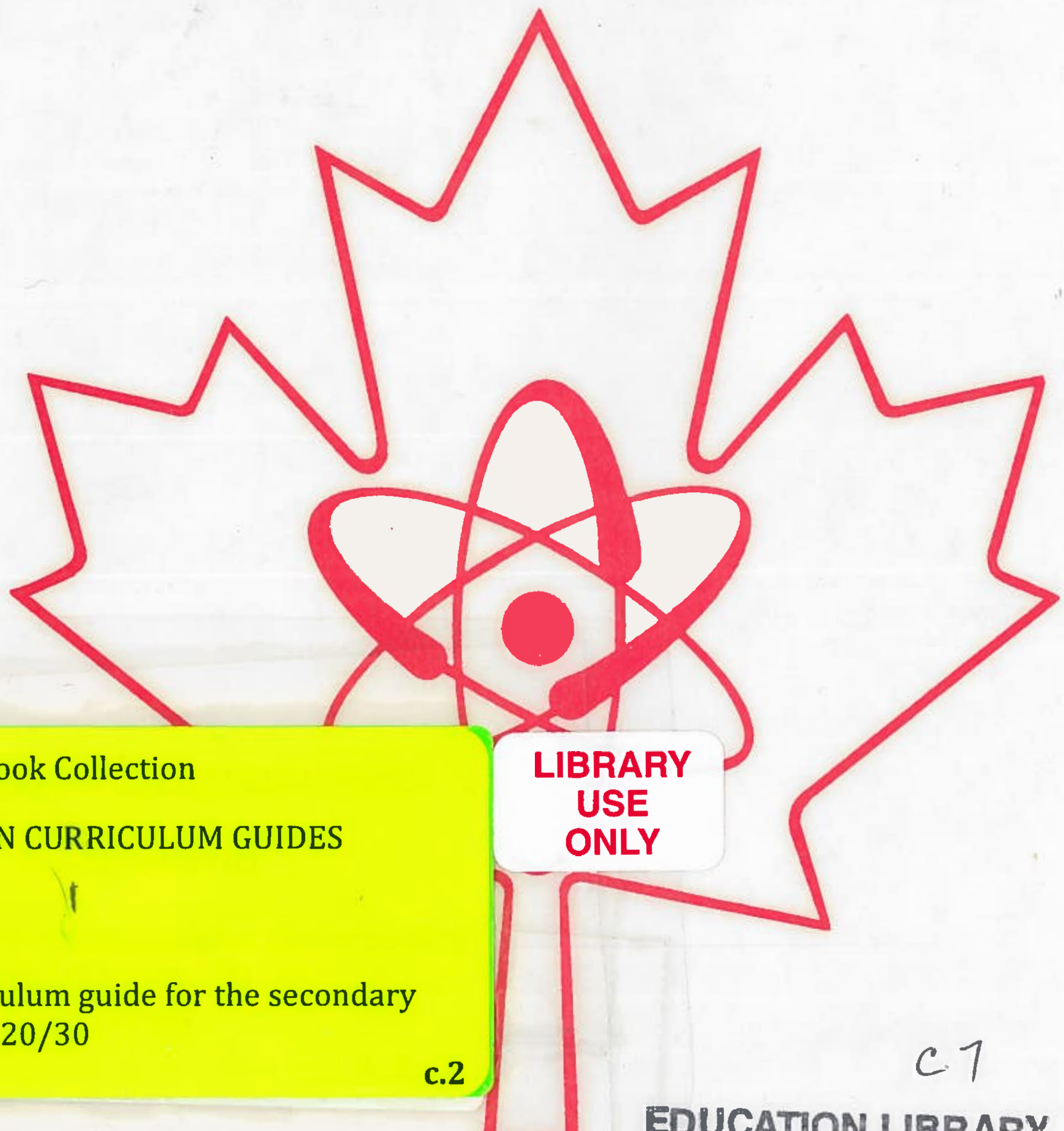
Saskatchewan
Education

Science
A Curriculum Guide for the Secondary Level
Chemistry 20/30



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Preface

Much of the foundation for curriculum renewal in Saskatchewan schools is based on *Directions* (1984). The excitement surrounding the recommendations for Core Curriculum developments will continue to build as curricula are designed and implemented to prepare students for the 21st century.

Science, as one of the Required Areas of Study, incorporates the Common Essential Learnings, the Adaptive Dimension, and other initiatives related to Core Curriculum. As we strive to achieve the goal of scientific literacy in Saskatchewan schools, much collaboration and cooperation among individuals and groups will be required. Science teachers are a key part of the process.

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Introduction

Science Program Philosophy, Aim, and Goals

The philosophy and spirit of science education renewal in Saskatchewan is reflected not only in the program aim and goals, but in the documents developed to support the new curricula, and in the inservice packages designed and utilized for implementation. In addition, the philosophy for science education is closely related to the concept of Core Curriculum based on the *Directions* philosophy for Saskatchewan.

Science is both a body of knowledge and a process of inquiry. Furthermore, science extends beyond understanding of abstract laws and principles of nature into the realm of technology and applied sciences. Many important technological developments can be appreciated through a solid foundation in science. Applications in agriculture, engineering, medicine, and many other fields can be comprehended by someone who has a good basic understanding of science.

In an information-based society, with widespread public concerns relating to issues as complex as the protection of the environment, manipulation of genetic material, the proliferation of technologically advanced weapons systems, and various other serious and often controversial issues, a scientifically literate society is needed more urgently than ever before. While solutions to these kinds of issues are indeed difficult to find, science provides a way in which these types of problems can be understood and approached. It offers one world view which, when taken in conjunction with other world views, empowers society to make informed, rational decisions based on diverse ways of thinking about problems.

Through the exemplary leadership of a few dedicated scientists, issues of grave concern to society have been brought to the forefront of public attention. Internalized, clearly defined values need to form the foundation for decisions relating to science. Fundamental moral principles, such as respect for the dignity of all persons, respect for the value of all forms of life, the protection of the environment, the need to promote peace and understanding among all people throughout the world, and other principles of natural justice, need to be emphasized. In a world in which advances in science and technology have led to the development of nuclear weapons, with their potential for the annihilation of human life, the need for clarity and reason in scientific decision making is quite apparent.

After all is said and done, making rational decisions in a seemingly irrational world is the moral responsibility of an informed, well-educated society. While science can make no claims to have all of the solutions to complex human problems, it does provide us with the necessary knowledge, skills, and attitudes to begin to approach these problems in a unique way.

Aim and Goals

The aim of the K-12 Science program is to develop scientific literacy in students. What, however, is scientific literacy?

For Saskatchewan schools, scientific literacy has been defined by seven Dimensions of Scientific Literacy that are the foundation for the renewed curriculum (Hart, 1987). Actively participating in K-12 Science will enable a student to:

- understand the **nature of science** and scientific knowledge as a unique way of knowing;
- understand and accurately apply appropriate science **concepts**, principles, laws, and theories in interacting with society and the environment;
- use **processes of science** in solving problems, making decisions, and furthering understanding;
- understand and appreciate the joint enterprises of **science** and **technology** and the interrelationships of these to each other in the context of **society** and the **environment**;
- develop numerous manipulative **skills** associated with science and technology, especially with measurement;
- interact with the various aspects of society and the environment in ways that are consistent with the **values** that underlie science; and,
- develop a unique view of technology, society, and the environment as a result of science education, and continue to extend this **interest and attitude** throughout life.

Each of these Dimensions has been defined further by a series of factors which delineate the science curriculum. The factors of scientific literacy are defined and examples are given starting on page 29. Further information about the factors can be found in *Science Program Overview and Connections K-12.*

The study of science should help students to understand the world in which they live. The objective is not to have students be able to repeat the words that teachers or scientists or others use to describe the world, although they may do that. It is to have students create their own conceptual maps of what surrounds them every day, and to realize that those concepts and the maps which describe the links between concepts are tentative, subject to questioning, and revised through investigation.

As consumers of goods and information, and as responsible citizens, scientifically literate individuals are able to exercise their freedom by basing economic and political decisions on their insights into science.

Related Documents

Saskatchewan Education has produced the following documents to support this Secondary Level science curriculum.

Science: A Curriculum Guide for the Secondary Level — Chemistry 20/30 contains the specific information needed to plan and deliver the Chemistry 20 and Chemistry 30 courses.

Science Program Overview and Connections K-12 contains important sections on the philosophy and rationale behind the teaching of science, and on planning for instruction in science for all teachers from kindergarten to grade 12. Sections of this document will also be useful for administrators, teacher-librarians, and others.

Science: An Information Bulletin for the Secondary Level — Chemistry 20/30 Key Resources lists the key resources which have been recommended to help achieve the factors and objectives outlined in the Chemistry 20/30 Curriculum Guide. It is organized so that the resources, with page or chapter references, are listed for each topic in the Curriculum Guide.

Secondary Sciences: Biology 20/30, Chemistry 20/30, Physics 20/30 — An Information Bulletin for Administrators has information regarding the organization of the secondary science courses, addresses implications for their implementation, and encourages support for the science program.

Science: A Bibliography for the Secondary Level — Biology, Chemistry, Physics contains an annotated listing of resources which can be used to enrich the chemistry program and to assist in implementing resource-based learning in the classroom. Each annotation contains a recommendation about the topic(s) for which the resource is most appropriate.

The Factors of Scientific Literacy

Before using this Curriculum Guide, teachers should be familiar with the *Science Program Overview and Connections K-12*, a document that provides background information about the factors of scientific literacy. A list of the factors, their definitions, and examples of instances in science where these factors are important, or can be developed, is also found beginning on page 29 of this Curriculum Guide. Nearly all of the factors which have been identified as components of the Dimensions of Scientific Literacy can be developed in Chemistry 20 and Chemistry 30.

Different students will exhibit varying degrees of sophistication in dealing with some factors of scientific literacy. Some may be at a rudimentary level in understanding; others will be advanced. The teacher will need to adapt the course to meet these student variations.

In order to emphasize as many of these factors as possible during the course, and to concentrate on those less well developed, teachers must have a thorough understanding of each factor and exhibit good lesson planning and lesson reflection skills. Lesson reflection means that, at the end of the lesson, the teacher thinks about what happened. Based on assessment of student interests, understandings, strengths, and needs, the teacher identifies what was covered and what needs more work. The teacher must verify the connections among the goals, factors, and objectives.

The K-12 science curriculum in Saskatchewan schools is intended to develop the understandings, abilities, and values specified by the factors of scientific literacy. The scope and depth of Chemistry 20 and Chemistry 30 is guided by these factors.

Using This Curriculum Guide

Each of the units in this guide has a similar structure, beginning with the **Unit Overview**. The **Overview** gives a brief synopsis of the unit, with some comments about the philosophy behind teaching that unit and its topics.

The section **Factors of Scientific Literacy Which Should Be Emphasized** follows. The introduction and development of the factors of scientific literacy form the basis for the science program from kindergarten through grade 12. **The factors can be thought of as the prime foundational objectives for each science course.** All other elements of the curriculum support the development of these factors of scientific literacy.

The section lists the factors which should be emphasized in that core unit. Teachers are free to emphasize what they feel are the most appropriate factors in a unit, whether or not they appear on this list. This section indicates that the factors are important and should be considered in the planning of each unit. It is a help for organization in that if those factors are emphasized in that unit, all appropriate factors will be covered during the course. It is not meant to restrict the coverage to those factors listed.

The **Foundational Objectives for Chemistry and the Common Essential Learnings** are statements of what students should be able to achieve during Chemistry 20 and Chemistry 30. The stating of objectives for the Common Essential Learnings is a reminder that one of the primary foci of the curriculum is the incorporation of the Common Essential Learnings into science instruction. They are described as foundational because they are general, guiding objectives. Since foundational objectives in the Common Essential Learnings are meant to be achieved over a student's entire school experience, students may come to chemistry classes with some understanding of these concepts, gained in previous science classes and in other areas of study. Encourage the development of their understanding of the objectives which are listed, and others which are perceived as appropriate for that unit, during the study of chemistry.

The foundational objectives for science describe the broad intent of the unit. They are intended to give the unit its focus and structure. **Learning Objectives** which will promote accomplishment of each foundational objective can be selected from those listed or can be developed by the teacher and students. The learning objectives define more specifically what will be dealt with during the unit of study. By giving careful consideration to the learning objectives, the Adaptive Dimension enters the classroom, and the foundational objectives for both chemistry and the Common Essential Learnings can be accomplished.

The **Suggested activities and ideas for research projects** section is, as the name indicates, meant to provide a broad choice from which ideas for activities may be taken. It is not intended that all activities from this section be done, or that this is the only source of ideas for activities and projects. The ideas included in this section are meant to supplement those found in laboratory manuals, texts, journals and other references. As with any activities, please ensure that the facilities and equipment available are appropriate for safe conduct of the activity. It is always good practice to try an activity before having students do it, if it involves laboratory procedures.

The **Sample ideas for evaluation and for encouraging thinking** section provides questions that may be used for assignments, class discussions or exams. The questions are designed to require abilities beyond the ability to recall information.

The outlines of the Chemistry 20 and Chemistry 30 courses are based on 100 hours being allotted to each course. Chemistry 20 is a prerequisite course for Chemistry 30.

The sequencing of the units is at the discretion of the teacher. Creative rearrangement of the topics is encouraged. Some teachers have had good experiences when starting with the unit on Chemical Reactions in Chemistry 20 and introducing the concepts of atoms, elements, molecules, compounds, symbols, formulas and stoichiometry as the reactions they observe in laboratory activities are discussed. Many of these topics may be integrated or developed simultaneously. Examples of integration are given after the Chemistry 20 outline.

Chemistry 20 Outline

The first seven units are compulsory. Time allotments for those units are suggested but may be altered according to the interests and needs of the students, the facilities and resources available, and the abilities and priorities of the teacher.

- Introduction to Chemistry (4 hours)
- Laboratory Activities (20 hours — integrated with other units)
- Independent Research (10 hours) — may be integrated with other units
- Atoms and Elements (8 hours)
- Molecules and Compounds (8 hours)
- Chemical Reactions (8 hours)
- Mole Concept and Stoichiometry (12 hours)
- Optional: Behaviour of Gases
- Optional: Consumer Chemistry
- Optional: Organic Chemistry
- Optional: Teacher Developed Unit

More time for the optional units may be gained by integrating those concepts and topics into the core units. For example, organic chemistry may be discussed in the context of molecules, compounds and chemical reactions. The behaviour of gases may form the basis for a significant part of the "Mole Concept and Stoichiometry " unit. The "Consumer Chemistry" unit may be used as an introduction to chemistry or as the focus of independent research. The Teacher Developed Unit may be an integrated unit involving objectives from the Molecules and Compounds unit, the Chemical Reactions unit and the Organic Chemistry unit.

Chemistry 30 Outline

The **Case Studies** unit and the **Teacher Developed Unit** are the only optional units. Each of the compulsory units offers extensive latitude for enrichment and extension.

- Review of Basic Principles (5 hours) — may be integrated with other units
- Laboratory Activities (20 hours) — integrated with other units
- Independent Research (10 hours) — may be integrated with other units
- Optional: Case Studies
- Solubility and Solutions (5 hours)
- Energy Changes in Chemical Reactions (5 hours)
- Reaction Kinetics (5 hours)
- Equilibrium (5 hours)
- Acid-Base Equilibria (8 hours)
- Oxidation and Reduction (8 hours)
- Optional: Teacher Developed Unit

Any one resource will not be sufficient to support the chemistry curriculum. Instead, teacher-selected activities and content from a variety of resources should be integrated to produce a comprehensive, activity-based program.

Chemical Terminology

The use of terminology to describe various aspects of chemistry evolves. Thus some terms in use in 1965 are now obsolete or recommended for change. Below are listed terms which are may cause confusion due to changing usage. Students should probably have some familiarity with all these terms.

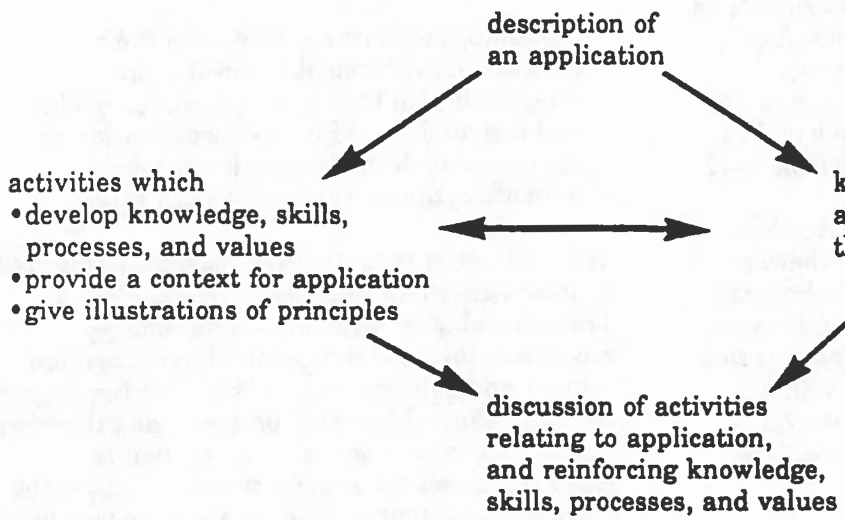
- Amphiprotic replaces amphoteric.
- Reaction diagram, reaction pathway, energy diagram are used interchangeably.
- Nucleon number (*A*) replaces mass number.
- *Z* is the symbol for proton number (atomic number).
- SATP replaces NTP and STP. Conditions at SATP are 25°C and 100 kPa. The volume of 1 mole of an ideal gas at SATP is 24.8 L.
- Mole is the SI unit. Its symbol is mol.
- $mol{\bullet}m^{-3}$ is preferred, but $mol{\bullet}L^{-1}$, M, and mole/litre are used for expressing concentration.
- Mass is used instead of weight, as in relative molar mass instead of molecular weight and relative atomic mass instead of atomic weight. Formula mass, molecular mass, and molar mass each have a particular use.
- Joules (J) replace kilocalories (kcal) for measuring and reporting energies of reactions. 1 kcal is equivalent to 4.18 J.

A Science-Technology-Society-Environment (STSE) Approach to Science Education

The Science-Technology-Society-Environment (STSE) approach to science education differs from the way science has traditionally been presented. The ideal is to introduce a topic for study through the description of an application. In order to understand the science behind the application, knowledge and skills must be developed, along with activities which give purpose to the newly acquired knowledge and skills. Alternatively, the activities may immediately follow the discussion of the application, and serve to develop the knowledge and skills needed to understand the application. The arrows on Figure 2 are meant to show the variety of paths from the description of an application to the final discussion.

Figure 1

An STSE Approach to Science Education



Guidelines To Using Resource Materials

A resource-based learning approach requires long-term planning and coordination within a school or school division. In-school administrators, teacher-librarians, and others need to take an active role to assist with this planning.

Science: An Information Bulletin for the Secondary Level – Chemistry 20/30 Key Resources correlates key resources to the topics of each unit. *Science: A Bibliography for the Secondary Level – Biology, Chemistry, Physics* provides an annotated listing of resources which further support resource-based learning. Teachers should consider the suggestions and recommendations in these documents. Other materials may also be used.

As new resource materials become available, **Information Bulletins** may be issued as updates. They will indicate which new resources can be used, as well as those resources that are no longer available.

As was indicated earlier, no single resource matches the chemistry curriculum. To facilitate a resource-based approach, the use of a variety of resources instead of a single textbook is highly recommended.

Teachers may wish to extend some of the topics that were selected for Science 10 into Chemistry 20 or Chemistry 30. One topic from Science 10 which has many ties to chemistry is the issue of water quality. Food additives and human nutrition is another topic which could be extended. This should be coordinated within schools. Resources should be selected with this in mind.

Instructional methods which emphasize group work and develop independent learning abilities make it possible to utilize limited resources in a productive way.

Core Curriculum and Other Initiatives

Core Curriculum: Plans for Implementation (Saskatchewan Education, 1987) defines the Core Curriculum as including seven Required Areas of Study, the Common Essential Learnings, the Adaptive Dimension, and Locally-Determined Options. Science is one of the Required Areas of Study.

