5 Students write a brief report explaining the importance of the choice of metals and electrolytes used in the production of electrochemical cells. This activity may be used as a proposal for the materials to be used by students in their End-of-Unit Task.

Assessment Lab report (I, C), Quiz (K/U, MC), Report (K/U, MC)

Cells

4.3.1 In a class discussion, students differentiate between galvanic cells and electrolytic processes. Using print sources or the Internet, students research and summarize the use of electrolytic processes in the refining of metals and the impacts of these processes on the environment. This may be done as open-ended research or as a more directed approach (online scavenger hunt) where students are provided with websites (see Resources) and questions to guide their search.

4.3.2 Working in small groups, students construct simple galvanic cells as described by the teacher. Using the cells as models, the students discuss and list the advantages and disadvantages or limitations of galvanic cells and the various uses of these cells. The groups will present their ideas to the class to generate a more complete list to be recorded as notes.

4.3.3 Students participate in a field trip to a local industry where electrochemical processes are used. A guest speaker, or video may also be used.

Assessment Galvanic Cell (K/U, I)

Corrosion

4.4.1 Students participate in a discussion around the rusting or corrosion of cars and factors that influence the process. The discussion may be prompted by a walk in the school parking lot to assess the state of the metal on the vehicles present. Brainstorm ways used to limit or slow the "aging" process. Back in the classroom, have students describe (on paper or verbally) the effect of acid rain and road salt on the metal of a car using terminology such as oxidation, reduction, and electrolyte. Students will define corrosion and use a Venn diagram to compare corrosion (as a chemical reaction) and reactions in an electrochemical cell.

4.4.2 Students design and conduct investigations focused on factors that influence the rate of corrosion. Factors that might be considered are bare metal surfaces (file or sand a portion of the metal), bends, or stress points in the metal, different types of metals, exposure of metals to water, combinations of metals, etc. Class results could be summarized on a Standard Results Sheet.

4.4.3 Students use the results from Activity 4.4.2 to hypothesize techniques that may be used to prevent corrosion. They design and conduct investigations focused on the prevention of corrosion or alternatively, students may merely propose methods to slow the rate of corrosion. This activity should involve an explanation of the chemical reactions involved in corrosion and how, chemically, the technique slows this reaction.

Assessment Venn diagram (MC, K/U), Lab Report – Standard Results Sheet (I, C, MC), Written Quiz (K/U, MC)

End-of-Unit Task – Cell Construction

4.5.1 Students design and construct a model of a cell. They should determine the cell's voltage and potential uses. Safety concerns for the use of this cell should be addressed and a written rationale of the design and material choice should be handed in. Alternatively, students could present their design to the class and include a sales promotion highlighting the strengths of the design and answering for its weaknesses (peers should be encouraged to question the design).

4.5.2 Written test.

Assessment Model/Presentation (C, I, K/U, MC), Written test (K/U, MC)

Resources

A Case Study in Battery Technology, a resource package published by the Manufacturing Resource Corporation of Ontario (MRCO) and the Ontario Centre for Materials Research (OCMR), 1991.

– http://www.cubicsci.com/chem/hs/index%20search/electro.htm
electrochemistry (redox reaction) tutorial site (links to background information).

– http://www.sparknotes.com/chemistry
link to electrochemistry background notes: galvanic cells, electrolytic cells, terminology, and equations.

– http://www.science.uwaterloo.ca/~cchieh/cact/c123/battery.html
chemistry of batteries, redox reactions and simple voltaic cells.

– http://www.chinooksedge.ab.ca/bowden/highschool/chem/chem.html#ec
link to activities and worksheets on electrochemistry.

– http://chemed.chem.purdue.edu/genchem/topicreview/bp/ch20/faraday.html
notes, background and examples of electrolytic cells

Electrochemistry, a 6 part video series from TVO, 1987.

Electroplating applications/information-site suggestions:
– http://www.finishing.com/faqs/howworks.html
– http://www.douglas-plating.co.uk/studentframe.html
– http://www.kodak.com/US/en/motion/support/processing/h245/h24056.shtml
– http://www.oit.doe.gov/factsheets/aluminum/pdfs/dyninertmetanodes.pdf
– http://www.efunda.com/processes/surface/electroplatings.cfm

Addison-Wesley: *Chemistry: A First Course* – activity series/oxidation–reduction reactions

Unit 5: Chemistry in the Environment

Time: 20 hours

Unit Description

This unit builds on students' understanding of key concepts found in two previous units, Matter and Qualitative Analysis and Chemical Calculations. The End-of-Unit Task includes an experimental investigation of water quality in the community. As much as possible, students are expected to ask their own questions, collect their own samples, and design their own procedures to test water quality, based on techniques learned in this and previous units. Where a local concern does not exist or student-directed investigations are not feasible, the teacher could create a simulation activity that includes prepared samples to be tested through student-designed procedures. This is a good unit to include the use of Probeware.

Unit Overview Chart

Activity/ Time	Title/Focus	Learning Expectations	Assessment Categories
5.1 2 h	Diagnostic Activities	CEV.02, CCV.02, MQV.02, CE2.01, CE2.03, CC2.01, CC2.03, CC2.08, MQ2.02, MQ2.03 SIS.01, SIS.02, SIS.05, SIS.08	Knowledge/Understanding Inquiry Communication
5.2 1 h	Acids and Bases	CEV.01, CEV.02, CE1.02, CE1.03, CE1.05, CE2.01	Knowledge/Understanding
5.3 4 h	Neutralization	CEV.02, CCV.02, CE2.01, CE2.02, CE2.04, CE2.05, CC2.02, CC2.08 SIS.01, SIS.02, SIS.03, SIS.07, SIS.08	Knowledge/Understanding Inquiry Communication
5.4 4 h	The Water We Drink	CEV.01, CEV.02, CEV.03, CE1.06, CE2.01, CE2.06, CE3.01, CE3.02, CE3.03 SIS.01, SIS.02, SIS.05, SIS.06	Knowledge/Understanding Inquiry Communication Making Connections
5.5 4 h	The Air We Breathe	CEV.01, CEV.03, CE1.01, CE1.04, CE1.07, CE3.01, CE3.03 SIS.01, SIS.02, SIS.03, SIS.05, SIS.06	Knowledge/Understanding Communication Making Connections
5.6 5 h	End-of-Unit Task – Environmental Issue	CEV.02, CEV.03, CE2.05, CE2.06, CE3.01, CE3.03 SIS.01, SIS.02, SIS.03, SIS.05, SIS.07, SIS.08	Knowledge/Understanding Inquiry Communication Making Connections

Suggested Activities

Diagnostic Activities

5.1.1 The teacher creates a carousel of laboratory activities to review acid and base concepts from Grade 10 Science and qualitative and quantitative analysis from earlier in this course. The various stations should be designed to assess student background knowledge before any formal evaluation. Activities might include looking at solubility and quantitative analysis of a precipitate, recognition of common acids and bases using indicators, drop-by-drop neutralization reactions, factors that affect rates of reaction, and antacid effectiveness.

5.1.2 Students are introduced to the End-of-Unit Task, the investigation of a local or global environmental concern. Possible concerns include acid rain, global warming, water hardness, smog, phosphate or nitrate contamination, heavy metal contamination of soil or waterways, pesticide residues, organic contamination of soil or waterways, ozone depletion, or ground level ozone. Care should be taken to ensure that the topic has not been previously studied and that the concern centres around chemicals. Students are asked to list what they presently know about the issue and then to read a newspaper article or other passage describing the issue. Students add any pertinent information to their list and use the list as a starting point for their research into the End-of-Unit Task. Students are reminded of the Final Assessment Task.

Assessment The teacher assesses student knowledge of acid and bases and the topic of the End-of-Unit Task in order to plan subsequent lessons. There is no formal evaluation.

Acids and Bases

5.2.1 The teacher directs a lesson (including demonstrations) on the properties of acids and bases. The depth and breadth of this lesson is determined by the information about student understanding gathered from Activity 5.1.1. Students should know basic definitions for acid and base, be able to distinguish between strong and weak acids and bases and understand the connection to solution conductivity, and be familiar with the dilution process for acids.

Assessment Quiz (K/U)

Neutralization

5.3.1 The teacher conducts a lesson describing neutralization reactions and indicators. Various applications for volumetric analysis and the correct procedure for using pipettes and burettes should also be explained.

5.3.2 Students practise burette techniques using water first, and then complete a titration with the entire class using the same stock base solution and the same unknown concentration of hydrochloric acid.

5.3.3 Students prepare their own stock solutions of base and using titration, calculate the concentration of an unknown sample of acetic acid. Each student has a different unknown.

Assessment Checklist for Lab Technique and Accuracy (I), Calculations (K/U)

The Water We Drink

5.4.1 Students select a chemical from a list of possible chemical contaminants of drinking water. Using the Internet or other research tools, students access and record information on their contaminant, including acceptable levels in drinking water, possible sources, environmental and economic effects, effects on human health. Students create a spreadsheet listing the results of their research.