Understanding the Common Essential Learnings: A Handbook for Teachers (Saskatchewan Education, 1988), as a foundation document for Saskatchewan Education, defines and expands on an understanding of these essential learnings. Other Saskatchewan Education documents elaborate on the concept of Core Curriculum. See the references in this Curriculum Guide and in *Science Program Overview and Connections K-12.*

There are other supportive initiatives for Core Curriculum being developed by Saskatchewan Education, including Gender Equity, Indian and Métis perspectives, and Resource-Based Learning. These initiatives can be viewed as principles that guide the development of curricula as well as instruction in the classroom. The initiatives outlined in the following statements have been integrated throughout the Curriculum.

The Adaptive Dimension in the Chemistry Curriculum

The Adaptative Dimension aims to meet learner needs and is an expectation inherent in the **Goals of Education.** It is an essential ingredient of any consideration of Instructional Approaches. In *Instructional Approaches: A Framework for Professional Practice* (Saskatchewan Education, 1991) the Adaptive Dimension is defined as:

> the concept of teachers exercising their professional judgement to develop an integrated plan that encompasses curricular and instructional adjustments to provide an appropriate education that is intended to promote optimum success for each child.

The continuum of curricular programs authorized by Saskatchewan Education – Regular, Transitional, and Alternative Programs – recognizes the need for variation in curriculum content and delivery mechanism. The continuum indicates that within each program, and therefore within each course of study, adaptation is required. Teachers are empowered to adjust the curriculum content in order to meet student needs; as professionals they must ensure that the instructional approaches are also adapted. This implies that teachers have at their "fingertips" a broad, strong repertoire of instructional strategies, methods, and skills and that conscious planning takes place to adapt these approaches to meet student needs. See Figure 2 on page 7.

The cues that some students' needs are not being adequately met come from a variety of sources. They may come to the perceptive teacher as a result of monitoring for comprehension during a lesson. The cue may come from a unit test, or from a student need or background deficiency that has been recognized for several years. A student's demonstrated knowledge of, or interest in, a particular topic may indicate that enrichment is appropriate. The adaptation required may vary from presenting the same content through a slightly different instructional method, to modifying the content because of a known information background deficit or to establishing an individual or small group enrichment activity. The duration of the adaptation may range from five minutes of individual assistance, to placement of the student in an alternative or enrichment

Figure 2

Correlating Instruction, Evaluation, and Science Goals

Instructional Strategies	Some Important Instructional Methods for Science (See p. 20, **Instructional Approaches: A Framework for Professional Practice**)	Some Corresponding Assessment Techniques* (See p. 45 ***Student Evaluation: A Teacher Handbook***)	DSL Major Emphasis (See p. 2 this Guide)
Direct	• Demonstrations • Mastery Lecture • Structured Overview	• Group/Individual (Peer/Self): Performance Assessments • Short-Answer Quizzes & Tests	B, E
Indirect	• Concept Mapping/Formation/ Attainment • Inquiry • Problem Solving	• Individual/Group: Presentations • Oral Assessments • Performance Assessments • Written Assignments	A-D
Experiential	• Conducting Experiments • Field Observations & Trips • Model Building • Simulations	• Group/Individual: Performance Assessments; Written Assignments; • Peer/Self: Oral Assessments • Technical Skills	B, C, E
Independent Study	• Computer Assisted Instruction • Essays & Reports • Homework • Research Projects	• Performance Assessments • Portfolios • Presentations • Quizzes • Written Assignments	All
Interactive	• Brainstorming • Co-operative Learning Groups • Discussion • Laboratory Groups	• Group/Peer: Oral Assessments • Written Assignments	All

* Ancedotal Records, Observation Checklists, and Rating Scales can be used as methods of data recording with all of the categories.

Some Adaptive Dimension Variables

Curriculum
- concepts
- content
- materials
- evaluation

Instruction
- strategies, methods, skills
- pacing and time
- feedback, modification and reflection

Learning Environment
- classroom climate
- grouping
- support
- physical setting

The diagnosis of the need may be handled adequately by the classroom teacher, or may require the expertise of other support specialists such as the school's resource teacher or the regional coordinator — special education.

The recognition of the need for adaptive instruction is dependent upon the professional judgement of the teacher. The decision to initiate adaptive practices must be an informed one. While the practice of adapting instruction may occur through the placement of students in programs other than those defined as regular, the most frequent application of the Adaptive Dimension will occur as teachers in regular classroom settings adjust their use of both content and instructional approaches.

Instructional Approaches: A Framework for Professional Practice identifies a hierarchy of approaches — models, strategies, methods, and skills. The four basic **models** of instruction do not change, whether used in a "regular" class setting, or with a small group as an adaptive approach. The strategies, methods, and skills may be altered or adapted. Hence a framework for inservice, investigation, and discussion among professionals has been established.

Science teachers will have to take advantage of and create inservice opportunities to adjust their repertoire of instructional strategies, methods, and skills.

Common Essential Learnings

Science offers many opportunities for incorporating the Common Essential Learnings into instruction. The purpose of this incorporation is to help students better understand the subject matter under study and to better prepare students for their future learning both within and outside the K-12 educational system. The decision to focus on a particular Common Essential Learning within a lesson is guided by the needs and abilities of individual students and by the particular demands of the subject area. Throughout a core unit, it is intended that the **Foundational Objectives for the Common Essential Learnings** will have been developed to the extent possible, regardless of the topics selected.

It is important to incorporate the **Foundational Objectives for the Common Essential Learnings** in an authentic manner. For example, some topics may offer many opportunities to develop the understandings, values, skills, and processes related to a number of the foundational objectives. The development of a particular foundational objective, however, may be limited by the nature of the subject matter under study.

It is intended that the Common Essential Learnings be developed and evaluated within subject areas. Therefore, **Foundational Objectives for the Common Essential Learnings** are included in the introductory section of each core unit in this Curriculum Guide. Since the Common Essential Learnings are not necessarily separate and discrete categories, it is anticipated that working toward the achievement of one foundational objective may contribute to the development of others. For example, many of the processes, skills, understandings, and abilities required for the Common Essential Learnings of Communication, Numeracy, and Critical and Creative Thinking are also needed for the development of Technological Literacy.

Incorporating the Common Essential Learnings into instruction has implications for the assessment of student learning. Assessment in a unit which has focused on developing the Common Essential Learnings of Communication and Critical and Creative Thinking should reflect this focus. Assessment strategies can allow students to demonstrate their understanding of the important concepts in the unit and how these concepts are related to each other and to previous learning. Questions can be structured so that evidence or reasons may accompany student explanations. If students are encouraged to think critically and creatively throughout a unit, then the assessment strategies for the unit should also require students to think critically and creatively.

It is anticipated that teachers will build from the suggestions in this Curriculum Guide and from their personal reflections in order to better incorporate the Common Essential Learnings into the teaching of science.

Throughout this Curriculum Guide, the following symbols may be used to refer to the Common Essential Learnings:

COM	Communication
CCT	Critical and Creative Thinking
IL	Independent Learning
NUM	Numeracy
PSVS	Personal and Social Values and Skills
TL	Technological Literacy

Incorporating the Common Essential Learnings into Chemistry Instruction

The science curriculum from Kindergarten to grade 12 involves the development of the factors within the Dimensions of Scientific Literacy. The main goal is to promote an interest in, and an understanding of, science.

The Common Essential Learnings should be planned and developed within the context of good science lessons. As lesson planning is taking place consideration should be given to how to incorporate the Common Essential Learnings. The **Factors of Scientific Literacy Which Should Be Emphasized**, and the **Foundational Objectives for Chemistry and the Common Essential Learnings** outlined at the beginning of each core unit, provide appropriate starting points in planning.

Science-Technology-Society-Environment Interrelationships (Dimension D) help to develop **Technological Literacy**. All eleven factors within Dimension D are developing by grade 10. Technology, as it is developed within this Dimension, is studied within a social context. The connections between science and technology are elaborated. Furthermore, the impact that technology has on society, on science, and on the environment is developed. Technology is defined as more than the gadgets and gizmos that are often the only things associated with it. Many of the topics within Chemistry 20 and Chemistry 30 can be structured to develop Technological Literacy.

Scientific and Technical Skills (Dimension E) also helps to develop Technological Literacy. Many scientific and technical skills in use today exist because of materials and instruments which have been developed through advances in technology. The impact that these new things have on our lives and on the environment is very important.

Numeracy can be developed through various factors of scientific literacy which are linked closely with this Common Essential Learning. Some of these include the empirical nature of science (A5), quantification (B8), probability (B19), accuracy (B21), measuring (C5), using numbers (C7), using mathematics (C17), and using quantitative relationships (E13). To anyone who understands science, the importance of Numeracy is readily apparent.

Problem solving can lend itself to developing Numeracy. Any other quantitative applications, of which there are many, further develop this Common Essential Learning. Students should be given many opportunities to develop ways in which quantities can be measured, recorded, manipulated, analyzed, and interpreted. Simply plugging numbers into obscure formulae is not nearly enough. Students must appreciate the importance of numeric information in the world of science.

Specific factors relating to the Common Essential Learning of **Communication** include communicating (C2), and observing and describing (C3). The public/private nature of science (A1) reveals the underlying importance of communication in science. Scientists share their discoveries with others. This involves the use of language and of written and verbal communication. When students explore important scientific principles, and discuss their understandings orally or in writing, using their own language, their ability to communicate evolves. Skills which help to promote and develop effective communication need to be reinforced. They are important aspects of a good science program.

Values that Underlie Science (Dimension F) and Science-Related Interests and Attitudes (Dimension G) help to develop **Personal and Social Values and Skills**. Attaining the factors in these two Dimensions of Scientific Literacy can lead to positive attitudes about science. These Dimensions involve the affective domain. Other factors, such as working cooperatively with others (C4), scientists and technologists are human (D2), and the human/culture related nature of science (A9), further help to develop Personal and Social Values and Skills.

An activity-oriented science program will develop critical and creative thinkers. Among other things, scientific inquiry involves hypothesizing (C8), designing experiments (C16), observing and describing (C3), inferring (C9), arriving at conclusions, formulating scientific laws, developing or testing theories, etc. These kinds of activities require higher level thinking.

The unit **Independent Research** in both Chemistry 20 and Chemistry 30, as well as **Consumer Chemistry** in Chemistry 20, support **Critical and Creative Thinking**. The emphasis on scientific research and on practical applications of science allows students to make meaningful connections with the real world, transferring their understanding of science to things which make their learning relevant. Problem solving activities and classroom outreach further develop the knowledge, values, skills, and processes related to Critical and Creative Thinking.

Considering controversial issues in science also leads students to develop Critical and Creative Thinking abilities when they analyze conflicting value positions. As they develop a knowledge base and begin to form their own value positions, Personal and Social Values and Skills are developed.

Independent Learning can also be developed well in Chemistry 20 and Chemistry 30 because of the emphasis being placed on variety in instructional approaches. By placing less emphasis on traditional lecture presentations, teachers transfer more of the responsibility for learning from themselves to their students. The student assumes a more active role in the classroom experience. The teacher assumes the role of the learning facilitator.

While some science content can be identified with specific Common Essential Learnings, quite often it can not. The Common Essential Learnings developed in any given lesson do not depend on content as much as they do on process. The teaching strategies selected, through careful unit and lesson planning, are what determine which Common Essential Learnings will be developed, and how well they will be developed. **The key point is that a conscientious effort to incorporate the Common Essential Learnings can make a tremendous impact on students.**

For many topics in science, any of the Common Essential Learnings can be developed. Which ones are developed, and to what extent any of the Common Essential Learnings are emphasized in a topic, depend on the goals of the new science curriculum, the foundational objectives being addressed in a particular core unit, as well as on the specific learning objectives for that topic. Just as there are many different ways to teach a lesson, so too there are many different ways of incorporating the Common Essential Learnings into that lesson. What matters is that teachers develop the Common Essential Learnings effectively, with the specific interests and needs of their students in mind. The beauty of incorporating the Common Essential Learnings into science is that, as in other subject areas, the ways in which this can be done are dynamic and flexible. The techniques used change as students' perceived needs change.

Gender Equity

Saskatchewan Education is committed to providing quality education for all students in the K-12 system. Expectations based primarily on gender limit students' ability to develop to their fullest potential. While some stereotypical views and practices have disappeared, others remain. Where schools endeavour to provide equal opportunity for male and female students, continuing efforts are required to achieve equality of benefit or outcome. It is the responsibility of schools to create an educational environment free of gender bias. This can be facilitated by increased understanding and use of gender balanced material and non-sexist teaching strategies. Both female and male students need encouragement to explore non-traditional, as well as traditional, options.

In order to meet the goal of gender equity in the K-12 system, Saskatchewan Education is committed to bringing about the reduction of gender bias that restricts the participation and choices of all students. It is important that Saskatchewan curricula reflect the variety of roles and the wide range of behaviours and attitudes available to all members of our society. The new curricula strive to provide gender-balanced content, activities, and teaching approaches. It is hoped that this will assist teachers in creating an environment free of stereotyping, enabling both females and males to share in all experiences and opportunities which develop their abilities and talents to the fullest.

Indian and Métis Curriculum Perspectives

The integration of Indian and Métis content into the Kindergarten to Grade 12 curriculum fulfils a central recommendation of *Directions*. *The Five Year Action Plan for Native Curriculum Development* further articulates the commitment and process. In addition, the *1989 Indian and Métis Education Policy from Kindergarten to Grade 12* makes the statement:

> Saskatchewan Education recognizes that the Indian and Métis peoples of the province are historically unique peoples and occupy a unique and rightful place in society today.
> Saskatchewan Education recognizes that education programs must meet the needs of Indian and Métis peoples, and that changes to existing programs are also necessary to benefit all students. (p.6)

It is recognized that, in a pluralistic society, affirmation of culture benefits everyone. Its representation in all aspects of the school environment enables children to acquire a positive group identity. Instructional resources which reflect Indian and Métis cultures similarly provide meaningful and relevant experiences for children of Indian and Métis ancestry and promote the growth of positive attitudes in all students towards Indian and Métis peoples. Awareness of one's own culture, and the cultures of others, forms the basis for positive self-concept. Understanding other cultures enhances learning and enriches society. It also promotes an appreciation of the pluralistic nature of Canadian society.

Indian and Métis students in Saskatchewan have varied cultural backgrounds and come from geographic areas encompassing northern, rural, and urban environments. Teachers must be given support that enables them to create instructional plans relevant to meeting diverse needs. Varied social, cultural, and linguistic backgrounds of Indian and Métis students imply a range of strengths and learning opportunities for teachers to draw upon. Explicit guidance, however, is needed to assist teachers in meeting the challenge by enabling them to make appropriate choices in broad areas of curriculum support. Theoretical concepts in anti-bias curricula, cross-cultural education, applied socio-linguistic, first and second language acquisition, and standard and non-standard usage of language are becoming increasingly important to classroom instruction.

Care must be taken to ensure teachers utilize a variety of teaching methods that build upon the knowledge, cultures, and learning styles students possess. All curricula need specific kinds of adaptations to classroom strategies for effective use.

The final responsibility for accurate and appropriate inclusion of Indian and Métis content in instruction rests on teachers. They have the added responsibility of evaluating resources for bias, and teaching students to recognize bias. The Science-Technology-Society-Environment emphasis of the new science curricula provides teachers with many opportunities to begin these integration and evaluation processes.

The following points summarize expectations for Indian and Métis content and perspectives in curricula, materials, and instruction:

- concentrate on positive and accurate images;
- reinforce and complement beliefs and values;
- include historical and contemporary insights;
- reflect the legal, political, social, economic and regional diversity of Indian and Métis peoples;
- affirm life experiences and provide opportunity for expression of feelings.

Instructional Approaches

The Dimensions of Scientific Literacy and the development of the Common Essential Learnings are the foundations of the K-12 Science program. In order to give students a chance to develop their understandings and abilities in these foundations, it is necessary for teachers to use a broad range of instructional approaches. *Instructional Approaches: A Framework for Professional Practice* (Saskatchewan Education, 1991) provides a framework to understand and implement a variety of approaches to teaching. The Chemistry 20/30 curriculum has been designed to support teachers in using such a broad-based approach in the classroom by providing opportunity for student-centred learning and encouragement for innovative teaching strategies and methods.

Student assessment should reflect the methods of instruction. Multiple choice questions can not fully assess students' progress when they have been involved in problem solving in cooperative learning groups. Figure 2 on page 7 outlines some of the relationships between instructional methods and assessment techniques.

More specific information about using a variety of strategies and methods in a science classroom can be found in *Teaching Science Through a Science-Technology-Society-Environment Approach: An Instruction Guide* (Aikenhead, 1988). See also the section on the Adaptive Dimension, on page 6 of this guide.

The verbs of the **Learning Objectives** listed for the core units suggest various approaches to instruction, and reiterate some of the processes of science. For example:

- analyze
- calculate
- classify
- collaborate
- create
- demonstrate
- determine
- develop
- discuss
- evaluate
- examine
- explore
- express
- identify
- investigate
- recognize
- share
- synthesize
- use
- work cooperatively

Resource-Based Learning

Resource-based teaching and learning is a means by which teachers can greatly assist the development of attitudes and abilities for independent, life-long learning. Resource-based instruction means that the teacher, teacher-librarian, and other professional staff plan units that integrate resources with classroom assignments, and teach students the processes needed to find, analyze, and present information.

Resource-based instruction is an approach to curriculum which involves students with all types of resources. Some possible resources are: books, magazines, films, audio and video tapes, computer software and databases, manipulable objects, commercial games, maps, community resources, museums, field trips, pictures and study prints, real objects and artifacts, and media production equipment.

Resource-based learning is student-centred. It offers students opportunities to choose, to explore, and to discover. Students who are encouraged to make choices, in an environment rich in resources where their thoughts and feelings are respected, are well on their way to becoming autonomous learners.

The following points will help teachers use resource-based teaching and learning.

- Discuss the objectives for the unit with students. Focus the discussion on how the students can relate the objectives to their environment, culture and other factors which are appropriate to their situation. Correlate needed research skills with the activities in the unit, so that skills are always taught in the context of application. Work with your teacher-librarian, if available.

- Plan in good time with other school staff so that adequate resources are available, and decisions are made about shared teaching responsibilities, if applicable.

- Use a variety of resources in classroom teaching, showing students that you are a researcher who constantly seeks out sources of knowledge. Discuss with them the use of other libraries, government departments, museums, and various outside agencies in their research.

- Ask the teacher-librarian (if available) to provide resource lists and bibliographies when needed.

- Participate in, and help plan, inservice programs on using resources effectively.

- Continually request good curriculum materials for addition to the library collection.

- Support the essential role of the library resource centre and the teacher-librarian in your talks with colleagues, principals, and directors.

More information on resource-based learning may be found in *Science Program Overview and Connections K-12.*

Assessment and Evaluation

Why Consider Assessment and Evaluation?

Much research in education around the world is currently focusing on assessment and evaluation. It has become clear, as more and more research findings accumulate, that a broader range of attributes need to be assessed and evaluated than has been considered in the past. A wide variety of ways of doing this are suggested. Assessment and evaluation are best addressed from the viewpoint of selecting what appears most valid in meeting prescribed needs.

In *Student Evaluation: A Teacher Handbook* (Saskatchewan Education, 1991) the difference between the various forms of evaluation is explained. Student evaluation focuses on the collection and interpretation of data which would indicate student progress. This, in combination with teacher self-evaluation and program evaluation, provides a full evaluation.

Phases of the Evaluation Process

Evaluation can be viewed as a cyclical process including four phases: preparation, assessment, evaluation, and reflection. The evaluation process involves the teacher as a decision maker throughout all four phases.

- In the **preparation** phase, decisions are made which identify what is to be evaluated, the type of evaluation (formative, summative, or diagnostic) to be used, the criteria against which student learning outcomes will be judged, and the most appropriate assessment strategies with which to gather information on student progress. The teacher's decisions in this phase form the basis for the remaining phases.

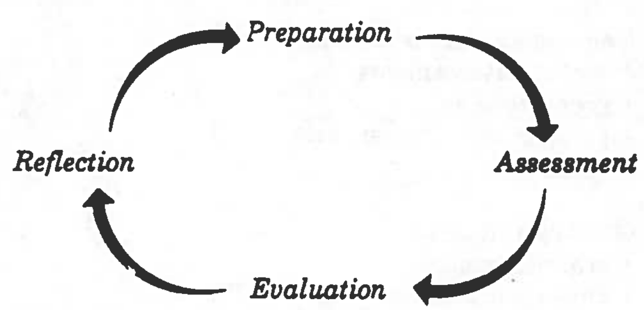
- During the **assessment** phase, the teacher identifies information-gathering strategies, constructs or selects instruments, administers them to the student, and collects the information on student learning progress. The teacher continues to make decisions in this phase. The identification and elimination of bias (such as gender and culture bias) from the assessment strategies and instruments, and the determination of where, when, and how assessments will be conducted are examples of important considerations for the teacher.