5.4.2 Plan a field trip to a land fill site, sewage treatment facility, or water purification plant with a focus on the disposal of household and industrial chemicals. As an alternative, a guest speaker could be invited to explain the disposal process and associated environmental concerns.

5.4.3 Students complete a laboratory activity where they determine the concentration of an ion in a sample, such as calcium, by reacting it with a sodium carbonate solution and comparing the colour intensity of the products to test tubes of known concentrations and by filtering and massing the precipitate. The ion tested could be related to the issue considered in the End-of-Unit Task.

Assessment Spreadsheet (C, K/U, MC), Lab Report (I, K/U, C)

The Air We Breathe

5.5.1 The teacher conducts a lesson, including demonstrations, describing qualitatively the properties of gases. (Boyle’s Law and Absolute Zero demonstrations can be used.) As an extension, graphing skills could be practised using data that could be analysed to determine the relationships of Boyle’s, Charles’ and Gay-Lussac’s Laws.

5.5.2 Students participate in a jigsaw activity examining the causes and consequences of acid rain, global warming, ozone depletion, carbon monoxide poisoning, etc.

5.5.3 Individual students write a letter to the editor, to a business leader, or to a politician, describing their concerns with one of the environmental problems outlined in the jigsaw activity and proposing possible solutions.

Assessment Quiz (K/U), Letter (C, MC)

End-of-Unit Task - Environment Issue

5.6.1 Students investigate their own questions related to an environmental issue. Samples could be taken of precipitation (rain or snow), from soil, or from bodies of water (both surface and underground) and analysed using techniques practised in this unit and previous units. Students present their findings in a formal report or alternative means such as a webpage or electronic slide presentation.

5.6.2 Written and practical (skills-based) test.

Assessment Written and practical test (K/U, I), Report or Alternate Presentation (C, I, MC)

Resources

Andrews, W. A. *Contours of the Environment*, a series of four books. Toronto: Prentice-Hall Canada, 1987.

Nebel, B. and Wright, R. *Environmental Science, The Way the World Works*. New Jersey: Prentice Hall, 1993. ISBN 0132854465

Gases: One of the States of Matter – A resource package published by Canadian Liquid Air Ltd., 1994.

Ozone Depletion – http://www.epa.gov/docs/ozone/

Drinking Water – http://www.eecs.umich.edu/~coalitn/sciedoutreach/funexperiments/agesubject/lessons/cdwater.html

World of Chemistry, TVO Series, 1988. The following episodes would be useful in this unit:

Protons of Chemistry (acid and bases)
Water (water pollution)
Precious Envelop (air pollution)

Acids from the Scientific Eye series, Marlin Motion Pictures, 1988.

Chemical Survey/Solutions and Pollution Module, a CEPUP (Chemical Education for Public Understanding Program) Kit and Resource book, California: Addison Wesley, Menlo Park, 1990. ISBN 0201284200

Unit 6: Final Assessment Task

Time: 10 hours

Unit Description

This culminating unit provides students with an opportunity to use the skills and knowledge acquired in the preceding units. Students carry out qualitative and quantitative analysis to help identify unknown substances. Practical lab skills such as distilling and determining conductivity, mass, volume, pH, and combustibility are used. Students incorporate their understanding of physical and chemical properties, chemical reactions, and environmental issues such as acid rain and corrosion to make educated predictions. Students communicate their results and assessments in a detailed report.

Unit Overview Chart

Activity/ Time	Title/ Focus	Learning Expectations	Assessment Categories
6.1 8 h	Identifying an Unknown	MQV.02, OCV.01, OCV.02, OC2.02, EL2.02, CCV.01, CC2.02, CEV.O2, CE2.02 SIS.01, SIS.02, SIS.03	Knowledge/ Understanding Inquiry Communication Making Connections
6.2 2 h	Written Exam	MQV.01, MQV.03, OCV.01, OCV.03, ELV.01, ELV.03, CCV.01, CCV.03, CEV.01, CEV.03	Knowledge/ Understanding Making Connections

Suggested Activities

Identifying an Unknown

6.1.1 The students act as forensic scientists and make use of the Analytical Chemistry Log Book that has been kept up-to-date throughout the course. A suggested scenario follows. The Special Crimes Unit of a regional police association is investigating a crime that took place on a vacant lot north of a major city. The police have gathered evidence that needs to be analysed to help determine when the crime was committed and by whom. The students are supplied with three vials each containing a substance that needs to be identified. Vial #1 (Organic mixture): Students design and carry out a procedure to separate the mixture (distillation), determine the physical and chemical properties and finally use the gathered data to identify the unknown. Vial #2 (Acid Rain): Students determine the pH and conductivity. They explain the impact this substance may have had on a metal tool (is it capable of corroding metal) and conclude what it is and from where it may have come. Vial #3 (Household Product): Students determine the ions present, perform flame tests, complete precipitation reactions (using a flowchart to organize data) and determine the mass (and moles) of the unknown. Students complete a 'sample' report for the police that may be used in court.

An alternative activity is Chemical Dumping. Provide students with an unknown mixture that was hypothetically taken from a body of water on the outskirts of a town. Some new industry is dumping what they call safe chemicals into the water. Students design a procedure using information from their Analytical Chemistry Log Book to test for the presence of various ions, quantify the ions present in the sample (calculations) and test the pH and conductivity. Students use this information to identify the chemical, explore the possible environmental implication and suggest methods to clean up the problem.

6.1.2 Written Exam

Assessment Identifying the Unknown (I, C, MC), Written Exam (K/U, MC)

Teaching/Learning Strategies

Since the over-riding aims of this course are to develop scientific literacy in all students and to prepare students for chemistry or chemistry-related technology courses at college, the teacher should use a wide variety of instructional strategies to provide learning opportunities that accommodate a range of learning styles and interest. In planning activities for a chemistry class, make sure that students will 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 help them succeed at college: note taking during a lecture, preparing for an examination, taking a multiple-choice test, conducting in-depth, independent research, writing a report and establishing good time management habits;
- opportunities to make connections between this chemistry course and senior level technology courses in which some students may also be enrolled.

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 Task 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 Task. Assessment and evaluation then become an integral part of the teaching/learning strategies.

Skills are Developed through Experience and Refined with Practice

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 for success. Within this 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 the information for patterns and meaning, and communicating their findings or conclusion. Students 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.
- **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 must be given instruction and repeated practice in: identifying and refining good inquiry questions; developing testable hypotheses; setting the parameters of the solutions to be sought; assessing results.

All forms of inquiry as well as other activities throughout the course help students develop **Communications 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, e.g., poster presentations; computer presentations, video, music. Through various formats of cooperative 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 skill that is to 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 what questions 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 since they enable 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 (e.g., class data from measurements taken in the laboratory), graphics (e.g., flow charts, concept maps, diagrams in place of written reports of investigations), databases (e.g., to gather observations taken by small groups or individuals into a class set); collections of data from replicated experiments, and presentation programs (e.g., an alternative for reporting on investigations, particularly by groups). 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 topics. 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 college.

Learning Skills

While not evaluated for marks, learning skills – Works Independently, Teamwork, Organization, Work Habits/Homework, Initiatives – are keys to success in school and beyond. As with other skills, they should be taught, practised, and assessed in the science classroom. Variety is essential: individual assignments foster independence; small group cooperative learning experiences (including laboratory work done in pairs) provides opportunities to develop teamwork.

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 awareness of 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 the 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.

Rubrics describe performance that is 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, involve students 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, pp. 172–175 in *The Ontario Curriculum, Grades 11 and 12: Science, 2000*. Every learning activity and its assessment should provide data for making judgements about performance in one or more of the Achievement Categories: Knowledge/Understanding, Inquiry, Communication and Making Connections. Within each unit and across the course, the teacher must collect sufficient data (in kind and number) to make valid judgements about student performances in all categories.

In the end, the evaluation of the assessment data is expressed as a percentage based on Achievement Chart levels. That evaluation must be based on individual student performances relative to the criteria, not to other students' performances. 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.

The teacher needs 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 broad range of knowledge and skills expectations. The teachers should consult individual IEPs for specific direction on accommodation for individuals.

There must be 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 learning skills. However, assessment must focus primarily on students' individual demonstration of the learning expectations;
- practical assessments and laboratory-based tests and examination components.

Diagnostic Activities

Students enrolled in SCH4C will come to this course with a wide variety of learning experiences. Certainly, the number and kind of science courses in students' background will vary, but students will also have completed technology courses in different disciplines. Part-time jobs and hobbies will also provide these students with various sets of knowledge and skills. Diagnostic activities, at the start of all units, are important for providing a context for the unit design (based on student interest and background), for planning lessons to meet student needs, for filling in gaps and correcting misconceptions, and for tapping into student strengths. Diagnostic activities should consider Knowledge/ Understanding, Inquiry, and Communication skills, and Making Connections. A range of activities should be considered including:

- pencil-and-paper quiz (marks are not recorded);
- class discussion suggested by one or more focus questions;
- brainstorming activities, such as placemat or graffiti (www.geocities.com/Athens/Parthenon/6549/art12.html);
- carousel of laboratory activities for assessment of skills;

- KWL charts (**K**now, **W**ant to know, and then later, what was **L**earned);
- carousel of different applications;
- student survey;
- responding to a short reading passage (fiction or non-fiction) or a video clip (fiction, documentary, or news broadcast) on a connected societal issue.