- During the **evaluation** phase, the teacher interprets the assessment information and makes judgements about student progress. Based on the judgements or evaluations, teachers make decisions about student learning programs and report on progress to students, parents, and appropriate school personnel.

- The **reflection** phase allows the teacher to consider the extent to which the previous phases in the evaluation process have been successful. Specifically, the teacher evaluates the utility and appropriateness of the assessment strategies used, and such reflection assists the teacher in making decisions concerning improvements or modifications to subsequent teaching and evaluation. *Science Program Overview and Connections K-12* contains questions which encourage teachers to reflect on student assessment, their own planning, and on the structure of the curriculum.

All four phases are included in formative, diagnostic, and summative evaluation processes. They are represented in Figure 3.

Figure 3 Process of Student Evaluation



Assessing Student Progress

Specific assessment techniques are selected in order to collect information about how well students are achieving objectives. The assessment technique used at any particular time depends on what facility with the knowledge, skills or processes the teacher wants the students to demonstrate. The appropriateness of the techniques therefore rests on the content, the instructional strategies used, the level of the development of the students, and what is to be assessed. The environment and culture of the students must also be considered.

Various assessment techniques are listed below. The techniques listed are meant to serve only for reference, since the teacher exercises professional judgement in determining which techniques suit the particular purposes of the assessment. For further information on the various assessment strategies and types of instruments that can be used to collect and record information about student learning, refer to the *Student Evaluation: A Teacher Handbook* (Saskatchewan Education, 1992). Refer also to Figure 2 on page 7.

A Reference List of Specific Student Evaluation Techniques

Methods of organization
- assessment stations
- individual evaluations
- group evaluations
- contracts
- self- and peer-assessments
- portfolios

Methods of data recording
- anecdotal records
- observation checklists
- rating scales

Ongoing student activities
- written assignments
- presentations
- performance assessments
- homework

Quizzes and tests
- oral assessment
- performance tests
- extended open response
- short answer items
- matching items
- multiple choice items
- true/false items

Student Assessment in Chemistry

At the start of any class, a teacher has a group of new students. The students are new, even if they know each other or the teacher, because they will be dealing with different material, from a different point of view, within an evolving system of interactions. The factors of scientific literacy and the learning objectives for the curriculum are the criteria for guiding student assessment. These may be attainable by the majority of students, but for some they will be outside their capabilities. Adaptations to expectations or methods will be required. The Adaptive Dimension recognizes that the needs of all students must be considered for effective teaching and learning to occur. The Adaptive Dimension is equally important in determining what is appropriate assessment.

"Graded" teaching resources and standardized tests are based on what is accepted as normal or average for a student of that age group and often for a specific segment of society. By using standardized tests a teacher is assessing how a student matches these culturally determined standards over a narrow range of skills. The results must be considered in that context. This measure may be unattainable by some students. Alternatively, some students may not reach full potential because they are not challenged but are allowed to remain at the acceptable "average". A range of assessment techniques is necessary to appropriately assess the range of students in any classroom.

Students deserve to be assessed on the range of abilities they have been, and are capable of, using. The overall assessment plan should reflect the students' different learning styles, and different ways of displaying their learning and the nature of the abilities being assessed. Self-referenced assessment is encouraged.

Assessment can be based on oral or written response or observations of performance. Ideally, it will be a combination of these. Performance tasks are an excellent way to assess scientific and technical knowledge and skills (Dimension E). For example, reading a thermometer diagram is not the same as knowing how best to use and place the thermometer in order to measure temperature. The best way to assess whether students can perform an activity is to observe them while they are actually performing the activity. Ask them probing questions. The use of anecdotal records, observation checklists, and rating scales can assist in data collection when these observations have taken place.

An example of a performance task would be to give an individual or group a card with the following instructions:

> Determine the mass of 0.120 mols of $NaCl_{(S)}$. Measure out that mass of the solid and submit it to me in a sealed envelope. On the envelope, indicate how you determined what mass of $NaCl_{(S)}$ to measure.

Such a task gives an opportunity to observe ability to calculate, knowledge and skill in using the balance, and chemical handling techniques. The task may be administered at any time during any class. Other tasks may involve using burets, pipets and graduated cylinders to measure, transfer or dilute solutions.

10% of the final grade should be based on performance tasks carried out either as separate activities or in conjunction with laboratory investigations.

The types of tasks and questions which students are expected to address influence their responses. When the tasks and questions are limited, so are the responses. Tasks and questions which elicit only one word or simple sentence answers often test recall of factual knowledge. As well, once students have, for example, formulated a model in a particular context during a science activity, if that same context is given in the assessment the response may be recall, and not a test of any conceptual or process ability. This is only one facet of intellectual development. Assessment of higher order skills (analysis, synthesis, evaluation) requires novel conditions or situations to consider with respect to factual knowledge possessed. The learning objectives and the factors of scientific literacy in Dimensions A through E can be assessed through both recall and manipulation of factual knowledge.

Good questioning is extremely important for effective teaching and testing. Avoid questions where there is only a single response. Structure questions so some type of reasoning is required. How? Why? Explain . . . Present problem solving activities. Develop Critical and Creative Thinking. All of these things promote and challenge higher level thinking.

Students may be asked to interpret a graph or photograph, or to answer a question orally. Assessment does not have to consist totally of written work. Varied formats adapt to students' differing learning styles.

Summative assessment items following the completion of a unit can cover more scope and depth than formative assessment items. Apart from the scope and depth of the activities selected, the format of summative assignments can be just as varied, including practical tasks (to reflect practical knowledge and abilities), interpretation of graphs and photographs, and investigative problems and assignments.

Multiple choice, true or false, or fill-in-the-blank tests usually assess factual recall. Such tests should be used when appropriate and not as the sole means of assessment.

Essay questions are useful. They can promote the processes of science and can be used in both formative and summative assessment. For those students who have difficulty writing, discuss alternatives for the assignment. Illustrations or art projects, an oral report, a concept map, a project, or journal writing may serve as significant supplements to the written essay.

Projects are useful items in summative assessment, because they can cover the breadth and depth of a topic. They also involve the use of process abilities. If the project is a group effort, difficulties might arise in assessing the individual participation of each member or the group. Individual contributions and participation can often be determined by observing the ways in which the group members interact with one another and with other members of the class. Student self-assessment and group self-assessment to weigh the various contributions of group members can also be utilized.

The number and type of assignments completed in a learning centre can be recorded as a summative assessment. Test stations are particularly useful for allowing students to demonstrate competence.

Assessing values is the most difficult of all the areas of assessment and evaluation. At one time, values were not considered a part of the school's written curriculum. Parents and society certainly required that students develop acceptable behaviours and attitudes, but these were promoted through the "hidden curriculum" – the teachers' and school's influences. Now, specific attitudes and values are to be openly promoted in students, so the teacher's influence must be directed to these objectives. Accordingly, they must be assessed. For further information on values review Chapter VI in *Understanding the Common Essential Learnings: A Handbook for Teachers* (Saskatchewan Education, 1988).

Remember that the values listed in Dimensions F and G of the Dimensions of Scientific Literacy, like understanding of any of the factors, develop over time. Emphasizing these same values throughout the grades can provide the reinforcement to help students to incorporate the values into their lives. There are valid reasons to cultivate and assess students' values and attitudes specified in Dimensions F and G.

Through the school years, students display their current values and attitudes by what they say, write, and do. These three actions can be used for assessment purposes. When a value or attitude is observed, record the observation. When setting an evaluation plan for the year, consider using an organizer such as Figure 4 on this page to give the plan a broad base in direction and techniques. The figure suggests a philosophical framework for ensuring that all Dimensions of Scientific Literacy (DSLs) are considered during assessment and evaluation. For specific unit planning based on the concepts promoted in the figure, use the Instruction Plan on page 29 of *Student Evaluation: A Teacher Handbook* (1991). The *Handbook* provides advice on how to use the plan. It **reinforces the principle that planning for assessment goes hand in hand with planning for instructional strategies and methods.** Recall Figure 2 on page 7.

Figure 4: Including Dimensions of Scientific Literacy in Planning for Assessment

	Possible evaluation techniques (abbreviation key below)												
DSLs	% wt.	ar	co	lr	oc	or	pa	pf	pr	pt	rs	sa	wt
A. nature of science	5-15		x	x		x			x	x	x	x	x
B. key concepts	25-40	x	x	x		x		x	x	x		x	x
C. processes	15-30	x	x	x	x			x	x		x	x	x
D. STSE	5-15					x	x	x	x		x	x	x
E. skills	5-15	x			x		x		x	x	x		
F. values	5-10	x			x	x	x	x		x	x	x	x
G. attitudes	5-10	x			x	x	x	x		x	x		x

Key to abbreviations of evaluation techniques:

ar anecdotal record
co contract
lr laboratory report
oc observation checklist
or oral response
pa peer assessment
pf portfolio
pr project or written report
pt performance test
rs rating scale
sa self assessment
wt written test

An 'x' in a cell indicates a stechnique that might be appropriate for assessing that Dimension of Scientific Literacy. The placement of an x in a cell is not definitive. You may not be able to use that technique to assess factors from the Dimension indicated. You may find that a blank cell indicates an opportunity which is appropriate for use in your class room. The terms for evaluation strategies are taken from *Student Evaluation: A Teacher Handbook*. Assistance in designing an evaluation plan that uses these techniques can be found in that document.

Summary of % weight by domains:

- Cognitive knowledge (Dim. A, B, D, F) ~60%
- Cognitive process/skill (Dim. C, E) ~30%
- Affective (Dim. F, G) ~10%

In order to help maintain a balance among the various techniques of evaluation and emphases of instruction, Saskatchewan Education recommends that all comprehensive or final exams in Chemistry 20 and 30 be open book exams. Open book is defined as allowing students to bring texts, laboratory manuals, and notebooks to use during the exam. The use of calculators during classes and exams is encouraged. Chemistry 30 final examinations prepared and administered by Saskatchewan Education will continue to be open book exams.

Record-Keeping

To aid data collection in order for the factors of scientific literacy to be addressed in student assessment, checklists have been included in the *Science Program Overview and Connections K-12* and in this guide. Teachers should adapt these to suit their needs.

Teachers differ in the way they like to collect data. Some prefer to have a single checklist, naming all the students in the class (or in one work group) across the top and listing the criteria to be assessed down the side. The students' columns are then marked if a criterion is met. In this case some information would have to be transferred later to a student's individual profile.

Other teachers prefer to have one assessment sheet per student, which is kept in the profile. That sheet would list the factors for assessment down the side, but along the top might be a series of dates indicating when assessment took place. Such an individual file would illustrate development over the year. In this case, information might have to be transferred from the profile to the official class mark book, as required.

Examples of these types of assessment sheets are also given in *Science Program Overview and Connections K-12*.

Program Evaluation

Program evaluation is a systematic process of gathering and analyzing information about some aspect of a school program in order to make a decision, or to communicate to others involved in the decision-making process. Program evaluation can be conducted at two levels: relatively informally at the classroom level, or more formally at the classroom, school, or school division levels.

At the classroom level, program evaluation is used to determine whether the program being presented to the students is meeting both their needs and the objectives prescribed by the province. Program evaluation is not necessarily conducted at the end of the program, but is an ongoing process. For example, if particular lessons appear to be poorly received by students, or if they do not seem to demonstrate the intended learnings from a unit of study, the problem should be investigated and changes made. By evaluating their programs at the classroom level, teachers become reflective practitioners. The information gathered through program evaluation can assist teachers in program planning and in making decisions for improvement. Most program evaluations at the classroom level are relatively informal, but they should be done systematically. Such evaluations should include identification of the areas of concern, collection and analysis of information, and judgement or decision making.

Formal program evaluation projects use a step-by-step problem-solving approach to identify the purpose of the evaluation, draft a proposal, collect and analyze information, and report the evaluation results. The initiative to conduct a formal program evaluation may originate from an individual teacher, a group of teachers, the principal, a staff committee, an entire staff, or central office. Evaluations are usually done by a team, so that a variety of background knowledge, experience, and skills are available and the work can be shared. Formal program evaluations should be undertaken regularly to ensure programs are current.

To support formal school-based program evaluation activities, Saskatchewan Education has developed the *Saskatchewan School-Based Program Evaluation Resource Book* (1989) to be used in conjunction with an inservice package. Further information on these support services is available from the Evaluation and Student Services Division, Saskatchewan Education.

Curriculum Evaluation

During the decade of the 1990's, new curricula will be developed and implemented in Saskatchewan. Consequently, there will be a need to know whether these new curricula are being effectively implemented and whether they are meeting the needs of students. Curriculum evaluation, at the provincial level, involves making judgements about the effectiveness of provincially authorized curricula.

Curriculum evaluation involves the gathering of information (the assessment phase) and the making of judgements or decisions based on the information collected (the evaluation phase), to determine how well the curriculum is performing. The principal reason for curriculum evaluation is to plan improvements to the curriculum. Such improvements might involve changes to the curriculum document and/or the provision of resources or inservice to teachers. It is intended that curriculum evaluation be a shared, collaborative effort involving all of the major education partners in the province. Although Saskatchewan Education is responsible for conducting curriculum evaluations, various agencies and educational groups will be involved. For instance, contractors may be hired to design assessment instruments; teachers will be involved in instrument development, validation, field testing, scoring, and data interpretation; and the cooperation of school divisions and school boards will be necessary for the successful operation of the program.

In the assessment phase, information will be gathered from students, teachers, and administrators. The information obtained from educators will indicate the degree to which the curriculum is being implemented, the strengths and weaknesses of the curriculum, and the problems encountered in teaching it. The information from students will indicate how well they are achieving the intended objectives and will provide indications about their attitudes toward the curriculum. Student information will be gathered through the use of a variety of strategies including paper-and-pencil tests (objective and open-response), performance (hands on) tests, interviews, surveys, and observation.

As part of the evaluation phase, assessment information will be interpreted by representatives of all major education partners including the Curriculum and Evaluation Divisions of Saskatchewan Education and classroom teachers. The information collected during the assessment phase will be examined, and recommendations, generated by an interpretation panel, will address areas in which improvements can be made. These recommendations will be forwarded to the appropriate groups such as the Curriculum and Instruction Division, school divisions and schools, universities, and educational organizations in the province.

All provincial curricula will be included within the scope of curriculum evaluation. Evaluations will be conducted during the implementation phase for new curricula, and regularly on a rotating basis thereafter. Curriculum evaluation is described in greater detail in the document *Curriculum Evaluation in Saskatchewan* (Saskatchewan Education, 1991).

Program Organization

Facilities

Adequate facilities and materials, by themselves, do not create a safe chemistry class. But they contribute greatly to the ability of a teacher to deliver an activity-based course. Proper use of the facilities and materials is also critical.

Since the use of a wide range of instructional methods in Chemistry 20/30 is desirable, more flexible teaching areas are useful. This might be a well designed laboratory which can be reconfigured to accommodate small group discussions, small group and large group laboratory activities, lectures, research work or other activities. Or, it may be a combination of two or more existing rooms.

Some features of a good science laboratory/facility are:

- two exits, remote from each other
- master shut-off controls for the water, natural gas, and electrical systems. These should be easily accessible and easy to operate
- a spacious activity area where students can work without being crowded or jostled
- safety equipment which is visible and accessible to all
- a ventilation system which maintains negative pressure in the lab
- enough electrical outlets to make the use of extension cords unnecessary. The plugs should be on a ground fault interruptor system or individually protected
- emergency lighting
- separate, locked storage rooms and preparation rooms to which students' access is restricted with approved storage areas for all classes of chemicals in the school. See the recommendations on page 76 of *Science Safety Manual*.
- adequate shelving so that materials do not have to be stacked, unless it is appropriate to store them that way
- an audiovisual storage area for charts, video and audio tapes, slides, and journals
- a storage area for student assignments

Safety

The Workplace Hazardous Materials Information System (WHMIS) regulations under the **Hazardous Products Act** govern storage and handling practices of chemicals in school laboratories. All school divisions should be complying with the provisions of the Act. Under WHMIS regulations, all employees involved in handling hazardous substances must receive training by their employer. If you have not been informed about or trained in this program, contact your director immediately. For more information, contact the Canadian Centre for Occupational Health and Safety, or Saskatchewan Human Resources, Labour and Employment.

Safety can not be mandated by rule of law, or by teacher command or by school regulation. **Safe practice in the laboratory is the joint responsibility of the teacher and student.** The teacher's responsibility is to provide a safe environment and to make the students aware of safe practice. The student's responsibility is to act intelligently based on the advice which is given and which is available.

Each school should have a copy of *Science Safety Manual*. Refer to *Science: A Bibliography for the Secondary Level — Biology, Chemistry, Physics* for information about ordering that resource and those listed below.

Other sources of information about safety in the chemistry classroom are:

Safety in the Secondary Science Classroom. (1978). National Science Teachers Association, 1742 Connecticut Avenue North West, Washington, D.C. 20009.

Prudent Practices for Handling Hazardous Chemicals in Laboratories. (1981). Washington, DC: National Academy Press.

A Guide to Laboratory Safety and Chemical Management in School Science Study Activities. (1987). Saskatchewan Environment and Public Safety, Regina. (A copy was sent to all schools in 1987.)

Hazardous Waste

The following are some general rules to help determine if the chemical waste being produced in your lab is hazardous. They are taken from an uncopyrighted newsletter distributed by the Chemical Health and Safety Committee of the Chemical Society of Washington, DC. Hazardous materials include:

- any solvent or solvent solution with a flashpoint of 60°C or less
- halogenated solvents (e.g. chloroform, hexachlorophene)
- oxidizers
- liquid with a pH of <2 or >12.5
- compounds containing sulfides or cyanides
- pesticides
- compounds or solutions containing heavy metals or heavy metal ions such as lead, chromium, cadmium, mercury and silver
- highly toxic chemicals (e.g. formaldehyde, colchicine)

A good rule is "When in doubt, don't throw it out!" If you have hazardous waste, store it in a secure place and get advice on what to do with it.

Disposing of Chemicals

A Guide to Laboratory Safety and Chemical Management in School Science Study Activities (Saskatchewan Environment, 1987) groups chemicals by disposal category. References to disposal categories in the following paragraphs are taken from that guide. See the *Bibliography* for ordering information.

- Chemicals in disposal categories 3 to 16 can be treated as hazardous waste unless they are chemically altered to fit into categories 1 or 2.
- The disposal of liquid or aqueous wastes containing substances from categories 1 and 2 should involve dilution before pouring them down the drain, then running tap water down the drain to further dilute their strength.
- Solid wastes from disposal categories 1 and 2 should be rinsed thoroughly with water. Then they should be disposed of in a specially marked waste container – not the general class waste basket. The janitor should be alerted to the existence of this container and be assured that none of the materials are hazardous.
- Wastes containing materials from disposal categories 3-16 should be stored securely on site until arrangements are made for appropriate disposal. Set aside some space which is used only for storage of waste chemicals.
- **Using microscale activities can greatly diminish the amount of chemicals which need disposal.**
- Caution should be exercised when disposing of chemicals.

Spill Mix (for most types of spills)

Note: For mercury spills use commercial kits. Any use of mercury or compounds which contain mercury should be discontinued.

- 1 part soda ash (anhydrous Na_2CO_3)
- 1 part clay cat litter
- 1 part dry sand

Mix equal volumes of each of these components thoroughly. Store it in plastic pails which have lids that seal. Ice cream pails or large white plastic lard or shortening pails are possibilities. Scoop or pour onto spill and allow to sit for a short time. Store the used mix in a sealed container. Dispose of the used mix in a manner that is appropriate to the type of chemical spilled. If the mix was used on an inorganic acid, it may be disposed of in an ordinary landfill. If it was used on an organic solvent, it should be disposed of in the same way the pure solvent would be.