A diagnostic activity suggested within the profile, can be substituted by any of the above or one of the teacher's own design. By varying the diagnostic activity from unit to unit, different learning styles of students will be addressed.

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 to some extent.

However, when group assignments are used to evaluate 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 basic, 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 from a certain activity, and then are evaluated 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 if they were 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 is aware of individual responsibilities.
  A quiz could be used to evaluate specific Knowledge or Making Connection expectations gained through a group activity.
- Teacher observation, using a checklist, and on the spot questioning can be used to assess and evaluate meeting of expectations on an individual basis.
- Acquisition of technical skills could be evaluated in another, individual situation such as 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 responsibility of the teacher.

Links to Technological Education

Students intending to enroll in Technology programs at a community college may be required to complete both SCH4C and SPH4C for most programs. These students may also be enrolled in a number of technological education courses related to their future community college studies. Some schools may wish to package a number of these courses together where numbers warrant to meet a community need. A Final Assessment Task that involves work experience (a one- to four-week learning opportunity in a workplace) could be designed using expectations from all the courses that were packaged together. For example expectations from SCH4C (Organic Chemistry), SPH4C (Mechanical Systems and Hydraulic and Pneumatic Systems), and TTJ4C could all be met through a placement with a mechanic. Expectations from SCH4C (Electrochemistry), SPH4C (Communications Technology and Electricity and Electronics), and ICE4M are connected in the computer industry. The same SCH4C and SPH4C expectations could link with expectations from TGJ4M in the communications industry.

Accommodations

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

- 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.
- 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 or provide a selection of materials at different reading levels.
- Have ESL students keep a science dictionary of terms using pictures and first language words
- Permit the use of a translation dictionary on assessments.
- Provide additional time on assessments for dictionary use and processing language.

OSS Policy Considerations

Students can apply and refine the skills, knowledge and habits of mind they acquire in SCH4C through Cooperative Education, work experience and service placements within the community.

A work site placement must be directly connected to the Expectations of SCH4C if it is to contribute to a student's perspective of future careers or educational opportunities. *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). 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 aspects of the goal of SCH4C – "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.

Students graduating from Ontario schools must be technologically literate. Through the study of this science course, students must come to understand and apply technological concepts, use computers in various applications, and analyse the implications of technology on individuals and society.

Appendix A

Unit 1: Graphic Organizer Rubric (for use with End-of-Unit Tasks)

Criteria	Level 1 (50-59%)	Level 2 (60-69%)	Level 3 (70-79%)	Level 4 (80-100%)
Understanding Concepts	- limited unit information has been integrated	- some unit information has been integrated	- most unit information has been appropriately integrated	- all or almost all unit information has been appropriately integrated
Communication Clarity and precision Use of terminology and spelling	- rarely communicates with clarity and precision - rarely uses appropriate terminology and spelling	- sometimes communicates with clarity and precision - uses some appropriate terminology and spelling	- usually communicates with clarity and precision - uses appropriate terminology and spelling	- always communicates with clarity and precision - routinely uses appropriate terminology and spelling
Inquiry Demonstrates skills and strategies of scientific enquiry	- demonstrates few of the skills and strategies of scientific inquiry	- demonstrates some of the skills and strategies of scientific inquiry	- demonstrates most of the skills and strategies of scientific inquiry	- demonstrates all or almost all of the skills and strategies of scientific inquiry
Making Connections	- shows limited understanding of connections among science, technology, society, and the environment	- shows some understanding of connections among science, technology, society, and the environment	- shows considerable understanding of connections among science, technology, society, and the environment	- shows thorough understanding of connections among science, technology, society, and the environment

Note: A student whose achievement is below Level 1 (50%) has not met the expectations for this assignment or activity.

Coded Expectations, Chemistry, Grade 12, College Preparation, SCH4C

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 equipment such as a spectroscope and centrifuge to conduct qualitative analysis);
SIS.03 - demonstrate the skills required to plan and carry out investigations using laboratory equipment safely, effectively, and accurately (e.g., manipulate burettes and other instruments used in an acid/base titration);
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., represent ionic and molecular compounds by their accepted formulae and names);
SIS.06 - select, integrate, and interpret information derived from experiments and from print and electronic sources, including Internet sites, and, either in writing or using a computer, compile and display the information in various forms, including diagrams, tables, graphs, and laboratory reports (e.g., using both experimental results and information from other sources, compile a table summarizing the physical and chemical properties of some common organic compounds);
SIS.07 - express the result of any calculation involving experimental data to the appropriate number of decimal places or significant figures;
SIS.08 - select and use appropriate SI units;
SIS.09 - identify and describe science- and technology-based careers related to the subject area under study (e.g., describe careers related to analytical chemistry, such as laboratory technician or quality control officer).

Matter and Qualitative Analysis

Overall Expectations

MQV.01 · demonstrate an understanding of the basic principles of qualitative analysis and underlying theories;
MQV.02 · carry out qualitative analyses, using flow charts and appropriate laboratory equipment and instruments;
MQV.03 · describe the role and importance in society of some of the applications of qualitative analysis.

Specific Expectations

Understanding Basic Concepts

MQ1.01 – explain the distinction between observation and inference;
MQ1.02 – describe and explain basic processes and phenomena involved in qualitative analysis, including flame tests, precipitation reactions, and absorption spectra;
MQ1.03 – relate observations from flame tests and absorption spectra to the concept of quanta of energy proposed by Bohr;

MQ1.04 – explain covalent bonding in simple molecules using Lewis structures (e.g., H_2, Cl_2, O_2, H_2O, CH_4);

MQ1.05 – demonstrate an understanding of the formation of ionic bonds between metals and non-metals, and relate the charge on an ion to the number of electrons lost or gained.

Developing Skills of Inquiry and Communication

MQ2.01 – use appropriate scientific vocabulary to communicate ideas related to qualitative analysis (e.g., *double displacement, precipitate, energy levels*);

MQ2.02 – conduct qualitative analyses using equipment and instruments such as the following: gas discharge tubes, high voltage electrical sources, spectroscope, centrifuge;

MQ2.03 – predict the precipitate formed in a chemical reaction by writing double displacement and net ionic equations and using a table of solubility rules;

MQ2.04 – use a flow chart and experimental procedures, including flame tests and precipitation reactions, to determine the presence of ions in an unknown sample (e.g., analyse a household or workplace chemical);

MQ2.05 – identify an unknown gas sample (e.g., hydrogen, helium, neon) by comparing its observed absorption spectrum with those of known gases.

Relating Science to Technology, Society, and the Environment

MQ3.01 – describe some applications of spectroscopy (e.g., in astronomy to identify the composition of stars);

MQ3.02 – explain applications of qualitative analysis in various fields (e.g., discuss the use of qualitative analysis techniques in drug detection or in the identification of counterfeit money).

Organic Chemistry

Overall Expectations

OCV.01 · demonstrate an understanding of the names and properties of organic compounds and some of their reactions;

OCV.02 · carry out various laboratory tests and reactions involving organic compounds;

OCV.03 · describe the importance of organic compounds in consumer products, technological devices, and biochemical applications, and explain some of the issues related to their environmental and social impact.

Specific Expectations

Understanding Basic Concepts

OC1.01 – demonstrate an understanding of the particular characteristics of the carbon atom in terms of the type of bonding and the formation of long chains;

OC1.02 – explain the general properties of molecules containing oxygen or nitrogen (e.g., polarity, solubility in water);

OC1.03 – identify the functional group structures that define common families (e.g., alkenes, alkynes, alcohols, aldehydes, ketones, acids, esters, amines);

OC1.04 – describe, using structural formulae, typical organic reactions such as addition, combustion, and addition polymerization reactions;

OC1.05 – explain the principle underlying the use of distillation to separate organic compounds.

Developing Skills of Inquiry and Communication

OC2.01 – use appropriate scientific vocabulary to communicate ideas related to organic chemistry (e.g., *electronegativity, covalent bond, functional group, polymer*);

OC2.02 – select and use apparatus safely to separate a mixture of liquids by distillation;

OC2.03 – draw Lewis structures to represent covalent bonding in organic molecules (e.g., methane, ethanol, butene, acetylene);

OC2.04 – determine through experimentation the physical and chemical properties of some common organic compounds (e.g., aqueous and non-aqueous solubility, combustibility, conductivity, odour), and identify patterns and trends in these observations;

OC2.05 – identify through experimentation some of the products of the combustion of a hydrocarbon and an alcohol, and write balanced chemical equations to represent the combustion reaction;

OC2.06 – synthesize a condensation product (e.g., aspirin or an ester), a common organic compound (e.g., soap), and a synthetic polymer (e.g., cross-link polyvinyl alcohol using a solution of borax).