Laboratory Practice

Safety in the classroom is of paramount importance. Other components of education – resources, teaching strategies, facilities – attain their maximum utility only in a safe classroom. Safety is no longer simply a matter of common sense. **To create a safe classroom requires that a teacher be informed, be aware, and be proactive and that the students listen, think and respond appropriately.**

Safety sessions are often offered at science teachers' conventions. Many articles in science teachers' journals provide helpful hints on safety. Professional exchange may provide teachers with an outside viewpoint on safety.

Encourage students to become aware that they must accept a large measure of the responsibility for their own safety. They can only do this if they are properly educated about what is safe. Once this education has begun, encourage the students to think about their actions. Such encouragement may take the form of safety-related questions on exams, preparing an outline of safety precautions

in a laboratory activity as part of the prelab preparation for the activity, using a safety contract signed by the student, parent(s) and teacher, and the modelling of safe practice in the laboratory. A sample safety contract is found on page 171 of the *Science Safety Manual.*

Awareness is not something that can be learned as much as it is developed through a visible safety emphasis: safety equipment such as a fire extinguisher, a fire blanket, and an eye wash station prominently displayed; safety posters on the wall; a "safety class" with students at the start of the year; and regular emphasis on safety precautions while preparing students for activities.

Proaction is accomplished by acting on what is known and on what one is aware of. **Six basic principles guide the creation and maintenance of a safe classroom.**

- Model safe procedures at all times.
- Instruct students about safe procedures at every opportunity. Stress that they should remember to use safe procedures when experimenting at home.
- Close supervision of students at all times during activities, along with good organization, can avert situations where accidents and incidents can occur. Inappropriate behaviours in a classroom, and more particularly in a laboratory, can result in physical danger to all present and destroy the learning atmosphere for the class.
- Be aware of any health or allergy problems that students may have.
- Display commercial, teacher-made, or student-made safety posters.
- Take a first aid course. If an injury is beyond your level of competence to treat, wait until medical help arrives.

James A. Kaufman, a chemistry professor at Curry College in Milton, MA and editor of the newsletter *Speaking of Safety*, lists three important principles for laboratory health and safety:

- **Be Aware.** Know the hazards before you do the experiment.
- **Be Prepared.** Answer the questions:
  -What are the worst things that can go wrong?
  -What must I do to be ready for these things?
- **Be Protected.** Make health and safety an integral part of your activity.

From the newsletter of the Chemical Health and Safety Committee of the Chemical Society of Washington, DC come some examples of safety-related errors of omission and commission discovered during a survey and inspection of high school laboratories in the Washington area. The terminology has been adapted for Canadian situation.

- eye or face protection not continuously worn where circumstances dictate it should be
- eye or face protection which does not meet CSA standards
- loose clothing, long unrestricted hair or dangling jewellery worn
- labels and Material Safety Data Sheets (MSDS) not in accordance with WHMIS regulations
- storage of chemicals not conforming to WHMIS standards
- poor housekeeping with cluttered table tops and glassware in sinks

From the *Speaking of Safety* newsletter are some ideas for making your classroom a safer place.

- One teacher carries a double copy sales slip pad in her lab coat. When she sees a student violating a safety rule, she gives that student a citation. The citations count as points against the student's 'lab license'. When a particular level of points have been accumulated the student loses the right to be in the lab. (The points accumulated could also be tied to the lab mark — inversely related of course!)
- A high school teacher has every student once in a term do a critique of another student's work. (The criteria for the critique could be given to the students, or the class as a whole could develop the criteria. The critique may focus only on safety or it may cover other aspects of work.)
- Another teacher offers a bonus point to everyone

- Another teacher offers a bonus point to everyone in the class if no one needs to be reminded to wear safety goggles. If one person needs reminding, no one gets the bonus point.

To compile a complete list of safety tips is impossible. To compile a comprehensive list would be to duplicate the materials which have been referenced previously. What follows is a 'highlights' list. **This list does not diminish the responsibility of each teacher to be functioning at the highest level with respect to creating a safe classroom climate.**

- Check your classroom for hazards on a regular basis.
- Create a bulletin board display with a safety theme.
- Make a rule that all accidents must be reported to the teacher.
- In case of a serious accident, pick one person who is present and send that person for expert, professional, or additional help. Then, take action. Remember, you are in charge of the situation.
- Become familiar with the school division's accident policy.
- Do not give medical advice.
- Move an injured person as little as possible until the injury assessment is complete.
- Emphasize that extra caution is needed when using open flames in the classroom.
- Require the use of goggles when using open flames, corrosive chemicals or other identifiable hazards.
- In case of fire, your first responsibility is to get students out of the area. Send **a specific person** to give an appropriate alarm. Then assess the situation and act.
- Avoid overloading shelves and window sills.
- Properly label, according to WHMIS standards, all containers of solids, liquids, and solutions.
- Separate broken glass from other waste.
- Advise students not to touch, taste, or smell chemicals unless instructed to do so.
- Each laboratory should have one first aid kit which is not accessible to students, but is only for the teacher's or administrator's use.
- Master shut-off controls for gas, electricity, and water should be tested periodically to ensure that they are operable.
- Safety equipment such as fire extinguishers, fire blankets, eye wash stations, goggles, fume hoods, test tube spurt caps, and explosion shields must be kept in good order and checked regularly.
- Electrical cords must be kept in good condition, and removed from outlets by grasping the plug.
- Students should use safety equipment — protective eye wear, protective aprons or coats, fume hoods, etc. — whenever practical and necessary.
- Students should tie back long hair and refrain from wearing loose and floppy clothing in the laboratory.
- Students should not taste any materials, eat, drink, or chew gum in a laboratory.
- Students should follow recommended procedures and check with teachers before deviating from such procedures.
- Students should be required to return laboratory equipment to its proper place.
- Chemicals or solutions should never be returned to stock bottles.
- Pipetting should be done only with a safety bulb, never by mouth.
- If, for any reason, substitutions are made for chemicals in activities, it is the responsibility of the teacher to research the toxicity and potential hazards of these substituted materials.
- Be aware that mixing acids or oxidizers with compounds containing chlorine (e.g., bleach) can generate chlorine gas.
- Mercury thermometers should be replaced with alcohol thermometers.
- Asbestos centred wire mats should be replaced with plain wire mats or with ceramic centred mats.
- Chemicals should be stored in a locked area, to which access is restricted.
- Be prepared to handle all chemical spills rapidly and effectively.
- Inspect glassware (e.g., beakers, flasks) for cracks and chips before using them to heat liquids or hold concentrated corrosive liquids or solutions.
- Chemical storage should be organized by groups of compatible compounds, rather than by alphabetical order. (Within a group of compatible compounds, alphabetizing can be used.)
- Electrical equipment (e.g., transformers, induction coils, electrostatic generators, oscilloscopes, discharge tubes, Crookes tubes, magnetic effects tubes, lasers, fluorescent effects tubes and ultraviolet light sources) must be kept in locked storage.
- Discharge tubes can produce x-rays which may penetrate the glass of the tube if operating voltages higher than 10 000 volts are used.
- Lasers are capable of causing eye damage. The lens of the eye may increase the intensity of light by 1 000 000 times at the retina compared to the pupil. To reduce risk, lasers rated at a maximum power of 0.5 mW should be used.

- Lasers should be used in normal light conditions so pupils are not dilated.
- Everyone should stay clear of the primary and reflected paths.
- Everyone should be alert to unintended reflections.

Contact Lenses

Contact lenses complicate eye safety. Dust and chemicals may become trapped behind a lens. Gases and vapours may cause excessive watering of the eyes and enter the soft material of the lens. Chemical splashes may be more injurious due to the inability to remove the lens rapidly and administer first aid. The loss or dislodging of a contact lens may cause a safety problem if it happens at a crucial moment.

On the other hand, contacts, in combination with safety eye wear, are as safe as eyeglasses in most cases. Contacts may prevent some irritants from reaching the cornea, thus giving the eye some measure of protection. The Saskatchewan Association of Optometrists feels that, as long as proper, vented safety goggles are worn, there is no greater risk in a lab situation for a person wearing contacts than for one not wearing contacts. The Association recommends that:

- teachers know which students wear contact lenses
- teachers know how to remove contact lenses from students' eyes should the need occur
- there be access to adequate areas for the removal and maintenance of contact lenses
- contact lens wearers have a pair of eye glasses to use in case the contact lenses must be removed.

A Broader Look at Safety

Normally, safety is understood to be concerned with the physical safety and welfare of persons, and to a lesser degree with personal property. The definition of safety can also be extended to a consideration of the well-being of the biosphere. The components of the biosphere — plants, animals, earth, air and water — deserve the care and concern which we can offer. From knowing what wild flowers can be picked to considering the disposal of toxic wastes from chemistry laboratories, the safety of our world and our future depends on our actions and teaching in science classes.

Measurement

An understanding of the importance of measurement in science is critical for each student to acquire. The importance of measurement can be seen when it is viewed as one component of the Common Essential Learning of Numeracy. There is an implicit assumption in science, and in society, that quantitative statements are more authoritative than are qualitative statements. Yet, many important advances in science are made through intuition and through creative leaps. Advances in science are not restricted to data analysis. Students must see that measurement is important, but important in its context.

To make quantitative statements, measurements must be made. The accuracy of the measurements determines the confidence placed in the facts which are derived from the measurements. If the facts are represented as being accurate, the measurements must be equally accurate. But accuracy is not the only factor to consider when measurement is discussed.

The ability to make measurements depends on the technology available. A metre stick can be used to measure the length of a table. What technology is available to measure the diameter of an atom? Such measurements require a greater degree of faith in the technology. At the furthest reaches of scientific inquiry, technology must be devised so that the results of exotic experiments can be detected, measured, and interpreted. What is measured depends upon the assumptions made in the design, and on the limitations of the technology.

The ability to make measurements depends on the correct use of the technology. Proper procedures must be followed, even with the use of simple devices such as thermometers, if measurements which accurately represent the system under observation are to be made. In addition to proper procedures, the measurement devices must be used appropriately. Even though a thermometer has a ruled scale, to measure the length of a pencil in degrees Celsius is not a useful way to represent length.

There must be as little interaction as possible between the technology, or application of it, and the object being measured. If the device used to measure the temperature of a system changes the temperature of that system by a significant amount, how useful is the measurement?

Heisenberg faced a similar problem in attempting to determine the momentum and the position of the electron in the atom. Precision in determining one results in less information about the other.

Before the matter of accuracy is addressed, the student must have an understanding of what technology is available, its appropriateness for the situation, the proper use of that technology, and the limits which are inherent in the technology. Once that is understood, the student can then manipulate the technology to give the most accurate and precise results.

One aspect of accuracy pertains to the matter of uncertainty in measurement. The percentage error in a measurement, or the absolute error, is a concept which students must deal with. No measuring instrument has zero margin of error. No operator is capable of using an instrument so that no measurement error is introduced. Measurement error exists and must be accounted for in recording and interpreting data. A particular balance may have an uncertainty of measurement of 0.01 g, for example, if the balance is levelled, properly adjusted, and working well. This balance has a suitable accuracy for measuring a mass of 142.87 g but not for measuring a mass of 0.03 g. Calculate the percentage error in each case and the point is clear. However, the 0.007% measuring error for the 142.87 g mass which is due to the balance may be made entirely insignificant by operator errors such as having the balance pan on the wrong hook, misreading the scale, not zeroing the balance before starting, stopping the oscillation of the beam with a finger, using a wet or dirty pan, and so on. Accuracy requires both good technology and good technique.

Another concern is that of significant figures. Measuring instruments can only supply a limited degree of accuracy. The problem most often encountered with students is to have them make use of the maximum precision possible, without having them overstate their case. If seven identical marbles have a total mass of 4.23 g, the average mass of a marble is not 0.604 285 714 g. A more reasonable report would express the average mass rounded off to two decimal places.

Many texts have sections dealing with the reporting of uncertainty in measurement and significant figures. Each teacher of chemistry should find an approach that is comfortable for both the teacher and the students and then adopt and emphasize that approach.

Data analysis is an important related topic. Often, in order to make sense of measurements, data must be organized and interpreted. Students must learn to organize their data collection and recording so that it is ready for analysis. Graphical analysis is often useful and should be stressed. The use of computer software is also an option for recording and analysis. Databases can be used to store and then manipulate large amounts of data. Spreadsheets are also useful for organizing data. Many database and spreadsheet programs, as well as integrated software packages, contain graphing utilities and may contain statistical analysis options. Graphing and statistical analysis packages may also be purchased as stand-alone software. The use of computer analysis should be encouraged wherever possible.

In addition to the use of computer analysis, hardware interfaces to allow the input of data through sensors, which the software then interprets as measurements, are a valuable addition to a science lab. It should be emphasized that the use of a computer does not mean that the results will be error free. Accuracy is mainly a function of the technician and, to a lesser degree, of the technology.

Measurements should be expressed using SI units, or SI acceptable units, whenever this is realistic or feasible to do so. Common non-metric units may be used if necessary. Conversion factors from non-SI to SI or within the non-SI units may be necessary. Each teacher should follow the recommendations of the Canadian Metric Commission with respect to the basic and derived units of measurement and the proper symbols for those units.

If detailed information is required, refer to the *Canadian Metric Practice Guide* (CAN3-Z234.1-79 from the Canadian Standards Association, 178 Rexdale Boulevard, Rexdale, Ontario M9W 1R3), the *International System of Units (SI)* (CAN3-Z234.2-76 from the CSA) or the *SI Metric Guide for Science* (Saskatchewan Education, 1978).

Scientific notation should be used so that students become familiar with reading, manipulating, and writing numbers in that format. In addition to the value of SI-notation for ease in handling very large or very small numbers, students must be able to use this notation to express the number of significant figures in a large number, and to perform calculations using scientific notation.

Organizing a Field Trip

Field trips can and should be valuable learning experiences which allow students to apply their classroom learnings to an actual or "real" situation. Field trips also allow students the opportunity to learn directly rather than indirectly. Learning is enhanced through direct experience. Field trips are fun for everyone involved! Use *Out to Learn.*

The key to successful field trip experiences is careful and thorough planning. This planning takes time and patience. Make sure to check to see if the school division has any special policies regarding field trips.

The simplest approach when planning a field trip is to treat the experience like the writing of a newspaper article, using the five Ws.

Why do you want to take your class on this particular trip?
- Is this mainly a science activity or does it integrate activities in other subjects as well?
- Are the planned activities valid learning experiences?

What learnings do you expect your students to gain from and apply to this experience?
- Have objectives for the field trip been established?
- Have appropriate activities and instructional approaches been selected?
- Have you and your students done your background research?
- Are expectations about student behaviour on the trip clear and realistic?

Where do you plan on going with your class?
- Is it accessible to all students?
- Is permission of landowners or officials required in order to visit this site?
- Does the site have facilities such as bathrooms, lunch areas, shelters, appropriate emergency facilities, etc.?
- Is it possible for you to visit the site beforehand?
- Are locations established at which various activities will occur?

When do you plan on taking this field trip?
- Is there adequate time to plan the trip?
- Will relevant information be provided to students **before** the field trip?
- Is there adequate time **after** the field trip to do a wrap-up?
- Are there any potential conflicts with the selected date?
- Does the selected date indicate the need for special clothing or supplies?
- Is there a contingency plan in case of bad weather?
- Has parental consent been obtained?

How are you going to get to the site?
- Will transportation be required?
- Is appropriate transportation available and affordable?
- Can the students be learning during the trip to the site?

How long will this particular trip be?
- Can time be used efficiently and effectively?
- Is there too much to do and too little time?
- How does the field trip affect the rest of the school?
- Will someone else have to do additional supervision duties?
- Will others have to change their planned activities?
- Will a substitute teacher be required?

Who is coming with you on the field trip?
- Are there sufficient supervisors for the number of students involved?
- Have the people in your community been utilized for their expertise?
- Has the class been divided into working groups?
- Have leaders responsible for coordinating the groups' activities been selected for the working groups?

Although this may seem like a great deal of work, planning should be done **before** embarking on a field trip. The more concrete and detailed the planning is, the more likely it is that the trip will be a success.

Once the groundwork has been set and administrative approval has been obtained, approach the parents and the students about the trip. It is advisable to send a letter home to the parents which details the proposed field trip. Include information on such things as the times of departure and return, the location of the field trip, the people responsible for supervision, clothing requirements, lunch plans, required materials, anticipated costs, and contingency plans. This letter could also include a request for parental help and a separate permission slip to be returned to the teacher. It is a good idea to have the letter signed by both the teacher and the principal before sending it to parents.

The parental consent form which follows serves as an example of one that could be used. Note that the use of a consent form does not remove the teacher or the school division from the possibility of incurring liability during the trip.

Sample Permission Form for Field Trips

Date:

Dear Parent/Guardian:

As a part of the chemistry program, we will be going on a field trip to ____________. This field trip will provide your daughter/son with the opportunity to experience the following: (provide a brief list of the activities you have planned).

An itinerary and a schedule of our proposed activities during the field trip is included for your information. Please review this material and contact the school if you have any questions about our plans.

Your daughter/son should bring the following supplies on the field trip: (list any special needs).

If she/he has any special physical or medical problems (e.g., allergies), please bring this to our attention. Contact the school if you feel that these problems may interfere with your daughter/son 's participation in this activity.

We would like you to come along on this exciting learning experience. We encourage you to sign up as a volunteer. Thank you for your cooperation.

________________ Teacher

________________ Principal

Consent Form

I will be able to take part in this field trip as volunteer.

Yes ___ No ___

Comments: ____

I permit ___________ to take part in the field trip described above. I have notified the school of any physical or medical problems which might interfere with my daughter/son's participation in this activity.

Date:

Signature:

Aids for Planning

Scope and Sequence of the Factors Forming the Dimensions of Scientific Literacy[1]

Levels

Dimensions; Factors	Elementary						Middle				Secondary		
	K	1	2	3	4	5	6	7	8	9	10	11	12
A Nature of Science													
1. public/private	—	—	—	—	—	—	—	—	—	—	—	—	—
2. historic	—	—	—	—	—	—	—	—	—	—	—	—	—
3. holistic	—	—	—	—	—	—	—	—	—	—	—	—	—
4. replicable	- -	- -	- -	—	—	—	—	—	—	—	—	—	—
5. empirical	- -	- -	- -	—	—	—	—	—	—	—	—	—	—
6. probabilistic			- -	- -	- -	- -	- -	- -	- -	—	—	—	—
7. unique				- -	- -	- -	- -	- -	—	—	—	—	—
8. tentative							- -	—	—	—	—	—	—
9. human/culture related							- -	- -	- -	- -	—	—	—
B Key Science Concepts													
1. change	—	—	—	—	—	—	—	—	—	—	—	—	—
2. interaction	—	—	—	—	—	—	—	—	—	—	—	—	—
3. orderliness	—	—	—	—	—	—	—	—	—	—	—	—	—
4. organism	—	—	—	—	—	—	—	—	—	—	—	—	—
5. perception	—	—	—	—	—	—	—	—	—	—	—	—	—
6. symmetry	—	—	—	—	—	—	—	—	—	—	—	—	—
7. force	- -	- -	—	—	—	—	—	—	—	—	—	—	—
8. quantification	- -	- -	—	—	—	—	—	—	—	—	—	—	—
9. reproducibility of results	- -	- -	- -	—	—	—	—	—	—	—	—	—	—
10. cause-effect	- -	- -	- -	—	—	—	—	—	—	—	—	—	—
11. predictability	- -	- -	- -	- -	—	—	—	—	—	—	—	—	—
12. conservation	- -	- -	- -	- -	- -	—	—	—	—	—	—	—	—
13. energy-matter		- -	- -	—	—	—	—	—	—	—	—	—	—
14. cycle		- -	- -	—	—	—	—	—	—	—	—	—	—
15. model		- -	- -	—	—	—	—	—	—	—	—	—	—
16. system		- -	- -	—	—	—	—	—	—	—	—	—	—
17. field		- -	- -	—	—	—	—	—	—	—	—	—	—
18. population				- -	—	—	—	—	—	—	—	—	—
19. probability				- -	- -	- -	- -	- -	- -	—	—	—	—
20. theory				- -	- -	- -	- -	- -	- -	- -	—	—	—
21. accuracy						- -	- -	- -	- -	—	—	—	—
22. fundamental entities							- -	—	—	—	—	—	—
23. invariance							- -	—	—	—	—	—	—
24. scale							- -	—	—	—	—	—	—
25. time-space							- -	- -	—	—	—	—	—
26. evolution							- -	- -	- -	—	—	—	—
27. amplification									- -	—	—	—	—
28. equilibrium										- -	—	—	—
29. gradient										- -	—	—	—
30. resonance										- -	—	—	—
31. significance										- -	—	—	—
32. validation										- -	—	—	—
33. entropy										- -	- -	—	—
C Processes of Science													
1. classifying	—	—	—	—	—	—	—	—	—	—	—	—	—
2. communicating	—	—	—	—	—	—	—	—	—	—	—	—	—
3. observing and describing	—	—	—	—	—	—	—	—	—	—	—	—	—
4. working cooperatively	—	—	—	—	—	—	—	—	—	—	—	—	—
5. measuring	—	—	—	—	—	—	—	—	—	—	—	—	—
6. questioning	- -	- -	—	—	—	—	—	—	—	—	—	—	—
7. using numbers	- -	- -	—	—	—	—	—	—	—	—	—	—	—
8. hypothesizing		- -	- -	—	—	—	—	—	—	—	—	—	—
9. inferring		- -	- -	—	—	—	—	—	—	—	—	—	—
10. predicting		- -	- -	—	—	—	—	—	—	—	—	—	—
11. controlling variables		- -	- -	—	—	—	—	—	—	—	—	—	—
12. interpreting data			- -	—	—	—	—	—	—	—	—	—	—
13. formulating models			- -	- -	- -	- -	- -	—	—	—	—	—	—
14. problem solving			- -	- -	- -	- -	- -	- -	- -	—	—	—	—
15. analyzing				- -	- -	- -	—	—	—	—	—	—	—
16. designing experiments				- -	- -	- -	- -	- -	- -	—	—	—	—
17. using mathematics							- -	—	—	—	—	—	—
18. using time-space relationships							- -	- -	—	—	—	—	—
19. consensus making							- -	- -	- -	—	—	—	—
20. defining operationally								- -	- -	- -	—	—	—
21. synthesizing										- -	- -	—	—

[1]Adapted from: Hart, E.P. (1987). *Science for Saskatchewan Schools: Proposed Directions. Field Study, Part B. A Framework for Curriculum Development.* A Saskatchewan Instructional Development Research Unit project funded by Saskatchewan Education.