Relating Science to Technology, Society, and the Environment

OC3.01 – identify useful organic compounds (e.g., non-stick coatings for cookware) on the basis of information gathered from print and electronic sources, and illustrate their molecular structure and functional groups using representations drawn by hand or by computer;

OC3.02 – describe the role of distillation and cracking in the production of useful fuels from crude oil;

OC3.03 – explain the dangers associated with the use of organic solvents (e.g., combustibility, toxicity) and the necessary precautions to be taken;

OC3.04 – identify issues connected to the growing use of plastics (e.g., the consumption of fossil fuels, waste disposal), and suggest alternative materials that could be used;

OC3.05 – describe how organic chemistry has led to the development of useful new products (e.g., synthetic fabrics, automobile body panels, artificial heart valves).

Electrochemistry

Overall Expectations

ELV.01 · demonstrate an understanding of the chemical processes that take place in galvanic and electrolytic cells;

ELV.02 · investigate through experimentation the ease of oxidation of metals, and build electrochemical cells and describe their functioning;

ELV.03 · explain the importance for industry and the consequences for the environment of common electrochemical processes.

Specific Expectations

Understanding Basic Concepts

EL1.01 – name the components of galvanic and electrolytic cells, describe their role, and explain how they function in terms of oxidation and reduction;

EL1.02 – explain the chemical reactions involved in corrosion, and describe their similarity to chemical reactions occurring in an electrochemical cell;

EL1.03 – identify and explain various techniques used to prevent corrosion of metals (e.g., painting, cathodic protection, galvanization).

Developing Skills of Inquiry and Communication

EL2.01 – use appropriate scientific vocabulary to communicate ideas related to electrochemistry (e.g., *ionic bonds, oxidation, anode, electrolyte*);

EL2.02 – use the following laboratory equipment and instruments safely and accurately: voltmeters, electrical sources, connecting wires;

EL2.03 – classify, using experimental evidence, metals, acids, bases, salt solutions, and covalent substances as conductors or non-conductors of electricity;

EL2.04 – interpret observations from experiments to determine an activity series of some metals;

EL2.05 – predict the spontaneity of displacement reactions between metal elements and metal salts based on the activity series, and verify the predictions through experimentation;

EL2.06 – construct a galvanic cell, and determine its advantages and disadvantages (e.g., source of energy, portability, rechargeability; chemical spillage, limited voltage);

EL2.07 – describe an electrochemical cell in terms of half-cell reactions, location of electrodes, direction of electron flow, and direction of migration of ions;

EL2.08 – design and carry out procedures to determine the factors that affect rate of corrosion (e.g., stress, two-metal contacts, surface oxide, nature of electrolyte, nature of metal).

Relating Science to Technology, Society, and the Environment

EL3.01 – describe applications of electrochemical cells, such as batteries;

EL3.02 – explain how electrolytic processes are used in the refining of metals (e.g., Al, Cu, or Ni), and evaluate the impact of such processes on the environment (e.g., production of acid rain, high-energy consumption);

EL3.03 – identify electrochemical processes used in industry (e.g., chrome-plating);

EL3.04 – describe the effects of road salt and acid rain on the process of corrosion, and suggest possible ways of counteracting these effects.

Chemical Calculations

Overall Expectations

CCV.01 · demonstrate an understanding of the mole concept as well as of quantitative relationships in chemical reactions;

CCV.02 · use techniques of quantitative analysis in the preparation of standard solutions, and solve problems involving the analysis of quantities in chemical reactions, using both theoretical and experimentally measured quantities;

CCV.03 · explain the importance of quantitative chemical relationships in industry and in everyday life.

Specific Expectations

Understanding Basic Concepts

CC1.01 – define the mole concept and demonstrate an understanding of its usefulness in the analysis of quantities involved in chemical reactions (e.g., explain how the mole concept allows the calculation of the number of atoms, ions, or molecules in a quantity of substance);

CC1.02 – explain how the following variables are related: coefficients in balanced chemical equations, quantity in moles, mass, and number of particles;

CC1.03 – identify sources of experimental error that would explain a percentage yield other than 100 per cent.

Developing Skills of Inquiry and Communication

CC2.01 – use appropriate scientific vocabulary to communicate ideas related to stoichiometry (e.g., *molar mass, molarity, percentage yield, Avogadro's number*);

CC2.02 – conduct quantitative analyses, using correctly and accurately the following instruments: pipette, burette, volumetric flask, spectrophotometer, electronic balance;

CC2.03 – calculate the molecular mass and molar mass of a compound with the aid of the periodic table;

CC2.04 – calculate percentage composition of a compound using experimental data or its chemical formula;

CC2.05 – solve problems involving relationships among the following variables: quantity in moles, mass, number of particles, concentration, volume of solution;

CC2.06 – solve problems involving stoichiometric relationships in balanced chemical equations;

CC2.07 – calculate percentage yield in a chemical reaction using experimental data, and identify sources of error;

CC2.08 – prepare aqueous solutions, using appropriate concentration units (e.g., grams per litre, moles per litre), and accurately dilute a stock solution to a specified lower concentration;

CC2.09 – prepare standard solutions and measure their absorbance in order to produce an experimental calibration curve.

Relating Science to Technology, Society, and the Environment

CC3.01 – give examples of everyday situations in which an understanding of quantitative relationships of substances is important (e.g., in making decisions about quantities in cooking recipes, in determining dosages in medical prescriptions);

CC3.02 – explain why it is important to ensure accuracy in the concentration of certain solutions (e.g., cough syrup, intravenous solutions);

CC3.03 – explain why the profitability of an industry (e.g., the pharmaceutical industry) depends in large part on its ability to maximize percentage yield of its products.

Chemistry in the Environment

Overall Expectations

CEV.01 · demonstrate an understanding of the nature and role of elements and compounds in the environment, including acids and bases, and gases in the atmosphere;

CEV.02 · use the techniques involved in the quantitative analysis of solutions effectively and accurately;

CEV.03 · assess the effects and the implications for society of the levels of various substances in the environment, and demonstrate an awareness of the need for both government and individual citizens to take measures that will ensure a healthy environment.

Specific Expectations

Understanding Basic Concepts

CE1.01 – explain in qualitative terms the effect of temperature and pressure on the volume of a fixed quantity of gas;

CE1.02 – state and explain the Arrhenius definition of acids and bases;

CE1.03 – explain the difference between strong and weak acids and bases in terms of degree of dissociation (e.g., as measured using solution conductivity);

CE1.04 – identify the gases responsible for acid rain, and describe their sources, the steps in acid-rain formation, and the chemical methods used to reverse the process (e.g., neutralization);

CE1.05 – demonstrate an understanding of the precise meaning of the terms *concentrated* and *dilute* when applied to acids (the terms do not indicate the reactivity of the acid – e.g., acetic acid, which is a weak acid, can be purchased in a concentrated form as glacial acetic acid), and explain the safety procedures that must be followed in diluting concentrated acids;

CE1.06 – identify substances in environmental water (including ions that contribute to hardness) whose concentration must be measured and controlled to ensure that the water is fit for human use;

CE1.07 – identify gases in the atmosphere that affect air quality (e.g., greenhouse gases, tropospheric and stratospheric ozone, carbon monoxide, chlorofluorocarbons).

Developing Skills of Inquiry and Communication

CE2.01 – use appropriate scientific vocabulary to communicate ideas related to chemical analysis (e.g., *ozone, hard water, titration, pH value*);

CE2.02 – use the following instruments correctly and accurately: electronic balance, burette, pH meter;

CE2.03 – demonstrate through experimentation the acid-base character of solutions of oxides of metals and non-metals, and compare these solutions to the substances present in acid rain;

CE2.04 – write balanced chemical equations to represent neutralization of acids and bases;

CE2.05 – conduct an acid-base titration to determine the concentration of an acid or a base (e.g., acetic acid in vinegar);

CE2.06 – determine the concentration of dissolved ions (e.g., calcium ions) in a water sample, using gravimetric and colorimetric analysis.

Relating Science to Technology, Society, and the Environment

CE3.01 – demonstrate an awareness of how governmental regulations (e.g., the Great Lakes Action Plan) as well as the actions of individual people can improve air and water quality (e.g., discuss how individuals can contribute to the improvement of air quality through their choice of transportation);

CE3.02 – assess the environmental, economic, and societal implications of methods of use and disposal of common household products (e.g., analyse the issues involved in the use and disposal in everyday life of detergents containing phosphates, or of batteries and cleaners containing acids and bases);

CE3.03 – explain the importance of quantitative analysis of substances in air and water samples (e.g., explain how measuring levels of dissolved oxygen in samples of lake or river water is important in monitoring the health and use of the surrounding ecosystem).

Unit 2: Chemical Calculations

Time: 20 hours

Unit Description

This unit is designed to expand the basic skills and knowledge of qualitative analysis, encountered in Unit 1, to quantitative analysis, since this combination is required for ensuing units. Real-life examples are used wherever possible and skills are introduced in the context of technical careers to allow students to appreciate chemistry in a practical setting. The activities show a progression towards independent note taking and lab skills, with an emphasis on proper lab technique, accuracy of results and procedures, and standardized recording of data and results, as would be required in the pharmaceutical industry, and by the International Organization for Standardization (ISO) or Canadian Good Manufacturing Practices (CGMPs). The unit begins with a discussion on the importance of accurate quantitative chemistry in industrial settings, including Canadian industries, and an introduction to the mole concept. Mole quantities are applied to both theoretical (calculating and quantifying relationships in chemical equations) and experimental (preparing and reacting standard solutions) situations. The End-of-Unit-Task involves designing an experiment to determine the quantitative identity of a substance, in preparation for Unit 6 Final Assessment Tasks. It must be noted that this unit is mathematics-intensive as well as lab-intensive, with a focus on the skills required for quantitative analysis in industry, e.g., quality control lab. Students are therefore advised to review basic algebraic manipulations, calculations, and ratios. Teachers should adapt the complexity of chemical calculations to the degree required to address the expectations. If such equipment is available, this is also a good unit in which to introduce micro-chemistry, since this simulates many “real-life” labs and reduces waste and chemical pollution in the environment. Proper disposal of materials in an environmentally responsible manner must be emphasised.

Unit Synopsis Chart

Activity/ Time	Learning Expectations	Assessment Categories	Task/Focus
2.1 The Mole Concept 4 h	CCV.01, CCV.02, CCV.03, CC1.01, CC2.02, CC2.03, CC2.05, CC3.01, CC3.02 SIS.01, SIS.02, SIS.03, SIS.04, SIS.05, SIS.06, SIS.07, SIS.08, SIS.09	Knowledge/ Understanding Inquiry Communication Making Connections	• notes • discussion (practical applications) • problems • results sheet (accuracy in recording as well as calculations) • student-generated results sheet (effectiveness as a tool)
2.2 Calculating Concentrations 5 h	CCV.02, CCV.03, CC2.01, CC2.02, CC2.05, CC2.06, CC2.08, CC3.01, CC3.02 SIS.01, SIS.02, SIS.03, SIS.04, SIS.05, SIS.07, SIS.08, SIS.09	Knowledge/ Understanding Inquiry Communication Making Connections	• lab (technique and results) • procedure for calibration curve • calibration curve • problems

Activity/ Time	Learning Expectations	Assessment Categories	Task/Focus
2.3 Stoichiometry and Percentage Yield 5 h	CCV.01, CCV.02, CCV.03, CC1.02, CC1.03, CC2.01, CC2.02, CC2.05, CC2.06, CC2.07, CC2.08, CC3.02, CC3.03 SIS.01, SIS.02, SIS.03, SIS.04, SIS.05, SIS.07, SIS.08, SIS.09	Knowledge/ Understanding Inquiry Communication Making Connections	• problems • lab (technique and results)
2.4 Percentage Composition 2 h	CCV.02, CC2.04 SIS.05, SIS.07, SIS.08, SIS.09	Knowledge/ Understanding Making Connections	• theoretical problems
2.5 End-of-Unit Task Concentration of a Non-standard Solution 4 h	CCV.01, CCV.02, CC1.01, CC1.02, CC1.03 CC2.01, CC2.02, CC2.03, CC2.04, CC2.05, CC2.08 SIS.01, SIS.02, SIS.03, SIS.04, SIS.05, SIS.07, SIS.08	Knowledge/ Understanding Inquiry Communication Making Connections	• effective procedure • lab technique • results (accuracy of prediction) • end-of-unit test

Activity 2.1: The Mole Concept

Time: 4 hours

Description

In this activity, students begin with a review of basic mathematics and chemistry concepts before extending their knowledge of chemicals and chemical reactions from qualitative to quantitative analysis. Students realize the importance of accurate measurements in industrial applications and labs and are introduced to the concept of the mole as one of the most important measurements in chemistry, as opposed to other measures they may be more familiar with, e.g., mass and volume. Students participate in a series of activities that clarify the mole as a quantity similar to a dozen, in that it represents a physical number of particles, which is independent of material. The focus of this set of activities is the relationship among moles, mass, and number of particles in various chemicals. In preparation for technical training in a college setting, this activity introduces the use of Standard Results Sheets to record experimental data instead of formal lab reports. Technology may be integrated into this activity, with students constructing a class website, with teacher assistance, and uploading both theory and calculations to it.

Strand(s) & Learning Expectations

Strand(s): Chemical Calculations

Learning Expectations

CCV.01 - demonstrate an understanding of the mole concept as well as of quantitative relationships in chemical reactions;
CCV.02 - use techniques of quantitative analysis in the preparation of standard solutions and solve problems involving the analysis of quantities in chemical reactions, using both theoretical and experimentally measured quantities;
CCV.03 - explain the importance of quantitative chemical relationships in industry and in everyday life;
CC1.01 - define the mole concept and demonstrate an understanding of its usefulness in the analysis of quantities involved in chemical reaction;
CC2.02 - conduct quantitative analyses, using correctly and accurately the following instruments: pipette, burette, volumetric flask, spectrophotometer, electronic balance;
CC2.03 - calculate the molecular mass and molar mass of a compound with the aid of the periodic table;
CC2.05 - solve problems involving relationships among the following variables: quantities in moles, mass, number of particles, concentration, volume of solution;
CC3.01 - give examples of everyday situations in which an understanding of quantitative relationships of substances is important;
CC3.02 - explain why it is important to ensure accuracy in the concentration of certain solutions;
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.06 - select, integrate and interpret information derived from experiments and from print and electronic sources, including Internet sites, and, either in writing or using a computer, compile and display the information in various forms, including diagrams, tables, graphs and laboratory reports;
SIS.07 - express the result of any calculation involving experimental data to the appropriate number of decimal places or significant figures;
SIS.08 - select and use appropriate SI units;
SIS.09 - identify and describe science and technology-based careers related to the subject area under study.

Prior Knowledge & Skills

- Basic arithmetic and algebra, such as manipulating equations and using division and multiplication appropriately for different calculations
- Knowledge of different classes of chemicals and material from Grade 9 and 10 Science, e.g., chemical formulae for some common compounds, chemical reactions, nomenclature of both ionic and covalent compounds, reactants, products and the phases in which reactants and products are available (solid, liquid, gas and aqueous)

Planning Notes

- Prepare a diagnostic activity on the following topics: identifying the number of atoms of each element from chemical formulae of ionic and covalent compounds, reactants, products in a reaction, phases in which reactants and products are available (solid, liquid, gas and aqueous).
- Prepare a series of real-life examples of situations where chemical accuracy is important and/or essential to life.
- Gather/prepare sample graphic organizers.
- If possible, facilitate access to webpage building software and presentation software.
- Gather print and electronic material for students emphasizing chemical technique and safety in different industries.
- Prepare review problems for students to practise basic arithmetic, manipulating formulae and conversion skills if necessary for review.
- Prepare problems on mole quantities, along with detailed answers, emphasizing real-life applications. Include both Canadian and global industries and other settings in these problems.
- Prepare instruction sheets for how to calculate molar mass from formulae, to be used in Activity 2.1.3, as well as a Standard Results Sheets, specific for Activity 2.1.3.
- Gather ionic compound and molecular compound models for students to use as manipulatives in determining molar mass, e.g., marshmallows and toothpicks, molecular models.
- Gather safety equipment for the lab: goggles, aprons, and gloves.
- Gather materials for lab activity: common over-the-counter pharmaceuticals, balances, weighing boats, spatulas, beakers, solid chemicals, e.g., sodium chloride, sodium sulphate, calcium carbonate, potassium nitrate, copper(II) carbonate, iron(III) oxide. If possible, use micro-chemistry equipment.
- Have available a list of active ingredients for the different household pharmaceuticals, where they are manufactured and their chemical formulae for students to refer to, if necessary.
- Follow board policy for proper safety in the handling and disposal of all chemicals, including the pharmaceuticals.

Teaching/Learning Strategies

2.1.1 **Student Activity**: Students participate in a discussion of everyday examples of situations where an understanding of quantitative relationships among substances is important, e.g., the pharmaceutical industry. They realize the importance of maintaining and ensuring accuracy in these situations, e.g., right strength of intravenous (IV) drip in hospitals, and link profitability and percentage yield. Students may work in small groups and generate a collective class list of important points of the discussion, using additional resources to integrate and report their information in a graphic organizer (concept map, informative webpage). They may present their findings using presentation software and/or engage in a debate. Students are introduced to the End-of-Unit Task and reminded of the Final Assessment Task.

Teacher Facilitation: The teacher facilitates a discussion on the importance of chemistry in different industries. Lead the discussion or guide students in their discussions. Allow students to work in small groups and allow the use of additional resources, e.g., access to presentation software, access to webpage building instructions, examples of sample graphic organizers to support a debate. Summarize the major points of the discussion, and major examples of real-life situations where accuracy in chemistry is important, to conclude the discussion. Introduce the End-of-Unit task and remind students of the Final Assessment Task.