Dimensions; Factors	Elementary						Middle				Secondary		
	K	1	2	3	4	5	6	7	8	9	10	11	12
D Science-Technology-Society-Environment Interrelationships													
1. science and technology	- -	- -	- -	—	—	—	—	—	—	—	—	—	—
2. scientists and technologists are human		- -	- -	- -	- -	- -	- -	—	—	—	—	—	—
3. impact of science and technology				- -	- -	- -	—	—	—	—	—	—	—
4. science, technology, and the environment				- -	- -	- -	—	—	—	—	—	—	—
5. public understanding gap				- -	- -	- -	- -	- -	- -	—	—	—	—
6. resources for science and technology				- -	- -	- -	- -	- -	- -	—	—	—	—
7. variable positions				- -	- -	- -	- -	- -	- -	- -	—	—	—
8. limitations of science and technology							- -	- -	- -	—	—	—	—
9. social influence on science and technology								- -	- -	- -	—	—	—
10. technology controlled by society										- -	—	—	—
11. science, technology, and other realms										- -	—	—	—
E Scientific and Technical Skills													
1. using magnifying instruments	—	—	—	—	—	—	—	—	—	—	—	—	—
2. using natural environments	—	—	—	—	—	—	—	—	—	—	—	—	—
3. using equipment safely	—	—	—	—	—	—	—	—	—	—	—	—	—
4. using audio-visual aids	—	—	—	—	—	—	—	—	—	—	—	—	—
5. computer interaction	—	—	—	—	—	—	—	—	—	—	—	—	—
6. measuring distance	- -	- -	—	—	—	—	—	—	—	—	—	—	—
7. manipulative ability	- -	- -	- -	—	—	—	—	—	—	—	—	—	—
8. measuring time		- -	—	—	—	—	—	—	—	—	—	—	—
9. measuring volume		- -	—	—	—	—	—	—	—	—	—	—	—
10. measuring temperature		- -	—	—	—	—	—	—	—	—	—	—	—
11. measuring mass			- -	—	—	—	—	—	—	—	—	—	—
12. using electronic instruments						- -	- -	- -	- -	—	—	—	—
13. using quantitative relationships						- -	- -	- -	- -	- -	—	—	—
F Values That Underlie Science													
1. longing to know and understand	—	—	—	—	—	—	—	—	—	—	—	—	—
2. questioning	—	—	—	—	—	—	—	—	—	—	—	—	—
3. search for data and their meaning	—	—	—	—	—	—	—	—	—	—	—	—	—
4. valuing natural environments	—	—	—	—	—	—	—	—	—	—	—	—	—
5. respect for logic	- -	- -	- -	—	—	—	—	—	—	—	—	—	—
6. consideration of consequence	- -	- -	- -	- -	- -	- -	—	—	—	—	—	—	—
7. demand for verification				- -	- -	- -	—	—	—	—	—	—	—
8. consideration of premises										- -	—	—	—
G Science-Related Interests and Attitudes													
1. interest	—	—	—	—	—	—	—	—	—	—	—	—	—
2. confidence	—	—	—	—	—	—	—	—	—	—	—	—	—
3. continuous learner	—	—	—	—	—	—	—	—	—	—	—	—	—
4. media preference	- -	- -	- -	—	—	—	—	—	—	—	—	—	—
5. avocation				- -	- -	- -	—	—	—	—	—	—	—
6. response preference				- -	- -	- -	—	—	—	—	—	—	—
7. vocation				- -	- -	- -	- -	- -	- -	—	—	—	—
8. explanation preference							- -	- -	- -	- -	—	—	—
9. valuing contributors							- -	- -	- -	- -	—	—	—

KEY: - - - - Preparation. Emerging in these grades. Limited focus.
——— Development. Addressed in full, and appropriate to the grade level. Emphasized.

Explanations of the Factors in the Dimensions of Scientific Literacy

A. Nature of Science

The scientifically literate person understands the nature of science and scientific knowledge.

Science is both public and private. Science experiences should introduce students to the private and intuitive aspects of scientific inquiry and discovery as well as to the more formal public aspects of science.

The nature of scientific knowledge is such that it is:

A1 public/private D(K-12)

Science is based on evidence, developed privately by individuals or groups, that is shared publicly with others. This provides other individuals with the opportunity to attempt to establish the validity and reliability of the evidence.

Examples:

After scientists have gathered and organized evidence for their ideas, they publish the evidence and the methods by which it was obtained, so that other scientists may test the validity and reliability of the evidence.

When Pons and Fleischman withheld some of the evidence and procedures for their cold-fusion discovery in order to protect their claims for patent, the principle of public disclosure was violated.

A2 historic D(K-12)

Past scientific knowledge should be viewed in its historical context and not be degraded on the basis of present knowledge.

Examples:

Each refinement of the model of the atom by Thompson, Rutherford, Bohr, and the quantum theorists has relied on the previous work of others.

Selective breeding of corn by the Indian peoples of North America produced a high quality food plant.

A3 holistic D(K-12)

All branches of science are interrelated.

Example:

The structure of molecules is a topic of interest for physicists, chemists, and biologists.

A4 replicable P(K-2), D(3-12) *

Science is based on evidence which could be obtained by other people working in a different place and at a different time under similar conditions.

Examples:

Any procedure which is repeated should give similar results.

A group of students all perform the same experiment and discover similarities in their results.

A5 empirical P(K-2), D(3-12)

Scientific knowledge is based on experimentation or observation.

Examples:

The gravitational field strength of the Earth can be determined in the laboratory.

Scientific theories must always be tested experimentally.

* The code **P(K-2)** means that preparation for development of this factor is to take place from kindergarten until grade 2. Development, coded **D(3-12)**, takes place from grades 3 to 12. Preparation involves such things as the teacher using the term or its concepts and the students being exposed to phenomena which illustrate or involve the factor. Development occurs when the student are encouraged to use the term or its concepts correctly.

A6 probabilistic P(2-8), D(9-12)

Science does not make absolute predictions or explanations.

Examples:

An electron orbital is a region in space where there is the greatest likelihood of finding an electron.

A weather forecaster predicts a 20% chance of precipitation tomorrow.

A7 unique P(3-7), D(8-12)

The nature of scientific knowledge and the procedures for generating new scientific knowledge are unique and different from those in other fields of knowledge such as philosophy.

Examples:

Compare the methods used for weather forecasting by meteorologists and those used by the people producing the forecasts for the Farmer's Almanac.

Compare Galileo's experimental approach to investigating the rate at which heavy and light objects fall and Aristotle's approach, based on reason alone.

A8 tentative P(6), D(7-12)

Scientific knowledge is subject to change. It does not claim to be truth in an absolute and final sense. This does not lessen the value of knowledge for the scientifically literate person.

Example:

As new data become available, theories are modified to encompass the new and the old data. Our understanding of atomic structure has changed considerably for this reason.

A9 human/culture related P(6-9), D(10-12)

Scientific knowledge is a product of humankind. It involves creative imagination. The knowledge is shaped by and from concepts that are a product of culture.

Examples:

Vertebrates, and specifically humans, are regarded as being at the pinnacle of evolution by some people.

The use of biotechnology has resulted in changes in rapeseed to remove erucic acid. This has led to the development of improved varieties of canola oil for human consumption.

B. Key Science Concepts

The scientifically literate person understands and accurately applies appropriate science concepts, principles, laws, and theories in interacting with society and the environment.

Among the key concepts of science are:

B1 change D(K-12)

It is the process of becoming different. It may involve several stages.

Examples:

An organism develops from an egg, matures, and eventually dies.

Stars use up their fuel and thus undergo change.

B2 interaction D(K-12)

This happens when two or more things influence or affect each other.

Example:

Within an ecosystem some animals have to compete for available food and space.

B3 orderliness D(K-12)

This is a regular sequence which either exists in nature or is imposed through classification.

Examples:

Crystal structures can be identified by diffraction techniques because of the regular arrangement of their atoms.

B4 organism D(K-12)

An organism is a living thing or something that was once alive.

Examples:

Whether or not a virus is a living organism is an interesting topic for scientific scrutiny.

Fossils found in sedimentary rock provide evidence of organisms which became extinct a long time ago.

B5 perception D(K-12)

Perception is the interpretation of sensory input by the brain.

Example:

Jet lag may impair the judgement of pilots during landing and takeoff.

B6 symmetry D(K-12)

This is a repetition of a pattern within some larger structure.

Example:

Some molecular structures and living organisms exhibit properties of symmetry.

B7 force P(K-1), D(2-12)

It is a push or a pull.

Example:

The weight of an object decreases at higher altitudes.

B8 quantification P(K-1), D(2-12)

Numbers can be used to convey important information.

Example:

The gravitational force of attraction between two objects can be calculated by using Newton's Law of Universal Gravitation.

B9 reproducibility of results P(K-2), D(3-12)

Repetition of a procedure should produce the same results if all other conditions are identical. It is a necessary characteristic of scientific experiments.

Example:

Heating a pure sample of paradichlorobenzene should cause it to melt at about 50 °C

B10 cause-effect P(K-2), D(3-12)

It is a relationship of events that substantiates the belief that natural phenomena do not occur randomly. It enables predictions to be made. The advent of chaos theory has caused some rethinking of this principle.

Examples:

The acceleration of a cart depends on the unbalanced force acting upon the cart.

Every event has a cause. It does not happen by itself.

B11 predictability P(K-3), D(4-12)

Patterns can be identified in nature. From those patterns inferences can be made.

Example:

When sodium metal reacts with water, the resulting solution turns red litmus paper blue.

B12 conservation P(K-4), D(5-12)

An understanding of the finite nature of the world's resources, and an understanding of the necessity to treat those resources with prudence and economy, are underlying principles of conservation.

Examples:

Insulating a home may reduce the amount of energy needed to heat it in the winter.

Smaller, more efficient internal combustion engines can be designed to use less fuel.

B13 energy-matter P(1-2), D(3-12)

It is the interchangeable and dependent relationship between energy and matter.

Example:

When a candle burns, some of the energy stored in the wax is released as heat and light.

B14 cycle P(1-2), D(3-12)

Certain events or conditions are repeated.

Examples:

The water cycle, nitrogen cycle, and equilibrium all serve as examples of cycles.

Change occurring in cycles or patterns is one of the twelve principles of Indian philosophy.

B15 model P(1-2), D(3-12)

It is a representation of a real structure, event, or class of events intended to facilitate a better understanding of abstract concepts or to allow scaling to a manageable size.

Example:

Watson and Crick developed a model of the DNA molecule which allowed people to gain a better understanding of genetics.

B16 system P(1-2), D(3-12)

A set of interrelated parts forms a system.

Example:

Chemical equilibrium can be established only in a closed system.

B17 field P(1-2), D(3-12)

A field is a region of space which is influenced by some agent.

Examples:

Similarly charged objects have a tendency to repel one another when they are in close proximity.

The sun is the source of a gravitational field which fills space. The Earth's motion is affected by the influence of this field.

B18 population P(3), D(4-12)

A population is a group of organisms that share common characteristics.

Example:

Wildlife biologists monitor white tail deer to determine the number of permits for hunting that will be issued in a particular zone.

B19 probability P(3-8), D(9-12)

Probability is the relative degree of certainty that can be assigned to certain events happening in a specified time interval or within a sequence of events.

Example:

The probability of getting some types of cancer increases with prolonged exposure to large doses of radiation.

B20 theory P(3-9), D(10-12)

A theory is a connected and internally consistent group of statements, equations, models, or a combination of these, which serves to explain a relatively large and diverse group of things and events.

Example:

As new experimental evidence becomes available, atomic theory undergoes further change and refinement.

B21 accuracy P(5-8), D(9-12)

Accuracy involves a recognition that there is uncertainty in measurement. It also involves the correct use of significant figures.

Example:

A stopwatch which measures to the nearest 1/10th of a second would be an inappropriate instrument for determining the duration of a spark discharge.

B22 fundamental entities P(6), D(7-12)

They are units of structure or function which are useful in explaining certain phenomena.

Examples:

The cell is the basic unit of organic structure.

The atom is the basic unit of molecular structure.

B23 invariance P(6), D(7-12)

This is a characteristic which stays constant even though other things may change.

Example:

Mass is conserved in a chemical reaction.

B24 scale P(6), D(7-12)

Scale involves a change in dimensions. This may affect other characteristics of a system.

Example:

A paper airplane made from a sheet of notebook paper may fly differently than a plane of identical design made from a poster-sized sheet of the same paper.

B25 time-space P(6-7), D(8-12)

It is a mathematical framework in which it is convenient to describe objects and events.

Examples:

An average human being has an extension in one direction of approximately 1 3/4 metres and in another direction of about 70 years.

According to general relativity, gravity is not a force, but a property of space itself. It is a curvature in time-space caused by the presence of an object.

B26 evolution P(6-8), D(9-12)

Evolution is a series of changes that can be used to explain how something got to be the way it is or what it might become in the future. It is generally regarded as going from simple to complex.

Example:

Organic evolution is thought to progress in small, incremental changes. Similarly, scientific theories undergo change to accommodate new data as they become available.

B27 amplification P(8), D(9-12)

Amplification is an increase in magnitude of some detectable phenomenon.

Example:

A loudspeaker produces an amplification of sound.

B28 equilibrium P(9), D(10-12)

Equilibrium is the state in which there is no change on the macroscopic level and no net forces on the system.

Examples:

Chemical equilibrium exhibits no change on the macroscopic level.

A first class lever in a condition of static equilibrium remains at rest. The sum of all of the moments of the forces acting is zero.

B29 gradient P(9), D(10-12)

A gradient is a description of a pattern or variation. The description includes both the magnitude and the direction of the change.

Examples:

Light intensity decreases in a predictable manner as the distance from the light source increases.

On a mountain, the direction in which the change of slope is smallest is the most desirable route to build a railroad line.

B30 resonance P(9), D(10-12)

It is an action within one system which causes a similar action within another system.

Examples:

A hollow wooden box can be used to amplify the sound of a tuning fork.

B31 significance P(9), D(10-12)

It is the belief that certain differences exceed those that would be expected to be caused by chance alone.

Example:

An analysis of Brahe's data led to the development of Kepler's First Law.

B32 validation P(9), D(10-12)

Validation is a belief that similar relationships obtained by two or more different methods reflect an accurate representation of the situation being investigated.

Example:

Carbon-14 dating can be used to check the authenticity of archaeological artifacts.

B33 entropy P(9-10), D(11-12)

Entropy is the randomness, or disorder, in a collection of things. It can never decrease in a closed system.

Example:

When solid sodium chloride dissolves in water, its particles are dispersed randomly.

C. Processes of Science

The scientifically literate person uses processes of science in solving problems, making decisions, and furthering understanding of society and the environment.

Complex or integrated processes include those which are more basic. Intellectual skills are acquired and practised throughout life so that eventually some control over these processes can facilitate learning.

This can provide information processing and problem solving abilities that go beyond any curriculum.

Process skills such as accessing and processing information, applying knowledge of scientific principles to the analysis of issues, identifying value positions, and reaching consensus are believed to include the more basic processes of science.

The basic processes of science are:

C1 classifying D(K-12)

Classifying is a systematic procedure used to impose order on collections of objects or events.

Example:

Grouping animals into their phyla or arranging the elements into the periodic table are examples of classifying.

C2 communicating D(K-12)

Communicating is any one of several procedures for transmitting information from one person to another.

Example:

Writing reports, or participating in discussions in class are examples of communicating.

C3 observing and describing D(K-12)

This is the most basic process of science. The senses are used to obtain information about the environment.

Example:

During an investigation, a student writes a paragraph recording the progress of a chemical reaction between hot copper metal and sulphur vapour.

C4 working cooperatively D(K-12)

This involves an individual working productively as a member of a team for the benefit of the team's goals.

Example:

Students should share responsibilities in the completion of an experiment.

C5 measuring D(K-12)

An instrument is used to obtain a quantitative value associated with some characteristic of an object or an event.

Example:

The length of a metal bar can be determined to the nearest millimetre with an appropriate measuring device.

C6 questioning P(K-1), D(2-12)

It is the ability to raise problems or points for investigation or discussion.

Example:

A student should be able to create directed questions about observed events. When migratory birds are observed, questions such as, "Why do birds flock to migrate?", "Do some birds migrate singly?", and "How do birds know where to go?" should direct further inquiry.

C7 using numbers P(K-1), D(2-12)

This involves counting or measuring to express ideas, observations, or relationships, often as a complement to the use of words.

Example:

1 litre contains 1 000 millilitres.

C8 hypothesizing P(1-2), D(3-12)

Hypothesizing is stating a tentative generalization which may be used to explain a relatively large number of events. It is subject to immediate or eventual testing by experiments.

Example:

Making predictions about the importance of various components of a pendulum which may influence its period is an example of hypothesizing.

C9 inferring P(1-2), D(3-12)

It is explaining an observation in terms of previous experience.

Example:

After noticing that saline sloughs have a different insect population than fresher sloughs, one might infer that small changes in an environment can affect populations.

C10 predicting P(1-2), D(3-12)

This involves determining future outcomes on the basis of previous information.

Example:

Given the results of the hourly population counts in a yeast culture over a 4 hour period, one could attempt to predict the population after 5 hours.

C11 controlling variables P(1-2), D(3-12)

Controlling variables is based on identifying and managing the conditions that may influence a situation or event.

Examples:

If all other factors which may be important in plant growth are identified and made similar (controlled), the effect of gibberellic acid can be observed.

In order to test the effect of fertilizer on plant growth, all other factors which may be important in plant growth must be identified and controlled so that the effect of the fertilizer can be determined.

C12 interpreting data P(2), D(3-12)

This important process is based on finding a pattern in a collection of data. It leads to a generalization.

Example:

Concluding that the mass of the pendulum bob does not affect the period of a pendulum might be based on the similarity of periods of 100 g, 200 g, and 300 g pendulums.

C13 formulating models P(2-6), D(7-12)

Models are used to represent an object, event, or process.

Example:

Vector descriptions of how forces interact are models.

C14 problem solving P(2-8), D(9-12)

Scientific knowledge is generated by, and used for, asking questions concerning the natural world. Quantitative methods are frequently employed.

Example:

A knowledge of genetics and the techniques of recombinant DNA are used to create bacteria which produce insulin.