2.1.2 **Student Activity:** Students complete a diagnostic activity on basics of chemical reactions.
Teacher Facilitation: The teacher sets up a diagnostic activity, e.g., "lab-stations," online quiz to assess student qualitative knowledge of chemical reactions before proceeding into quantitative chemistry. Lab stations may include: identifying the number of atoms of each element from chemical formulae of ionic and covalent compounds, reactants, products in a reaction, phases in which reactants and products are available (solid, liquid, gas and aqueous). Depending on the results of the diagnostic activity, it might be necessary to prepare review activities. These could be individualized. As part of the follow-up, the teacher introduces the End-of-Unit Task with reference to the Final Assessment Task, allowing time for students to ask clarification questions regarding the task and/or its assessment.

2.1.3 **Student Activity:** Students determine the formula and/or molecular mass of an assigned group of molecules/ionic compounds from the average atomic mass of the constituent atoms, as read from a periodic table. They complete a Standard Results Sheet (see Appendix B) and generate notes on calculating molecular mass from a teacher-led lesson and the activity. They may compare their notes to those made available by the teacher. Student notes could take on a variety of formats depending on student learning style.
Teacher Facilitation: The teacher provides students with models of individual and/or groups of molecules and ionic compounds. Generate a Standard Results Sheet for students to use. Compile notes on calculating molecular mass and post these for students to compare to their own. These notes should be presented in a number of formats to encourage students to employ a method suited to their learning style. Notes may be posted online.

2.1.4 **Student Activity:** Students note that that mole is a quantity similar to a dozen (12) or a ream (500 pages). They also note the relationship among moles, mass, molar mass and Avogadro's number and that the terms molecular mass/formula mass and molar mass are synonymous, for calculation purposes. They follow a demonstrated method of analysis to solve problems and present their work in organized fashion. Students may work in groups or individually.
Teacher Facilitation: The teacher provides students with problems on converting quantities of different materials into quantities of moles, e.g., number of shoes to moles of shoes; moles of atoms into numbers of atoms, and mass of molecules into moles. The teacher may lead into these problems with problems on converting dozens and gross, in order to address student misconceptions about the mole. Review the relationship among moles, mass, molar mass and Avogadro's number. Also review synonymous new terminology, e.g., formula mass/molecular mass and molar mass. The teacher may provide formula triangles to help students with mathematical conversions and demonstrate a structured method for solving these problems such as G.R.A.S.P (Given, Required, Analysis, Solution, Paraphrase) or G.R.A.S.S.S (Given, Required, Analysis, Solution, Statement, Synthesis). The teacher may allow group work and provides assistance as necessary.

2.1.5 **Student Activity:** Students determine the quantity, in moles, of an assigned chemical sample, demonstrating proper lab safety procedures and proper technique for using balances.
They complete a Standard Results Sheet. They then use different pharmaceuticals, e.g., antacid tablets to determine the quantity in moles of the active ingredient present in one dosage, from the given or researched formula. For this, they generate their own results sheet. Students may also generate a table, from class data, comparing the amount of active ingredient in various similar pharmaceuticals, e.g., ranitidine in Zantac® and in generic ranitidine.

Teacher Facilitation: The teacher explains to students that pharmaceuticals are chemicals and must be handled as such, and also reminds students of the safe handling and disposal procedures for all the chemicals being used. Provide students with assigned chemicals and balances to be used, as well as a Standard Results Sheet. The teacher may provide students with the formula of the active ingredient or guide students in researching the formula, e.g., Aspirin®, active ingredient is acetylsalicylic acid, chemical formula $C_9H_8O_4$; Zantac® for acidity, active agent is ranitidine hydrochloride, chemical formula $C_{13}H_{22}N_4O_3S.HCl$; Aludrox® for hyperacidity, active agent is alumina, chemical formula is $Al(OH)_3$; Baygon® for insecticide spray, active agent is propoxur, chemical formula $C_{11}H_{15}NO_3$; Oxy® for acne, active agent is benzoyl peroxide, chemical formula is $C_{14}H_{10}O_4$; Zovirax® for cold sores and herpes, active agent is acyclovir, chemical formula is $C_{13}H_{20}N_6O_4$.

Assessment & Evaluation of Student Achievement

- The teacher monitors and assesses students on their effective participation in group work (discussions, reviewing problems and lab work) as well as individual performance in the classroom (note taking, participating during teacher-led lessons, reviewing problems). Assigned problems should be assessed to gauge student understanding of the basics of quantitative analysis in chemistry. By assessing the results sheet for safety, technique, and accuracy in both recording and calculations, the teacher can set the tone for a safe and accuracy-oriented lab environment. Also, the independent investigation can be assessed on effectiveness of student-generated results sheet as a data recording tool and the accuracy of results.
- Problem Sets (K/U, MC), Formula/Molecular Mass Results Sheet (I, C), Moles of Active Ingredient (I, C)

Accommodations

- Some students may be sensitive to some or all of the chemicals that are used in this activity. Adaptations include not using these particular chemicals, or allowing students to work from previously collected data.

Resources

ISO website – www.iso.ch/

WHO website – www.who.int/

Health Canada Therapeutics Protection Programme website – www.hc-sc.gc.ca/hpb-dgps/therapeut/

Chemistry: a Brief History – www.nidlink.com/~jfromm/history2/chemist.htm

Chemical calculations (worksheets and problems):
– www.tntech.edu/www/acad/chem/jackson/notes7.htm
– www.mhhe.com/catalogs/sem/chemistry/
– www.wpbschoolhouse.btInternet.co.uk/page04/4_73calcs.htm
– www.tntech.edu/www/acad/chem/jackson/notes7.htm
– www.mhhe.com/catalogs/sem/chemistry/
– www.wpbschoolhouse.btInternet.co.uk/page04/4_73calcs.htm

Activity 2.2: Calculating Concentrations

Time: 5 hours

Description

This activity commences with an introduction to the concepts of concentration and dilution. One or both of these concepts may be introduced in connection with mole quantities. Proper technique for preparing solutions is demonstrated and students use these techniques to prepare solutions of required concentration from solids and from other solutions. When diluting solutions from a standard to a required concentration, students calculate concentration from simple volume ratios. Students should be introduced to the dilution formula: $C_1V_1 = C_2V_2$. The activity concludes with students using their skills in preparing solutions to generate an experimental calibration curve and perhaps use this to predict concentration. They may use Probeware in this activity.

Strand(s) & Learning Expectations

Strand(s): Chemical Calculations

Learning Expectations

CCV.02 - use techniques of quantitative analysis in the preparation of standard solutions and solve problems involving the analysis of quantities in chemical reactions, using both theoretical and experimentally measured quantities;
CCV.03 - explain the importance of quantitative chemical relationships in industry and in everyday life;
CC2.01 - use appropriate scientific vocabulary to communicate ideas related to stoichiometry;
CC2.02 - conduct quantitative analyses, using correctly and accurately the following instruments: pipette, burette, volumetric flask, spectrophotometer, electronic balance;
CC2.05 - solve problems involving relationships among the following variables: quantities in moles, mass, number of particles, concentration, volume of solution;
CC2.06 - solve problems involving stoichiometric relationships in balanced chemical equations;
CC2.08 - prepare aqueous solutions, using appropriate concentration units, and accurately dilute a stock solution to a specified lower concentration;
CC3.01 - give examples of everyday situations in which an understanding of quantitative relationships of substances is important;
CC3.02 - explain why it is important to ensure accuracy in the concentration of certain solutions;
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 - express the result of any calculation involving experimental data to the appropriate number of decimal places or significant figures;
SIS.08 - select and use appropriate SI units;
SIS.09 - identify and describe science and technology-based careers related to the subject area under study.

Prior Knowledge & Skills

- Knowledge of the definition and components of a solution, as well as how to apply mathematical ratios effectively and accurately
- Note-taking skills

Planning Notes

- Gather materials for the lab activity: balances, weighing boats, adequate number of volumetric flasks, burettes, pipettes, Erlenmeyer flasks, tap-water, distilled water, salt solution, solid soluble ionic compounds e.g., potassium nitrate, copper(II) sulphate, ammonium carbonate. If possible, use micro-chemistry equipment. If possible, use a spectrophotometer or lab-interfaced colorimeter.
- Organize instruction sheets for using various pieces of equipment, preparing solutions from solids, serial dilution, measuring absorbance, and generating a calibration curve.
- Prepare problems on concentration, dilution, and preparing and/or using calibration curves. Include both Canadian and global industries and other settings in these problems.

Teaching/Learning Strategies

2.2.1 **Student Activity**: Students observe proper techniques for using laboratory equipment, as demonstrated by teacher. Using a set of prepared notes and their own observations, students practise measuring different volumes of solution and liquid for a titration set up, e.g., set up a burette, use a pipette to fill material into an Erlenmeyer flask. Students participate in a peer assessment of the technique.

Teacher Facilitation: The teacher demonstrates proper techniques for use of a variety of lab equipment, e.g., burette, pipette, volumetric flask for dilution, volumetric flask for making a solution from solid. Provide equipment for students to set-up titration apparatus using tap-water and/or table salt solution for practice.

2.2.2 **Student Activity**: In groups of two or three, students follow an instruction sheet to prepare a solution from solid, e.g., copper(II) sulphate, which they then sequentially dilute to a specified concentration. They determine the concentrations of all three solutions using given formulae and ratios. They demonstrate proper lab safety and techniques, as practised in the previous activity, e.g., they can calculate the concentration of the first solution using the given formula: concentration = mass/volume. They then determine the dilutions through ratios, e.g., 1:1 means the second concentration is half the first concentration) and record this data on their own results sheet. They also convert the mass concentration to mole concentration from their knowledge of the link between mass and moles.

Teacher Facilitation: The teacher reminds students of the safe handling and disposal procedures or the chemicals being used and provides an instruction sheet for students to review, for preparing a solution from solid and for serial dilution. Monitor the lab activity for proper technique by students. The teacher introduces the idea of molar concentration, as investigated in the lab and provides students with the molar concentration formula.

2.2.3 **Student Activity:** Students complete notes from teacher-led lesson on concentration and the concept of dilution. In groups or individually, they complete problems including some that require manipulating equations to solve for an unknown.

Teacher Facilitation: The teacher conducts a lesson on concentration and dilution. The teacher reviews the molar concentration formula and introduces the dilution formula ($C_1V_1 = C_2V_2$). Problems are assigned, e.g., textbook, problems sheet on concentration and dilution quantities, including those that require manipulating formulae.

2.2.4 **Student Activity:** Students design and conduct a procedure to prepare a standard solution and prepare various concentrations by dilution. Following teacher instruction, students prepare and conduct a procedure to measure absorbance and generate an experimental calibration curve. Again they demonstrate proper lab technique and safety procedures. They predict a non-standard concentration using the curve.

Teacher Facilitation: The teacher reminds students of the safe handling and disposal procedures for the chemicals being used. Assign standard solution for students to prepare, from dilution. Approve and provide suggestions for improvement on procedure for this before allowing students to continue with experiment. Instruct on generating a calibration curve for absorbance. The teacher may demonstrate the procedure to clarify further. Prepare a solution of unknown concentration, of which students determine concentration, using the calibration curve and provide probe-ware, if possible, for calibration curve.

Assessment & Evaluation of Student Achievement

- Students are assessed on four assignments in this activity: lab safety and technique (both titration set-up and preparing solutions), results sheet (for preparing standard solution and serial dilutions), procedure for preparing solutions for a calibration curve and the calibration curve itself. Students may continue to be assessed on their ability to work independently and in groups, participate effectively and follow instructions (Learning Skills). Students complete concentration and dilution problems and may be formally assessed on these problems after this activity or, after further practice, at the end of Act 2.3.
- Lab Technique (I), Results Sheet (I, C), Problem Set (K/U, MC)

Accommodations

- Students may be sensitive to some or all of the chemicals that are used in this activity. Adaptations include not using these particular chemicals, or allowing students to do dry labs instead.

Resources

Chemical Calculations (worksheets and problems)
– www.tntech.edu/www/acad/chem/jackson/notes7.htm
– www.mhhe.com/catalogs/sem/chemistry/
– www.wpbschoolhouse.btInternet.co.uk/page04/4_73calcs.htm
– www.tntech.edu/www/acad/chem/jackson/notes7.htm
– www.mhhe.com/catalogs/sem/chemistry/
– www.wpbschoolhouse.btInternet.co.uk/page04/4_73calcs.htm

Activity 2.3: Stoichiometry and Percentage Yield

Time: 5 hours

Description

Students have already reviewed the meaning of atomic subscripts in chemical formulae when starting the unit. In this activity, students are introduced to both the meaning of coefficients in balanced chemical reactions, using manipulatives, and the basic theory of stoichiometry. This activity introduces students to the basics of percentage yield, with an emphasis on the stoichiometry. Students use given theoretical data and use their own experimental data to determine percentage yield of a reaction. Using the experiment as a starting point, students discuss the reasons for observing the difference between theoretical and actual yield, the importance of percentage yield in real-life applications, e.g., the Haber process, and methods of modifying the procedure to increase actual yield. Their understanding is reinforced by a series of problems and experiments.

Strand(s) & Learning Expectations

Strand(s): Chemical Calculations

Learning Expectations

CCV.01 - demonstrate an understanding of the mole concept as well as of quantitative relationships in chemical reactions;
CCV.02 - use techniques of quantitative analysis in the preparation of standard solutions and solve problems involving the analysis of quantities in chemical reactions, using both theoretical and experimentally measured quantities;
CCV.03 - explain the importance of quantitative chemical relationships in industry and in everyday life;
CC1.02 - explain how the following variables are related: coefficients in balanced chemical equations, quantities in moles, mass and number of particles;
CC1.03 - identify sources of experimental error that would explain a percentage yield other than 100 per cent;
CC2.01 - use appropriate scientific vocabulary to communicate ideas related to stoichiometry;
CC2.02 - conduct quantitative analyses, using correctly and accurately the following instruments: pipette, burette, volumetric flask, spectrophotometer, electronic balance;
CC2.05 - solve problems involving relationships among the following variables: quantities in moles, mass, number of particles, concentration, volume of solution;
CC2.06 - solve problems involving stoichiometric relationships in balanced chemical equations;
CC2.07 - calculate percentage yield in a chemical reaction using experimental data, and identify sources of error;
CC2.08 - prepare aqueous solutions, using appropriate concentration units, and accurately dilute a stock solution to a specified lower concentration;
CC3.02 - explain why it is important to ensure accuracy in the concentration of certain solutions;
CC3.03 - explain why the profitability of an industry depends in large part on its ability to maximize percentage yield of its products;
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 - express the result of any calculation involving experimental data to the appropriate number of decimal places or significant figures;
SIS.08 - select and use appropriate SI units;
SIS.09 - identify and describe science and technology-based careers related to the subject area under study.

Prior Knowledge & Skills

- Proper technique in using laboratory equipment
- Chemical formulae for simple ionic and covalent compounds
- Ability to manipulate and calculate percentages effectively

Planning Notes

- Gather materials for lab activity: balances (electronic, if possible), pre-made measuring boats, adequate number of beakers, spatulas and stirring rods, distilled water, solid soluble ionic compounds that generate a solid during double displacement reaction, e.g., copper(II) sulphate and dilute calcium chloride.
- Some of the chemicals used may be toxic or contain heavy metals. Follow board policy for the safe handling and disposal of all materials.
- Prepare problems on mole ratios and percentage yield. Include both Canadian and global industries and other settings in these problems, e.g., percentage yield in mining industries.
- Research and prepare information on importance of percentage yield in real-life applications, to assist students in discussion. Include both Canadian and global content in this information.
- Prepare Standard Results Sheet for Act 2.3.3.

Teaching/Learning Strategies

2.3.1 **Student Activity:** Students use models to simulate chemical reactions and realize that atoms for each element must be equal on both sides of a chemical reaction (Law of Conservation of Mass). They use these models to determine the relationship between coefficients in a balanced chemical reaction and mole ratios, e.g., if two NO particles react, it translates to twice Avogadro's number, which means two moles.
Teacher Facilitation: The teacher provides models, e.g., molecular models, paper models, marshmallow/toothpick models, and an instruction sheet to guide students with activity. The teacher then presents a lesson that summarizes the meaning of balanced chemical reactions, e.g., the meaning of coefficients and subscripts in a balanced chemical reaction; how to translate these into moles.

2.3.2 **Student Activity:** Students participate in a class discussion of the importance of mole ratios in industry. They complete problems on mole ratios.
Teacher Facilitation: The teacher leads students in a discussion on the importance of mole ratios in industry and other real-life applications. Problems on mole ratios in balanced chemical reactions, e.g., lab stations, group problem-assignment, textbook problems, are assigned.

2.3.3 **Student Activity:** Students complete a Standard Results Sheet (see Appendix C) to determine percentage yield of a double-displacement chemical reaction, e.g., copper (II) sulphate with calcium chloride. When conducting the reaction, they demonstrate proper lab safety procedures and technique. They discuss why the actual yield is not the same as the expected yield and how this is important in industry. As an extension, students use their percentage yield to predict the amount of reactants needed to generate a required amount of product, and conduct an experiment to verify their prediction.

Teacher Facilitation: The teacher provides a Standard Results Sheet and expected yield so that students may compare this to their actual yield, in order to generate a percentage yield. The teacher guides the students through a discussion of the difference between expected and actual yield and its importance in industry. For the lab extension, either allow students to determine their own amount of required product or assign a required amount of product.

2.3.4 **Student Activity:** Students complete problems on percentage yield.
Teacher Facilitation: The teacher provides students with problems on percentage yield, e.g., lab stations, group problem assignment, textbook problems.