C15 analyzing P(3-5), D(6-12)

It is examining scientific ideas and concepts to determine their essence or meaning.

Examples:

Determining whether a hypothesis is tenable requires analysis.

Determining which amino acid sequence produces insulin requires analysis.

C16 designing experiments P(3-8), D(9-12)

Designing experiments involves planning a series of data-gathering operations which will provide a basis for testing a hypothesis or answering a question.

Example:

Automobile manufacturers test seat belt performance in crash tests.

C17 using mathematics P(6), D(7-12)

When using mathematics, numeric or spatial relationships are expressed in abstract terms.

Example:

Projectile trajectories can be predicted using mathematics.

C18 using time-space relationships P(6-7), D(8-12)

These are the two criteria used to describe the location of things or events.

Example:

Describe the migratory paths of the barren lands caribou.

C19 consensus making P(6-8), D(9-12)

Consensus making is reaching an agreement when a diversity of opinions exist.

Examples:

A discussion of the disposal of toxic waste, based on research, gives a group of students the opportunity to develop a position they will be using in a debate.

Scientists were initially divided regarding the cold fusion debate. They held conferences but were still unable to agree on this issue. Further experimental results were needed.

C20 defining operationally P(7-9), D(10-12)

It is producing a definition of a thing or event by giving a physical description or the results of a given procedure.

Example:

An acid turns blue litmus paper red and tastes sour.

C21 synthesizing P(9-10), D(11-12)

Synthesizing involves combining parts into a complex whole.

Examples:

Polymers can be produced through the combination of simpler monomers.

A student essay may involve the synthesis of a wide variety of knowledge, skills, attitudes, and processes.

D. Science-Technology-Society-Environment Interrelationships

The scientifically literate person understands and appreciates the joint enterprises of science and technology, their interrelationships, and their impacts on society and the environment.

Some of the factors involved in the interrelationships among science, technology, society, and the environment are:

D1 science and technology P(K-2), D(3-12)

There is a distinction between science and technology, although they often overlap and depend on each other. Science deals with generating and ordering conceptual knowledge. Technology deals with design and development, and the application of scientific or technological knowledge, often in response to social and human needs.

Example:

The invention of the microscope led to new discoveries about cells.

D2 scientists and technologists are human P(1-6), D(7-12)

Outside of their specialized fields, scientists and technologists may not exhibit strong development of all or even most of the Dimensions of Scientific Literacy. Vocations in science and technology are open to most people.

Example:

By researching the biographies of famous scientists, students can begin to appreciate the human elements of science and technology.

D3 impact of science and technology P(3-5), D(6-12)

Scientific and technological developments have real and direct effects on every person's life. Some effects are desirable; others are not. Some of the desirable effects may have undesirable side effects. In essence, there seems to be a trade-off principle working in which gains are accompanied by losses.

Example:

As our society continues to increase its demands on energy consumption and consumer goods, we are likely to attain a higher standard of living while allowing further deterioration of the environment to occur.

D4 science, technology, and the environment P(3-5), D(6-12)

Science and technology can be used to monitor environmental quality. Society has the ability and responsibility to educate and to regulate environmental quality and the wise usage of natural resources, to ensure quality of life for this and succeeding generations.

Example:

Everyone should share in the responsibility of conserving energy.

D5 public understanding gap P(3-8), D(9-12)

A considerable gap exists between scientific and technological knowledge, and public understanding of it. Constant effort is required by scientists, technologists, and educators to minimize this gap.

Examples:

Some people mistakenly believe that irradiation causes food to become radioactive.

Buttermilk is often mistakenly regarded as having a high caloric content.

Folklore has it that the best time to plant potatoes in the spring is during the full moon.

Many believe that technology is simply applied science.

D6 resources for science and technology P(3-8), D(9-12)

Science and technology require considerable resources in the form of talent, time, and money.

Example:

Further advances in space exploration may require the collective efforts of many nations working together to find the necessary time, money and resources.

D7 variable positions P(3-9), D(10-12)

Scientific thought and knowledge can be used to support different positions. It is normal for scientists and technologists to disagree among themselves, even though they may invoke the same scientific theories and data.

Examples:

The debate about the possibility of cold fusion illustrated variable positions among scientists.

There is a debate about whether or not controlled burning techniques should be used in national parks.

D8 limitations of science and technology P(6-8), D(9-12)

Science and technology can not guarantee a solution to any specific problem. In fact, the ultimate solution of any problem is usually impossible, and a partial or temporary solution is all that is ever possible. Solutions to problems can not necessarily be legislated, bought, or guaranteed by the allocation of resources. Some things are not amenable to the approaches of science and technology.

Example:

The solutions that technology now proposes for nuclear waste storage often have significant limitations and are, at best, only short-term solutions until better ones can be found.

D9 social influence on science and technology P(7-9), D(10-12)

The selection of problems investigated by scientific and technological research is influenced by the needs, interests, and financial support of society.

Example:

The race to put a person on the moon illustrates how priorities can determine the extent to which the study of particular scientific and technological problems are sanctioned and thus allowed to be investigated.

D10 technology controlled by society P(9), D(10-12)

Although science requires freedom to inquire, applications of scientific knowledge and of technological products and practices are ultimately determined by society. Scientists and technologists have a responsibility to inform the public of the possible consequences of such applications. A need to search for consequences of scientific and technological innovations exists.

Examples:

Einstein's famous letter to President Roosevelt, warning about the possibility of developing nuclear weapons, and his pacifist views, illustrate the responsibility that scientists must have as members of society.

Governments must make decisions regarding the support and funding of important scientific research.

D11 science, technology, and other realms P(9), D(10-12)

Although there are distinctive characteristics of the knowledge and processes that characterize science and technology, there are many connections to, and overlaps with, other realms of human knowledge and understanding.

Example:

The Uncertainty Principle in science, the Verstehen Principle in anthropology, and the Hawthorne Effect in social psychology all express similar types of ideas within the realm of their own disciplines.

E. Scientific and Technical Skills

The scientifically literate person has developed numerous manipulative skills associated with science and technology.

The list of skills that follows represents manipulative skills important to the achievement of scientific literacy:

E1 using magnifying instruments D(K-12)

Some magnifying instruments include the magnifying lens, microscope, telescope, and overhead projector.

Examples:

Fine dissections of earthworms are done with the aid of stereoscopic microscopes.

E2 using natural environments D(K-12)

The student uses natural environments effectively and in appropriately sensitive ways (e.g., collecting, examining, and reintroducing specimens).

Example:

Students can do a study of the margin of a pond by observing and describing a particular section at two week intervals for three months. After they collect and examine specimens, they should reintroduce them to their natural environment.

E3 using equipment safely D(K-12)

The student demonstrates safe use of equipment in the laboratory, in the classroom, and in everyday experiences.

Example:

A student recognizes a situation where goggles should be worn, and puts them on before being instructed to wear them.

E4 using audiovisual aids D(K-12)

The student independently uses audiovisual aids in communicating information. (Audiovisual aids include such things as: drawings, photographs, collages, televisions, radios, video cassette recorders, overhead projectors.)

Examples:

A student shows the teacher how to operate the VCR.

A student uses a camera to record natural phenomena.

E5 computer interaction D(K-12)

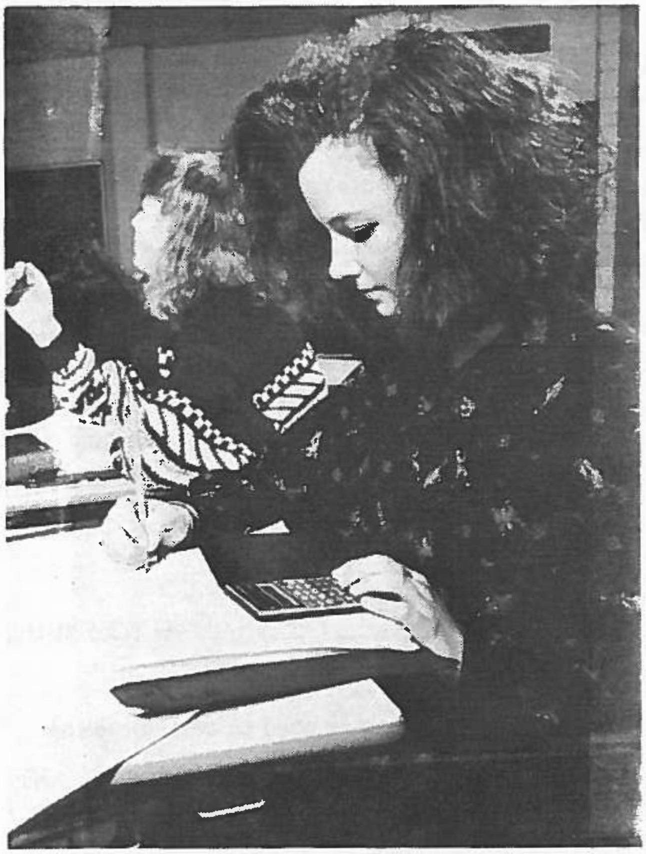
The student uses the computer as an analytical tool, a tool to increase productivity, and as an extension of the human mind.

Examples:

Using photocells connected to the proper interface, the computer can be used as a timing device.

Logging on to an information service gives students an opportunity to perform a keyword search of a chemical database.

Computer software can be used to simulate a natural event or process which may be too dangerous or impractical to perform in the laboratory.



E6 measuring distance P(K-1), D(2-12)

The student accurately measures distance with appropriate instruments or techniques such as rulers, metre sticks, trundle wheels, or rangefinders.

Examples:

The length and width of a room can be determined using a metre stick.

Large distances can be determined using parallax or triangulation methods.

E7 manipulative ability P(K-2), D(3-12)

The student demonstrates an ability to handle objects with skill and dexterity.

Example:

A student uses a graduated cylinder to measure 35 mL of liquid. The liquid is then transferred into a flask and heated.

E8 measuring time P(1), D(2-12)

The student accurately measures time with appropriate instruments such as a watch, an hourglass, or any device which exhibits periodic motion.

Example:

A student uses an oscilloscope to measure a short time interval accurately.

E9 measuring volume P(1), D(2-12)

The student measures volume directly with graduated containers. The student also measures volume indirectly using calculations from mathematical relations.

Examples:

The volume of a graduated cylinder is read at the curve inflection point of the meniscus.

Archimedes' principle is used to determine the volume of an irregular solid.

E10 measuring temperature P(1), D(2-12)

The student accurately measures temperature with a thermometer or a thermocouple.

Example:

Thermometers must be properly placed to record accurate measurements of temperature.

E11 measuring mass P(2), D(3-12)

The student accurately measures mass with a double beam balance or by using other appropriate techniques.

Example:

Balances may be used to determine the mass of an object, within the limits of the precision of the balance.

E12 using electronic instruments P(5-8), D(9-12)

The student can use electronic instruments that reveal physical or chemical properties, or monitor biological functions.

Example:

Following the recommended procedures allows an instrument to be used to the maximum extent of its precision (e.g., ammeter, oscilloscope, pH meter, camera).

E13 using quantitative relationships P(5-9), D(10-12)

The student uses mathematical expressions correctly.

Examples:

To calculate instantaneous acceleration, find the slope at one point on a velocity versus time graph.

Calculate the volume of a cube given the length of one side.

F. Values That Underlie Science

The scientifically literate person interacts with society and the environment in ways that are consistent with the values that underlie science.

The values that underlie science include:

F1 longing to know and understand D(K-12)

Knowledge is desirable. Inquiry directed toward the generation of knowledge is a worthy investment of time and other resources.

Example:

A group of four students asks the teacher if they can do a Science Challenge project on a topic that they are all interested in.

F2 questioning D(K-12)

Questioning is important. Some questions are of greater value than others because they lead to further understanding through scientific inquiry.

Example:

Students ask questions which probe more deeply than the normal class or text presentation.

F3 search for data and their meaning D(K-12)

The acquisition and ordering of data are the basis for theories which, in turn, can be used to explain many things and events. In some cases these data have immediate practical applications of value to humankind. Data may enable one to assess a problem or situation accurately.

Example:

In a **Science Challenge** activity, a group of students asks a question about a natural occurrence. They then design an experiment in an attempt to answer the question. Variables which may influence the results of the experiment are controlled. Careful observations are made and recorded. Data are collected and analyzed to test the hypothesis that is under scrutiny. Further testing then takes place.

F4 valuing natural environments D(K-12)

Our survival depends on our ability to sustain the essential balance of nature. There is intrinsic beauty to be found in nature.

Example:

On a field trip the actions of the participants should be considerate toward and conserving of all components of the ecosystem.

F5 respect for logic P(K-2), D(3-12)

Correct and valid inferences are important. It is essential that conclusions and actions be subject to question.

Example:

Errors in logic are recognized. Information is viewed critically with respect to the logic used.

F6 consideration of consequence P(K-5), D(6-12)

It is a frequent and thoughtful review of the effects that certain actions will have.

Example:

Experimental procedures can affect the outcome of an experiment.

Transporting oil by tankers might cause an oil spill with very serious environmental consequences.

F7 demand for verification P(3-5), D(6-12)

Supporting data must be made public. Empirical tests must be conducted to assess the validity or accuracy of findings or assertions.

Example:

Media reports and research are reviewed critically and compared to other sources of information before being accepted or rejected.

F8 consideration of premises P(9), D(10-12)

A frequent review should occur of the basic assumptions from which a line of inquiry has arisen.

Examples:

In a lab investigation into the rate of chemical reactions, the control of variables is examined.

A critical examination is made of the factors under consideration in explaining the extinction of dinosaurs.

G. Science-Related Interests and Attitudes

The scientifically literate person has developed a unique view of science, technology, society and the environment as a result of science education, and continues to extend this education throughout life.

Science-related interests and attitudes include:

G1 interest D(K-12)

The student exhibits an observable interest in science.

Example:

Students and teachers who spend a great deal of time outside of class on science fair projects exhibit a keen interest in science.

G2 confidence D(K-12)

The student experiences a measure of self-satisfaction by participating in science and in understanding scientific things.

Example:

Students and teachers read science literature and are interested in discussing with others what they read.

G3 continuous learner D(K-12)

The individual has gained some scientific knowledge and continues some line of scientific inquiry. This may take many forms.

Example:

A person joins a natural history society to learn more about wildlife.

G4 media preference P(K-2), D(3-12)

The student selects the most appropriate media, depending on the information needed, and on his or her present level of understanding.

Examples:

Students and teachers who watch science-related television programs demonstrate a real interest in science.

When researching a science project, a student might have to determine which sources of information are most appropriate. The choice could include such things as television programs, newspaper articles, books, public displays, and scientific journals.

G5 avocation P(3-5), D(6-12)

The student pursues a science-related hobby.

Example:

By pursuing a hobby such as bird watching, astronomy, or shell collecting, a student demonstrates a keen interest in science.

G6 response preference P(3-5), D(6-12)

The way in which people behave can be an indication of whether or not they are striving to attain scientific literacy.

Example:

In an election, voters might consider the candidates' positions on environmental issues.

G7 vocation P(3-8), D(9-12)

The student considers a science-related occupation.

Example:

By modelling appropriate behaviours, teachers can encourage their students to become interested in science education or other science-related fields.

G8 explanation preference P(6-9), D(10-12)

The student chooses a scientific explanation over a nonscientific explanation when it is appropriate to do so. The student also recognizes that there may be some circumstances in which it may not be appropriate to select a scientific explanation.

Example:

By resorting to logic in a debate, students demonstrate logical thinking similar to that used in science.

G9 valuing contributors P(6-9), D(10-12)

The student values those scientists and technologists who have made significant contributions to humanity.

Examples:

A person wears a T-shirt bearing the image of some famous scientist.

Some students may hold the science teacher in very high regard.

Templates for Assessment and Evaluation

Rating Scale Template

1) ______________________________ 1 2 3 4 5

2) ______________________________ 1 2 3 4 5

3) ______________________________ 1 2 3 4 5

4) ______________________________ 1 2 3 4 5

5) ______________________________ 1 2 3 4 5

6) ______________________________ 1 2 3 4 5

7) ______________________________ 1 2 3 4 5

8) ______________________________ 1 2 3 4 5

9) ______________________________ 1 2 3 4 5

10) ______________________________ 1 2 3 4 5

11) ______________________________ 1 2 3 4 5

12) ______________________________ 1 2 3 4 5

13) ______________________________ 1 2 3 4 5

14) ______________________________ 1 2 3 4 5

Anecdotal Record Template

Report

Subject

Student

School

Teacher

Date

Teacher's Signature

Checklist of Laboratory Procedures

Name ______________ Date ______________

Activity ______________________________

Key: 1 = Rarely 2 = Occasionally 3 = Frequently

	1	2	3
Instructions followed	___	___	___
Safety precautions observed	___	___	___
Equipment handled correctly	___	___	___
Equipment cleaned thoroughly	___	___	___
Equipment stored properly	___	___	___
Lab area kept clean	___	___	___
Spills cleaned promptly	___	___	___
Chemical disposed of properly	___	___	___
Cooperation with others	___	___	___
Improvisation	___	___	___
Appropriate use of time	___	___	___
Observations noted and recorded	___	___	___
Other: ______________	___	___	___
______________	___	___	___
______________	___	___	___

Group Self-Assessment of Laboratory Activities

_______________ Group   _______________ Date   _______________ Activity

Use these descriptors to assess how effectively your group performed a specific activity. Choose one or several numbers from the list of criteria.

1 = yes   2 = no   3 = we think so

4 = needs improvement   5 = satisfactory   6 = excellent

Things to consider	
Did we develop a clear plan before we began?	
Did each group member have specific things to do?	
Were we able to work together as a team?	
Did we discuss the purpose for doing the activity?	
Was a hypothesis developed and recorded?	
How well did we predict what took place?	
Were instructions followed correctly?	
How well did we use equipment and materials?	
Did we observe all safety precautions?	
Were measurements made accurately?	
How well were data recorded?	
Did we clean up thoroughly after the activity?	
Were the data examined closely to search for meaning?	
Did we use accepted techniques for data analysis?	
Were the conclusions consistent with the data?	
Did we re-examine our initial hypothesis?	
Did we account for experimental error?	
Was relevant research used to support our work ?	
Other:	

Project Presentation — Individual Questionnaire

Your name ______________________ Topic ______________

Group Members ______________________ Date ______________

Circle the following on working within the group. Additional written responses may be included.

1. I encouraged others.	Seldom Sometimes Often
2. I shared ideas and information.	Seldom Sometimes Often
3. I checked to make sure that others in the group knew what they were doing.	Seldom Sometimes Often
4. I was willing to help others.	Seldom Sometimes Often
5. I accepted responsibility for completing the work properly and on time.	Seldom Sometimes Often
6. I was willing to listen to others in the group.	Seldom Sometimes Often
7. I was willing to receive help from others in the group.	Seldom Sometimes Often
8. I offered encouragement and support to others in the group.	Seldom Sometimes Often
9. Others in the group shared ideas and information.	Seldom Sometimes Often
10. The group checked with the teacher to make sure we knew what we were supposed to be doing.	Seldom Sometimes Often
11. All members of the group contributed equally to this project.	Seldom Sometimes Often

Answer the following questions about working in a group.

12. How did you distribute the workload within your group?

13. What problems, if any, arose within your group?

14. What would you do differently next time?

15. How is working in a group different from working by yourself?

Science Report Evaluation Form*

Name: Date:

Activity:

Written Presentation	Weight	Score
Title Page	5	
Introduction	10	
Body	30	
Conclusion	20	
Supporting References	5	
Neatness	10	
Organization	20	
Content		
Communication Skills	25	
Originality	25	
Accuracy	20	
Appropriateness	30	
Creativity	25	
Overall Impression	10	
Total Score	185	

Other Comments:

* Criteria for an oral presentation may be developed. Teachers are encouraged to develop criteria for each element on this page (e.g, Title page must include title centered left/right and vertically, student's name and class number) and share those with the students before they do their report.

Laboratory Report Evaluation

______________________ ______________
Name Date

____
Activity

	Excellent	Good	Satisfactory	Unsatisfactory
Completeness				
Accuracy				
Organization				
Presentation				

Comments: ____

Overall Report Grade: __________

Data Collection/Notebook Checklist*

Name ____________________ Date __________

A checkmark indicates that the criterion is satisfactory. No mark indicates that the criterion is either missing or unsatisfactory.