Assessment & Evaluation of Student Achievement

- By the time students commence Activity 2.3, they have had extensive assessment on their ability to work in groups and individually in labs and in other class activities. It would be appropriate to shift the focus of assessment on ability to solve theoretical problems, lab safety and technique and accuracy of results.
- Problem Sets (K/U, MC), Results Sheet (I, C)

Accommodations

- Some students may be sensitive to some or all of the chemicals that are used in this activity. Adaptations include not using these particular chemicals, or allowing students to use previously collected data.

Resources

Percentage Yield (chemistry websites for worksheets and examples):
– antoine.fsu.umd.edu/chem/senese/101/moles/slides/tsld020.htm
– www.scidiv.bcc.ctc.edu/wv/ex/percent-yield.html
– learn.chem.vt.edu/tutorials/stoichiometry/percentyield.html
– www.westminster.net/faculty/dingle/hworkyield.doc
– www.ucdsb.on.ca/tiss/stretton/chem1/stoich7.htm

Activity 2.4: Percentage Composition

Time: 2 hours

Description

In this activity, students are introduced both qualitatively and quantitatively to percentage composition of various compounds and the importance of this concept in various fields of applied chemistry, e.g., geochemistry. They calculate percentage composition of a compound using both theoretical and experimental values.

Strand(s) & Learning Expectations

Strand(s): Chemical Calculations

Learning Expectations
CCV.02 - use techniques of quantitative analysis in the preparation of standard solutions and solve problems involving the analysis of quantities in chemical reactions, using both theoretical and experimentally measured quantities;
CC2.04 - calculate percentage composition of a compound using experimental data or its chemical formula;

SIS.05 - select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate scientific ideas, plans and experimental results;
SIS.07 - express the result of any calculation involving experimental data to the appropriate number of decimal places or significant figures;
SIS.08 - select and use appropriate SI units;
SIS.09 - identify and describe science and technology-based careers related to the subject area under study.

Prior Knowledge & Skills

- Knowledge of effectively manipulating and applying percentages

Planning Notes

- Prepare problems on chemical composition of compounds.
- Review End-of-Unit task so that students may prepare a procedure for approval.

Teaching/Learning Strategies

2.4.1 **Student Activity:** Students participate in a teacher-led lesson on percentage composition calculations. They complete problems on percentage composition and discuss the importance of percentage composition to industrial applications, e.g., impurities in mineral ores.
Teacher Facilitation: The teacher introduces the End-of-Unit Task. The teacher instructs on percentage composition in chemical compounds and provides practice problems through a variety of strategies, e.g., lab stations, group problem-assignment, textbook problems, using both theoretically and experimentally measured quantities. The teacher then leads a discussion about the practical applications of percentage composition.

Assessment & Evaluation of Student Achievement

- Since this activity does not have a lab component, students are assessed on their ability to solve theoretical problems and practical problems, using previously collected data.
- Problem Set (K/U, MC)

Accommodations

- As an extension, the teacher may combine problems on stoichiometry and percentage composition.

Resources

The Chemistry and Processing of Jamaican Bauxite
– http://wwwchem.uwimona.edu.jm:1104/lectures/bauxite.html
Chemical Calculations (worksheets and problems):
– www.tntech.edu/www/acad/chem/jackson/notes7.htm
– www.mhhe.com/catalogs/sem/chemistry/
– www.wpbschoolhouse.btInternet.co.uk/page04/4_73calcs.htm
– www.tntech.edu/www/acad/chem/jackson/notes7.htm
– www.mhhe.com/catalogs/sem/chemistry/
– www.wpbschoolhouse.btInternet.co.uk/page04/4_73calcs.htm

Activity 2.5: End-of-Unit-Task

Time: 4 hours

Description

Students combine their knowledge of moles, stoichiometry, solubility, and concentration to experimentally determine the amount of soluable compound dissolved in a solution. This assignment, along with a unit test, constitutes the summative evaluation of this unit.

Strand(s) & Learning Expectations

Strand(s): Chemical Calculations

Learning Expectations

CCV.01 - demonstrate an understanding of the mole concept as well as of quantitative relationships in chemical reactions;
CCV.02 - use techniques of quantitative analysis in the preparation of standard solutions and solve problems involving the analysis of quantities in chemical reactions, using both theoretical and experimentally measured quantities;
CC1.01 - define the mole concept and demonstrate an understanding of its usefulness in the analysis of quantities involved in chemical reaction;
CC1.02 - explain how the following variables are related: coefficients in balanced chemical equations, quantities in moles, mass and number of particles;
CC1.03 - identify sources of experimental error that would explain a percentage yield other than 100 per cent;
CC2.01 - use appropriate scientific vocabulary to communicate ideas related to stoichiometry;
CC2.02 - conduct quantitative analyses, using correctly and accurately the following instruments: pipette, burette, volumetric flask, spectrophotometer, electronic balance;
CC2.03 - calculate the molecular mass and molar mass of a compound with the aid of the periodic table;
CC2.04 - calculate percentage composition of a compound using experimental data or its chemical formula;
CC2.05 - solve problems involving relationships among the following variables: quantities in moles, mass, number of particles, concentration, volume of solution;
CC2.08 - prepare aqueous solutions, using appropriate concentration units, and accurately dilute a stock solution to a specified lower concentration;
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 - express the result of any calculation involving experimental data to the appropriate number of decimal places or significant figures;
SIS.08 - select and use appropriate SI units.

Prior Knowledge & Skills

- Knowledge of chemical formulae and percentage calculations

Planning Notes

- Review student procedure, assigned in Activity 2.5.1, before allowing students to proceed on their own.
- Prepare a number of non-standard solutions of copper(II) sulphate. (Other soluble ionic compounds may be used.)
- Gather materials for lab activity, as required by student procedure.
- Prepare a unit test covering Avogadro's number, moles, mass, molar mass, percentage composition, concentration, dilution, and percentage yield.
- Prepare materials for practical component of unit test, e.g., concentrated solutions of copper(II) sulphate and iron(III) nitrate.
- Gather equipment for practical component, e.g., pipettes of various volume, volumetric flasks of various volumes.

Teaching/Learning Strategies

2.5.1 **Student Activity:** Students design and conduct an experiment to determine the amount of soluable compound (e.g., copper (II) sulfate) in a unknown, non-standard solution by using a double displacement reaction. Throughout, they demonstrate proper lab safety procedures and technique.

Teacher Facilitation: The teacher provides a different non-standard solution of a soluable ionic compound for each student of the class. Several different compounds may be used. The teacher also makes available compounds that students can use to produce solutions of known concentrations for their double displacement reactions. The teacher should approve student procedures prior to performance and make suggestions where necessary. A possible procedure might involve reacting the unknown copper (II) sulfate solution with a solution of sodium carbonate of known concentration (prepared by the student). The resulting precipitate is then filtered, dried, and massed. From there, the unknown amount of soluble compound is determined.

Assessment & Evaluation of Student Achievement

- The activity is assessed on four components: the procedure used to determine percentage composition, lab safety and technique during the experiment, use of an effective data recording and results sheet, and accuracy of results in determining concentration of solution. The unit test will focus primarily on knowledge but will include some practical components as suggested above.
- Student Designed Procedure (K/U, I, C, MC), Unit Test (K/U, MC, I)

Accommodations

- Some students may be sensitive to some or all of the chemicals that are used in this activity. Adaptations include not using these particular chemicals.

Resources

Chemistry Education Sites – science.uniserve.edu.au/disc/chem/schools.html

Links to Chemistry Online – antoine.fsu.umd.edu/chem/senese/101/reverse-links.shtml

Woodrow Wilson Leadership Programme in Chemistry – www.woodrow.org/teachers/chemistry/

Appendix B

Molecular Mass Calculation Form (for use with Task 2.1.3)

Name: **Date:**
Time started:
Time completed:

1. **The molecular formula of the chemical: ________________________**

Column A	Column B	Column C	Column D	
				Total molecular mass
				=

2. **Column A:** symbol of element
   Column B: average atomic mass of element (calculated to 3 decimal places)
   Column C: number of atoms of element denoted by the subscript, e.g., C_2H_4 has two carbons and 4 hydrogens
   Column D: total atomic mass = column B × column C (calculated to 3 decimal places)
   Total molecular mass: add all values in column D (calculated to 3 decimal places)
3. **The total molecular mass of the compound is ____________________ g/mol.**

Signature: _______________________

Appendix C – Sample Results Sheet

Percentage Yield Calculation Form (for use with Task 2.3.3)

Name: **Date:**
Time started:
Time completed:

1. **Chemical A name: ____________________**
   Chemical A formula: __________________

2. **Chemical B name: ____________________**
   Chemical B formula: __________________

3. **Expected yield, as provided by authority: _______________________ g**

4. **Actual mass** **(reading 1): __________________________g** (read to 2 decimal places)
   (reading 2): __________________________g (read to 2 decimal places)
   (reading 3): __________________________g (read to 2 decimal places)

5. **Average actual mass: _____________________________g** (calculated 2 decimal places)
6. **Percentage yield: _________________________________%**
   (calculate with the following formula **[(#5 - #3)/3] × 100**)

Signature: _________________