Documentation is complete.	
The information or data collected is accurate.	
Written work is neat and legible.	
Tables and diagrams are completed neatly.	
Each new section begins with an appropriate heading.	
Errors are crossed out but not erased.	
Spelling and language usage are edited and corrected.	
Information is recorded in a logical sequence.	
Technological aids are used appropriately.	
Notes are collected in a folder or binder.	
Colour or graphics are used to enhance the appearance.	
Rough work is done separately.	

Comments/Overall Impressions:

* This checklist may be used by teachers, or by students for self-evaluation. It may be used to evaluate notebooks, laboratory data collection done during investigations, or more formal written laboratory reports. Students should be made aware of these criteria at the start of the term.

Observation of Group Behaviours

____

Student or Group

Activities:

a ______________________________

b ______________________________

c ______________________________

d ______________________________

e ______________________________

f ______________________________

1 = rarely 2 = occasionally 3 = frequently 4 = consistently

	a	b	c	d	e	f
Remains on task						
Follows directions						
Exhibits leadership						
Respects the ideas of others						
Works cooperatively						
Communicates effectively						
Shares tasks equitably						
Works safely						
Handles equipment correctly						
Displays initiative						
Exhibits scientific curiosity						

Science Challenge Suggested Marking Scheme

Name

Description of Activity

Due Date

	Weight	Score
Content		
Accuracy	5	____
Completeness	10	____
Range of coverage	10	____
Concept attainment	30	____
Presentation of Material		
Layout	5	____
Neatness	5	____
Organization of ideas	10	____
Language usage	10	____
Originality	10	____
Sources acknowledged	5	____
Graphs, tables, and charts	10	____
Supporting exhibits (models, etc.)	10	____
Deadline met	5	____
Interest level	10	____
	____	____
Oral Report	25	
	____	____
Bonus (submitted before due date)	5	____
Total		____

Factors of Scientific Literacy Developed in Chemistry

These checklists may be used in a variety of ways. Teachers may wish to use them to determine which factors have been covered throughout the entire year to ensure that adequate coverage has been provided for them. The checklists could also be used when covering a particular topic. Once factors which have not been emphasized in that topic have been identified, teachers can then use that information in their planning of subsequent topics to ensure that all of the factors have been given sufficient coverage by the end of the course.

Dimension A Nature of Science

Factors							
1. public/private							
2. historic							
3. holistic							
4. replicable							
5. empirical							
6. probabilistic							
7. unique							
8. tentative							
9. human/culture related							

Note: See the Appendices of *Science Program Overview and Connections K-12* for criteria on Dimension A useful for Rating Scales and Checklists.

Dimension B Key Science Concepts

Factors							
1. change							
2. interaction							
3. orderliness							
4. organism							
5. perception							
6. symmetry							
7. force							
8. quantification							
9. reproducibility of results							
10. cause-effect							
11. predictability							
12. conservation							
13. energy-matter							
14. cycle							
15. model							
16. system							
17. field							
18. population							
19. probability							
20. theory							
21. accuracy							
22. fundamental entities							
23. invariance							
24. scale							
25. time-space							
26. evolution							
27. amplification							
28. equilibrium							
29. gradient							
30. resonance							
31. significance							
32. validation							

Dimension C Processes of Science

Factors							
1. classifying							
2. communicating							
3. observing and describing							
4. working cooperatively							
5. measuring							
6. questioning							
7. using numbers							
8. hypothesizing							
9. inferring							
10. predicting							
11. controlling variables							
12. interpreting data							
13. formulating models							
14. problem solving							
15. analyzing							
16. designing experiments							
17. using mathematics							
18. using time-space relationships							
19. consensus making							
20. defining operationally							

Note: Teachers are encouraged to adapt this chart to create student Observation Checklists, Rating Scales, or Performance Assessments.

Dimension D Science-Technology-Society-Environment Interrelationships

Factors							
1. science and technology							
2. scientists and technologists are human							
3. impact of science and technology							
4. science, technology, and the environment							
5. public understanding gap							
6. resources for science and technology							
7. variable positions							
8. limitations of science and technology							
9. social influence on science and technology							
10. technology controlled by society							
11. science, technology, and other realms							

Note: See the Appendices of *Science Program Overview and Connections K-12* for criteria on Dimension D useful for Rating Scales and Checklists.

Dimension E Scientific and Technical Skills

Factors							
1. using magnifying instruments							
2. using natural environments							
3. using equipment safely							
4. using audiovisual aids							
5. computer interaction							
6. measuring distance							
7. manipulative ability							
8. measuring time							
9. measuring volume							
10. measuring temperature							
11. measuring mass							
12. using electronic instruments							
13. using quantitative relationships							

Note: See the Appendices of *Science Program Overview and Connections K-12* for criteria on Dimension E useful for Rating Scales and Checklists.

Dimension F Values that Underlie Science

Factors							
1. longing to know and understand							
2. questioning							
3. search for data and their meaning							
4. valuing natural environments							
5. respect for logic							
6. consideration of consequence							
7. demand for verification							
8. consideration of premise							

Dimension G Science-Related Interests and Attitudes

Factors							
1. interest							
2. confidence							
3. continuous learner							
4. media preference							
5. avocation							
6. response preference							
7. vocation							
8. explanation preference							
9. valuing contributors							

Note: Teachers are encouraged to adapt these charts for student Rating Scales or Checklists. The Appendices of *Science Program Overview and Connections K-12* contain criteria for these Dimensions.

Another approach is: on a scale of 1 to 5 how have your values or interests/attitudes changed? For the top 4 scores, describe the changes.

Unit Planning

What follows is one of many ways to plan a unit. No one method of planning is prescribed for use. What is important is that units be planned. Through planning, the maximum benefit for the students in each classroom can be achieved. The topics can be tailored to the interests, needs, and conditions which prevail within each class. Unit planning is an important part of adapting the curriculum to the classroom.

- Scan the unit overview and the foundational objectives to become familiar with the concepts to be discussed.

- Decide on the approach to be used with that unit. Consider the Common Essential Learnings, the Dimensions of Scientific Literacy, the interests of the students in your classes and the resources available.

- Analyze the resources you have. Select activities which deal with the foundational objectives for both chemistry and the Common Essential Learnings and promote development of scientific literacy. Adapt these activities so that they suit your students, the facilities and resources available, the learning objectives, and the initiatives of Core Curriculum. Try to select activities which involve varied instructional strategies so that the different learning styles and needs of your students are accommodated.

  Consider the initiatives of the Core Curriculum. How can Gender Equity, the Indian-Métis perspective, and agriculture in the classroom be emphasized and developed through this unit?

- Plan a sequence of the activities. Make sure that the schedule is flexible enough to make best use of the opportunities for enrichment and extension which will arise as the learning progresses in the classroom.

- Develop an evaluation plan. Select evaluation instruments and techniques which match the instructional methods you have used. Consider how self- and peer evaluation can be used to enhance the students' learning. Discuss with the students how evaluation of this unit will be done.

- Create a time schedule.

Model unit: Acid Rain

Unit overview and approach

This unit deals with the nature of acids and bases, the interaction of H^+ and OH^- ions with water, and the neutralization process. This is outline is presented as one way to approach the topic of acids and bases. Modify, adapt and use parts of this unit as you see fit.

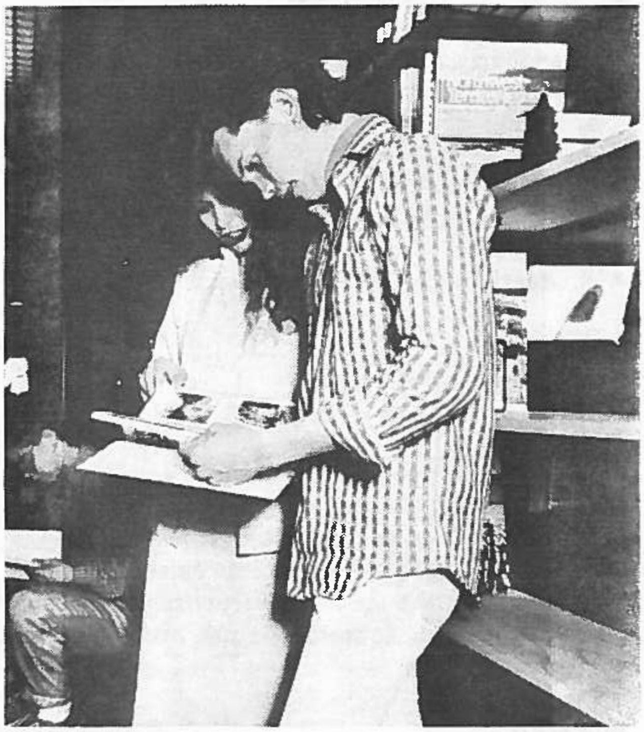
The unit will be developed as a study of acid deposition, more commonly known as acid precipitation or acid rain. The introduction of the topic to the classroom by newspaper articles highlights some of the relationships among chemistry, technology, society and the environment. Citizens must be scientifically literate to understand the source and extent of the problem and to be able to evaluate proposed solutions.

This unit, as do all units in grade 12 chemistry offers many opportunities to review and use the concepts and abilities learned during Chemistry 20 and during the preceding units of Chemistry 30. It is always good practice to assess the entry level of students and adjust the teaching to help them progress from that level to the desired standing. Concepts that are used in this unit to which students have had previous exposure are outlined below:

- the use of symbols, formulas, balanced equations for chemical reactions in all lessons
- lesson 2- solubility, chemical reactions
- lesson 3- chemical reactions, solubility, equilibrium
- lesson 4- use of mathematics, dissociation
- lesson 5-
- lesson 6- dissociation, equilibrium, stoichiometry
- lesson 7- chemical reactions, solubility
- lesson 8- solubility, chemical reactions
- lesson 9- chemical reactions

The times estimated for the lessons in this unit add to a total of 17 to 22 hours. Of this total, 8 to 10 hours can be allocated to the Acid-Base core unit, 7 to 8 hours to the Laboratory activities unit, and 3 to 4 hours (from lesson 9) to the Independent Research unit. Please note that 2 or 3 months preparation time is needed for you or the teacher-librarian to gather materials for lesson 9.

All the Common Essential Learnings can be developed and emphasized in the course of this unit. Personal and Social Values and Skills are promoted within class discussions and in the consideration of the question of how our lifestyle contributes to the production of acid deposition.



Considering the relationship between the demand for energy and the production of acid rain can lead to a discussion of individual responsibility for corporate action. Is a scientist responsible for all consequences which lead from a discovery, for only those reasonably foreseeable, or only for the direct effects? Does our desire to have gasoline cheaply available for our cars, our desire to have warm houses in winter and cool houses in summer, make us individually responsible for a related outcome — acid deposition?

This last matter links also to the Common Essential Learning of Technological Literacy, as do the measurements of the levels of acidity in rain and in lab samples, and the discussion of ways to reduce the impact of acid rain.

Independent Learning is inherent in lesson 9, where individuals or groups of students are responsible for finding answers to some questions and arguing others. Many of the activities (in lessons 1 and 2 for example) are structured to encourage Independent Learning. In these same activities are fostered the Common Essential Learning of Communication. As students discover information, devise procedures for experiments and consider issues, as well as present their reports to the class, their communication skills and abilities are enhanced.

Creative and Critical Thinking also has a strong presence in this unit. In the creation of the unit-end reports, the consideration of the reports of other groups and in the design and analysis of experimental procedures, students' reasoning and understanding is expanded. Numeracy is enhanced when students are asked to estimate, to use charts and graphs to extract information and meaning, and to apply the logic of proportionality in the stoichiometric sections of this unit.

Many of the factors of the Dimensions of Scientific Literacy can be developed within this unit. With the description of each lesson, the is a commentary on one or more of the factors of the Dimensions of Scientific Literacy which could be developed during that lesson. The description is not meant to restrict which factors are dealt with during the lesson, but simply to remind you that a **consideration of the factors of scientific literacy is an important part of planning for and reflecting upon science teaching**.

The same components which make the unit useful for dealing with the Common Essential Learning of Personal and Social Values and Skills also are critical for developing students' attitudes towards science and their understanding of the interrelationships among science, technology, society and the environment. The unit can be a forum for the discussion of factors D2, D3, D7, D8, D9, and D10. By looking at the unit in light of the factors of each Dimension, help in planning the approach to discussion and formulating evaluation and research questions is available. Here is an opportunity to discuss technology being controlled by society (D9), both from the point of view that publicly-held corporations are major emitters of the precursors of acid rain and that government regulatory agencies set standards for emissions. Society controls the emitters, the regulators, and is composed of people who have the power to demand that technology be developed to reduce the impact. How does the factor D8 — limitations of science and technology — interact with demands that the emissions of acid rain-causing chemicals be reduced?

Science is human/culture related (A9). With data gained (C3, D4) by monitoring the quality of air and water, we recognize that we affect our environment, we analyze both qualitatively and quantitatively (C12) how we affect that environment, extrapolate (B11, C10) to produce future scenarios, and debate (A9, C19, F6) what actions could and should be taken to make our future environment habitable. These considerations are also important in giving students a chance to examine some of the values which underlie science. The search for data and their meaning (F3), respect for logic (F5), consideration of consequence F6), valuing natural environments(F4), demand for verification (F7), and consideration of premises (F8) all have strong links to the possible activities in this unit. This unit, too, is one in which both avocation (G5) and vocation (G7) in science and science-related topics can be encouraged. By giving students a chance to develop a strong understanding of the issue both response preference (G6) and explanation preference (G8) for science can be developed. Those persons who do the basic research in this area, as well as those who take public stands and popularize the concern, can be seen here as persons who are making valuable contributions to science, technology, and to our society.

Among the key science concepts, B1- change, B2- interaction, B5- perception, B16- system, B15- model, B10- cause-effect, B11- predictability, B19- probability, B21- accuracy, B27- amplification, B28- equilibrium, B31- significance, and B32- validation could be emphasized.

Resources identified

- newspaper articles
- ideas for activities from a variety of sources, including the curriculum guide, texts, journals and other print materials
- videos
- SRC Technical Report #122 (December 1981)
- household solvents and solutions brought by students
- chemicals and equipment from the laboratory

Lesson 1 (1 hour)

Objectives

- Observe some physical and chemical characteristics of acids and bases.
- Investigate the nature of the production and use of acids and bases in our society.
- Appreciate how use of the principles of acid/base reactions has influenced our lives.
- Value the role of technology in studying acid/base reactions.

The day before you start this unit, assign reading the newspaper articles titled ***North of Sixty*** and ***Alberta oil sands plants may threaten Saskatchewan*** (pages 71,72) to your students as homework. Ask them to make brief notes on their reading. You might assign both articles to each student, or one to each member of a pair. This would depend on the time available, the reading abilities, interest levels, and motivation levels of the students, and the degree to which you wish to immerse them, figuratively speaking, in the topic. Ask them to generate a list of questions about acid rain raised by the articles, and a list of terms which must be understood to make sense of the articles.

During the first class of the unit, discuss with them what they know about acid rain, and what questions and terms they listed. If it becomes necessary, supplement the points raised in the discussion and the students' responses to the above questions with those from this list, and others you may create.

Questions

- How can an expansion of the capacity at the Syncrude plant poison Saskatchewan lakes with acid rain?
- Why are pre-Cambrian shield lakes sensitive to acid rain?
- How does acid rain kill the lakes?
- What is a lake with high tolerance for acid rain?
- What is a moderately sensitive lake?
- What does air quality monitoring have to do with acid rain?
- What are background levels of acids?
- Where do airborne sulphates and nitrates come from?
- Why is the northern environment fragile?
- How do magnesium and calcium act as buffering agents?

Terms

- nitrogen oxides
- pre-Cambrian shield
- neutral
- acid levels
- acid rain
- migration of airborne emissions
- oil sands
- sensitive lakes
- emissions
- sulphur dioxide
- pollution
- inorganic ions
- ion balance

Record on a large poster the questions and terms identified during the discussion. Use this poster for reference during the course of the unit and to help adapt and select activities.

Construct a concept map with acid rain (or acid deposition or acid deposition) as the central concept. This can be done as a class or can be assigned to groups of three or four. On the concept maps, highlight areas which involve the questions and terms generated during the class discussion.

Factors The factor A3 – holistic – could be emphasized in this lesson. The newspaper articles deal with the chemical aspects of the production of acid deposition and the interaction of the precipitation with the chemistry of the lakes in northern Saskatchewan. The precipitation has an effect on the ecology of the region. Weather systems move the pollutants from their source to where they are deposited. An understanding of aspects of chemistry, biology and meteorology are needed to understand the production, distribution and impact of acid deposition.

Factor D8 – limitations of science and technology – could be discussed in the context of Syncrude spokesman David Young's comment that emissions will be reduced with expansion of the plant because of improvements in pollution control. What are these improvements? Why can't they be implemented in the current plant? Why will 265 tonnes per day still be emitted after improvements are made? Why can't all emissions be eliminated?

Evaluation The discussion of the articles, the creation of a list of questions and terms, and the development of concept maps gives the teacher a chance to informally assess the students' understandings of acids, bases and associated concepts. This information can be used in adapting and shaping the activities of the unit to be of most benefit to the students. Some planned activities may be omitted or extensively altered, others added, and the concept mapping exercise may be repeated at intervals in order to meet the needs of the students.

Concept maps are a form of student self-evaluation. Their construction gives students a chance to express their understanding and monitor the development of their thinking about the concept. It gives them a chance to discuss their ideas with their peers and compare and assess their understanding.

Lesson 2 (2 hours)

Objectives

- Identify some acids and some bases which are used in common household products.
- Observe some physical and chemical characteristics of acids and bases.
- Construct an operational definition of an acid and a base, using the characteristic properties of those substances.
- Describe the Brønsted-Lowry conceptual definition of acids and bases.
- Collect and organize data in charts and graphs.
- Interpret collected data.

As you explore the concepts in these activities, relate them to the questions and terms listed during the discussion in lesson 1. What is an acid? How can acids be produced? What is a base? How can bases be produced? These questions form the focus of the second lesson.

Use litmus paper to test various substances. These substances may include those prepared in the laboratory and those which students have brought from home. Check the substances which the students have brought from home to ensure that they are safe to use in this activity. Substances provided from the laboratory might include these chemicals, all with strengths of 0.1 mol•L^{-1}: $HCl_{(aq)}$, $CH_3COOH_{(aq)}$, $NaHCO_{3(aq)}$, $Na_2CO_{3(aq)}$, $NH_4OH_{(aq)}$ and $NaOH_{(aq)}$. $CH_3COOH_{(aq)}$ and $Na_2CO_{3(aq)}$ with strengths of 6.0 mol•L^{-1} and 1.0 mol•L^{-1} can also be used.

Regardless of source, the samples should be clearly labelled by the chemical or common name. Save what is not used of these samples in this lesson for use in lesson 3. Discuss the litmus test as an example of an operational definition: An acid is a substance which causes litmus to be red; a base is a substance which causes litmus to be blue. How can litmus be used to establish that a solution or liquid is neither acidic nor basic? Identify other properties which contribute to operational definitions of acids and bases.

Ask the students to design a procedure to discover if the pH is altered when $CO_{2(g)}$ dissolves in water. When the students' designs have been discussed, have them do the activity.

Use also the activity involving $SO_{2(g)}$ and car exhaust on page 156 of this guide.

Have the students make and test a base by reacting a very small piece (equivalent to 2 mm length of a toothpick) of calcium or sodium with about 5 mL water. Discuss the nature of the reaction with them so that they understand completely the need to wear goggles and follow safety precautions during this, and every other, activity. (Exercise extreme caution in reacting calcium or sodium with water – make sure that the piece is small.)

Burn a small piece of magnesium ribbon in air to illustrate the production of MgO from Mg. Distribute a small portion of magnesium oxide powder to each group. Have them mix it with water and test the mixture with litmus. The powder distributed to each group need not come from the burning process. The burning process is only to show one way that $MgO_{(S)}$ is produced.

Concepts which can be reinforced or reviewed during this lesson are the use of symbols and formulas, the writing of balanced equations for chemical reactions, and solubility.

Assign for reading a section in the text which deals with characteristics of acids and bases, and the Brønsted-Lowry definition of acids and bases.

Factors Classifying (C1) and manipulative ability (E7) are two of the factors which could be emphasized during this lesson. The use of litmus paper to group chemicals according to their acidic character is part of one of the fundamental activities of science. In classification, we search for an organizing principle which can help us understand how things work. What are the common characteristics of those substances which are classified as acids? Can such a recognition help us to predict whether untested substances will be acidic? Manipulative ability is the key to producing consistent, replicable results in these activities.

Evaluation Select three lab groups and fill in the group checklist. (Distribute copies of this checklist to students at the start of the year. Inform them that in each lab activity period, two or three groups will be rated, with all group members receiving the same mark.) Also provided (page 65) is a checklist which the students may use to rate your performance as you do demonstrations. In this lesson, you may distribute it for use during and after the burning of magnesium demonstration. Create written response test questions dealing with the lesson's objectives.

students' names: criteria for assessment	rating
uncluttered workspace	yes no
materials for activity organized	yes somewhat no
entries made in journal of each group member	yes no
safe practices followed notes on safety:	yes no
area cleaned	yes no

criteria	rating
Was the workspace uncluttered?	yes no
Were the materials for the demonstration well organized?	yes somewhat no
Were student tasks during the demonstration clearly explained?	yes somewhat no
Were safe practices followed? notes on safety:	yes no
Could you see all aspects of the demonstration?	yes no
Was the demonstration discussed or summarized?	yes no
Was the work area cleared after the demonstration?	yes no

Lesson 3 (1 hour)

Objectives

- Observe some physical and chemical characteristics of acids and bases.
- Estimate the pH of solutions, using indicator solutions and indicator papers.
- Interpret collected data.
- Observe and record carefully during experimental or investigative procedures.
- Develop and conduct investigations and research.

Investigate the relative strength of the acidic or basic properties of each substance from lesson 2, plus additional solutions if desired. Two questions students could investigate are: how fast do the bubbles form when an acidic solution is dropped onto a piece of zinc? how does mixing a drop of an acid with a drop of the base change the pH of the solution?).

Factors Do the investigations produce predictable results? Can cause and effect be identified? Understanding of these concepts (factor B11 — predictability and factor B10 — cause-effect) develops during the consideration of results from these activities. To be able to distinguish between correlation and cause is a critical ability for scientifically literate citizens. The pseudosciences base much of their argument for validity on correlation. **Science is based on cause and effect relationships established by empirical investigation.**

The opportunity to comment upon the importance in science of the search for data and their meaning (factor F3) is also a part of this activity.

Evaluation This is a good opportunity to stress the importance of complete, organized, and accurate recording of data from investigations. You may prefer this to be submitted in a formal lab report, or may require a journal-type notebook, but the importance of accurate records of what has been done should be stressed. Holistic rating scales or checklist can be used to rate reports or journal entries. Students should be aware of the critieria on which their work is being assessed.

Rate another two groups using the checklist introduced in lesson 2. As well, scenarios involving data from these activities could be created for use on exams. Students could be asked to interpret a series of observations and measurements dealing with the effects of an acid on an unknown substance, and make judgements about the unknown substance. Alternatively, data from the reaction between an unknown substance and a metal could be given, with interpretations requested about the acid character or strength of the substance.

Continue evaluation of the safety of the facilities and equipment.

Lesson 4 (1 hour)

Objectives

- Describe the Brønsted-Lowry conceptual definition of acids and bases.
- Identify the conjugate bases formed in acid dissociation.
- Identify the conjugate acid of any base.
- Write the equilibrium constant expression for the dissociation of water.
- Recognize the relationship between the $[H^+]$ and $[OH^-]$ in an aqueous system.

Examine conceptual definitions of acids and bases, including the Brønsted-Lowry definition. Stress the importance of dissociation to release H^+ ions which can associate with water molecules to form H_3O^+.

Consider the dissociation of water, the value of Kw, and the role of water in acid dissociations, as well as its capability of acting as an acid. Describe litmus as a dye which is sensitive to the level of H^+ or H_3O^+ in a solution. If there are more H^+ or H_3O^+ ions than in water, litmus is red. If there are fewer H^+ or H_3O^+ ions than in water, litmus is blue. That the change point is equivalent to the level in water is the circumstance which allows litmus to divide substances into the groups acids and bases. Other indicators have different change points.

Demonstrate the differences in conductivity among acids. You may need to establish the relationship between conductivity and presence of ions in a solution. Appropriate acids for this demonstration are 6.0 $mol{\bullet}L^{-1}$ HCl, glacial acetic acid, 1.0 $mol{\bullet}L^{-1}$ HCL, 1.0 $mol{\bullet}L^{-1}$ acetic acid and distilled water. Ask students to account for the difference in terms of dissociation.

Introduce the relationship between the amount of dissociation and the acidic properties of the solution.

Factors In this lesson, quantitative relationships (E13) are used to relate the concept of equilibrium (B28) to the study of acid deposition. Equilibrium is described mathematically. The theory of equilibrium can be used together with measurements from systems which were not used during the origination or the testing of the theory to help explain what is happening in the new system. This illustrates the power and the validity of the theory. It is important that students understand the power of scientific theories.

Evaluation This is a good point in this unit to use a short quiz to assess students' ability to use numbers expressed in scientific notation and to do calculations involving multiplication, division and square root using numbers in scientific notation. Extra teaching or review may have to be undertaken. Often, students who understand the principles can be invaluable in explaining them to their peers. Organizing of heterogeneous lab /working groups in your classroom promotes this interaction.

Lesson 5 (1 hour)

Objectives

- Estimate the pH of solutions, using indicator solutions and indicator papers.
- Interpret collected data.
- Discuss with peers how estimates of values are made.
- Observe and record carefully during experimental or investigative procedures.
- Develop and conduct investigations and research.

What is meant by acid level and the pH of a substance? Ask the students to recall where they have seen or heard the term pH used. (shampoos, swimming pools...) Recall how litmus was used to determine whether a substance was an acid, a base or neither.

Distribute a pH scale diagram (page 70). Identify neutral as 7 and that litmus simply places a substance on one side or the other of that line. Also distribute (page 70) or refer in a text to a list of dyes (indicators) which change colour at pH values other than 7. Discuss how these indicators could be used to estimate pH.

Supply the students with a variety of indicators. Methyl violet, methyl orange, bromothymol blue, and alizarin yellow would be an appropriate selection. Ask them to use the indicators to estimate the pH of each unknown solution. Use the substances from lesson 2.

After they have estimated the pH of the solutions, discuss the variety of levels of acidity found and the difficulty of using one indicator to estimate pH.

Introduce the use of universal indicators, pH paper or pH meters to pinpoint the pH more easily.

Factors Understanding the use of indicators as boundary markers between regions of lower pH and higher pH requires them to understand the logic (F5) of how indicators work and how we do classification. The selection and use of two or more indicators to narrow the pH range in which the test solution is found requires application of logic. In addition to an appreciation that the steps must be logical, the identification of the pH of solutions by use of indicators requires problem solving (C14) and analysis (C15). Within a lab group, the estimation of a pH value from the data available may require some consensus making (C19). The use of a pH meter will make them appreciate the contributions of technology (D1) to the study of science.

Evaluation Rate two more lab groups, using the checklist introduced in lesson 2. Remind students of the importance of keeping complete records of what is done in the laboratory. Do spot checks on their notebooks or journals. If they are making measurements, ask them to consider whether there are visual observations which they can record as well. If they are making descriptive observations, ask them if there is anything they could measure. Set a date for laboratory reports or journals to be turned in for marking. Rating scales and checklists are useful for deciding upon grades. Ensure that students understand the criteria on which the marking is based.

Lesson 6 (2 hours)

Objectives

- Identify the conjugate bases formed in acid dissociation.
- Associate acid or base strength with magnitudes of K_a and K_b.
- Identify the conjugate acid of any base.
- Recognize substances which are amphiprotic (amphoteric).
- Compare the strengths of the dissociations in the dissociation series for a polyprotic acid.
- Calculate the $[H^+]$ in a solution.
- Express the $[H^+]$ as a pH value.
- Explain how a logarithmic scale differs from an arithmetic scale.
- Use information from K_a tables to calculate pH values in solutions and check results of calculations with indicators.
- Compare the nature of scientific knowledge with knowledge in other areas of study.

Review dissociation of water and acids. Relate the pH value to the level of H^+ ions in the solution. Write equations for the dissociation of several acids. Use a K_A chart to calculate and estimate levels of acidity ($[H^+]$) in solutions. Do calculations involving integral pH values.

Factors This lesson is important in the development of response preference (G6). The narrative report is easier for most students. Encourage them to use measurement, and mathematical analysis and manipulation of their measurements, to communicate what happens during an investigation. It is also important to stress that valid measurements can be replicated (A4). This process of replication of results is critical in establishing the validity of both results and theory. Theories must make predictions which are testable, and the tests probe those predictions.

The Proton in Chemistry, from the **World of Chemistry** series, is available from Media House and is a good support for this lesson.

Evaluation This lesson is a good source of problems for examinations. Distribute a mid-unit take home exam booklet to gain an idea of how students are progressing in problem solving. The exam booklet format can be produced by folding two sheets of paper in half and stapling along the fold to produce a 14 cm by 21 cm booklet of eight pages. The front cover can describe the assignment, and the problems distributed one per page. This gives students a chance to try questions similar to those which will be on the exam in a situation where they can work at their own speed and ask you or their peers for help. When all have finished, answers can be posted for the questions or they may be taken up as part of the review for the unit test.

This suggestion is adapted from an idea submitted by Elsie Eade of Moose Jaw.

Lesson 7 (4 hours)

Objectives

- State the general neutralization equation: acid + base $\rightarrow$ salt + water
- Write equations for specific neutralization reactions, identifying the nature of each species.
- Solve mathematical problems involving data from titrations.
- Develop skill in doing titrations.
- Observe and record carefully during experimental or investigative procedures.
- Collect and organize data in charts and graphs.
- Interpret collected data.

What is neutralization? Add, by drop, some base to a sample of acid. Monitor the pH, using a pH meter, pH paper, or universal indicator in the solution. Continue adding base until the limit of your indicator or pH paper is reached. If you use dilute (0.1 $mol \cdot L^{-1}$) HCl as the acid, a concentrated strong base such as 2.0 $mol \cdot L^{-1}$ NaOH is appropriate. 10 mL of the HCl is a reasonable volume for this activity. Graph the approximate pH against the number of drops of base used.

Discuss the stoichiometry of neutralization. Do an activity involving a titration.

Factors A critical factor when using indicators to estimate pH values is the perception of colour. During the shift of bromothymol blue from yellow to blue, just how green the solutions is (yellowish-green or bluish-green) is a matter of perception (B5). If there is some way to measure the colour or some standard series of colour gradations to match, the estimate can be less reliant on individual perception. That is why phenolphthalein, with its change from colourless to pink at pH=8, is preferred for titration. From absence of colour to pink is an easier judgement than judging the tone of green of a titration.

Evaluation In addition to providing test problems, this activity may serve as a source for components of a performance task. Techniques appropriate for performance testing might include: reading the level of a buret; delivering a particular volume from a buret; graphing a titration curve when given data; colour matching indicators; and, using a serial dilution to produce a solution of a particular strength. A checklist of process skills which are expected to be exhibited during the performance task facilitates assessing the achievement of the student or group.

Lesson 8 (1 hour)

Objectives

- Estimate the pH of solutions, using indicator solutions and indicator papers.
- Write equations for specific neutralization reactions, identifying the nature of each species.
- Explore how knowledge about acid/base reactions has both explained existing applications and suggested new applications .
- Value the role of technology in studying acid/base reactions.

Use dilute H_2SO_4 to simulate acid rain. Why is this acid a good choice for this simulation? Write a series of equations for the reactions involved in converting the sulphur atoms in crude oil into acid rain. You might demonstrate the effect of one or two drops of concentrated H_2SO_4 on a piece of paper towel

Each group should prepare or obtain 10 mL of 1.0×10^{-1} $mol \cdot L^{-1}$ H_2SO_4. On a strip of pH paper, make a reference spot with a small drop of distilled water and another with a small drop of H_2SO_4. You might practice so that you can place small drops side by side on the paper but yet remain discrete or at least distinguishable.

To 5 mL distilled water in a 50 mL beaker, add a drop of the H_2SO_4. Mix thoroughly and place a small drop of this solution at one end of another strip of pH paper. Add another drop of H_2SO_4, mix, and place another small drop of the solution next to the first on the pH paper. Continue this process until the colour on the pH paper matches the colour of the acid reference spot. By counting the dots on the pH paper the number of drops added can be determined.

Repeat this process using 5 mL of 1.0×10^{-2} $mol \cdot L^{-1}$ $NaHCO_3$ instead of distilled water.

Repeat again, using 5 mL of 1.0×10^{-2} $mol \cdot L^{-1}$ Na_2CO_3 instead of distilled water.

Compare and discuss the results of all three procedures. Why can the distilled water be compared to the northern lakes of Saskatchewan, and the $NaHCO_3$ and Na_2CO_3 solutions to the southern lakes?.

Factors This simulation of the acid systems in Saskatchewan lakes is an attempt to link the learning from science to a concern for the natural environment (F4) and understanding of how human and natural activity influences the environment (D4). Whether the $SO_{2(g)}$ comes from avolcano, a smelter or the combustion of coal, its chemistry and ecological effects are identical.

Evaluation Two more lab groups can be rated using the checklist introduced with lesson 2. A written response question on the unit examination could ask students to discuss why lakes in the pre-Cambrian region of Saskatchewan are more sensitive to the effects of acid deposition than are the lakes of southern Saskatchewan. Develop criteria for assessment of the responses. Consider sharing these criteria with the students.

Lesson 9 (3 - 5 hours)

Objectives

- Investigate the nature of the production and use of acids and bases in our society.
- Develop and conduct investigations and research.
- Understand the meaning of theory in science.
- Compare the nature of scientific knowledge with knowledge in other areas of study.
- Value the role of technology in studying acid/base reactions.

This lesson is one which would benefit greatly by some cooperative planning with the teacher-librarian. Two to three months to assemble appropriate and adequate resources for the research is not unreasonable. This is an important lesson. It shows the strong ties between chemistry, biology and geology.

Divide the class into six groups. Assign each group the task of reporting on one of the areas described below. The report should include a written report of the group's findings, a summary of this report for distribution to all class members and an oral presentation to the class. The oral presentation should be illustrated with posters, pictures, diagrams and equations for chemical reactions.

- What are the main chemical components of acid deposition? How do these substances get into the air? How does our lifestyle contribute to their presence in the air? How far can they travel from their source? What are some of the ways of preventing them from getting into the air?
- Does the pH of soil change because of acid deposition? How does the geological history of southern Saskatchewan ensure that lakes in that region are resistant to the effects of acid deposition? Why are lakes found in the pre-Cambrian bedrock region susceptible to lowered pH levels from acid deposition?
- How does the pH of lake or river water influence plant life in that medium? What specific effects of a decreased pH level are seen in aquatic plant growth? Is there the same degree of effect on all aquatic plants? How do acidic conditions cause these effects?
- What are some of the direct and the indirect effects of increased acidity on aquatic animals? How does the acid cause these effects?
- How does acid deposition affect buildings and statues of stone? Is all stone affected? Does acid deposition affect other human structures or artifacts?
- Is there a direct effect of acid deposition on the leaves and stems of terrestrial plants, or as the acidic water is picked up by the roots? Are there indirect effects on plant growth attributable to acid deposition?

The lesson is allotted three hours. Identifying, organizing, and allocating tasks, and beginning the research should take one period. The second period could be used for organizing the information discovered and starting the synthesis of this information into a report. The third class is left for the presentation of reports. Students should do about three hours work and preparation outside of class time for this lesson.

Some groups may want to view the videos *Acid Rain Part 1 — What is Acid Rain* and *Acid Rain Part 2 — The Effects of Acid Rain*, available from Media House Productions, as part of their research for their presentation.

The third video in that series, *Acid Rain Part 3 — What Can We Do?* is an excellent summary of the problem of acid deposition and the difficulty of finding solutions. Consider using it as a centre for a discussion to conclude lesson 9. The article "Acid aerosols a problem" (page 73) could also provide a starting point for discussion.

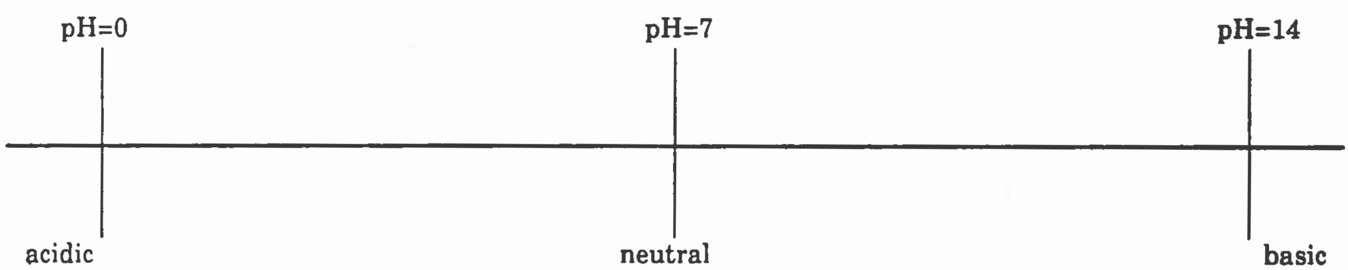
Factors This lesson affords the chance for students to develop an explanation preference (G8) for arguments supported by theories and explanations from science. The nature of the questions posed forces them to consider the consequences of acid deposition (F6), demand verification of propositions (F7) and consider the premises (F8) of the arguments of both sides in the acid deposition debate. Social influences on science and technology (D9) will almost certainly be considered.

Evaluation During the first period of this lesson use a class discussion to decide upon the criteria with which the projects developed will be assessed. Consider using some component of peer assessment, especially in rating the oral presentations. Use this opportunity to discuss with the students why and how they are evaluated.

Lesson 10 (1 - 4 hours)

Review the concept map(s) produced during lesson 1. Revise the map(s) in accordance with the understanding of acid deposition which the students now have. Review the questions and terms that arose from the reading of the newspaper articles. Discuss the important concepts in acid-base chemistry which have been studied in this unit. Introduce any concepts which have not yet been introduced, but which are needed for an adequate understanding of this area of chemistry.

Factors Depending on what is done during this lesson, opportunities to discuss various factors will emerge. Please keep in mind that the overall goal of science in Saskatchewan classrooms is to develop scientifically literate students, as defined by the factors of the Dimensions of Scientific Literacy, and that you have the chance to do that in the context of chemistry.



Indicator	Colour at acidic end of range (lower pH)	pH values for colour change	Colour at basic end of range (higher pH)
methyl violet	yellow	0 1.6	blue
methyl orange	red	3.2 4.4	yellow
litmus	red	5.5 8.0	blue
bromothymol blue	yellow	6.0 7.6	blue
phenolphthalein	colourless	9.4 10.6	red
alizarin yellow	yellow	10.0 12.0	red

Alberta oil sands plants may threaten Saskatchewan lakes

Saskatoon (CP) – Thousands of lakes in northern Saskatchewan could be polluted by full-scale development or oil sands in northeastern Alberta, says a government spokesman.

Larry Lechner, director of Saskatchewan's air quality branch, said Wednesday a new study has confirmed fears that lakes in the pre-Cambrian shield region, downwind from the Syncrude Canada Ltd. and Suncor Inc. oil sands plant in Alberta, are sensitive to acid rain.

Lechner said if oil market conditions encourage an expansion of capacity at the Syncrude plant near Fort McMurray, lakes and rivers in Saskatchewan could be poisoned by acid rain.

A spokesman for Syncrude, which now is permitted to release 292 tonnes a day of sulphur dioxide and other emissions from its oil sands plant, said pollution will actually be reduced by future expansion.

Lechner said if emission of sulphur dioxide and other pollutants was substantially increased through a proliferation of oil sands plants, lakes in northern Saskatchewan could wind up like the thousands of dead and dying lakes in Central and Eastern Canada.

Syncrude spokesman David Young said emissions from the plant will be reduced to 265 tonnes a day when the current expansion is completed because of improvements in pollution control.

Emissions will remain at that level even if Syncrude decides to go ahead in 1989 with a further 50-percent expansion of its capacity to 225,000 barrels a day, Young said.

Suncor, which produces about half as much oil as Syncrude, has not announced expansion plans.

Lechner said a survey of northern lakes, coupled with material from environmental impact statements and other sources, indicates Saskatchewan lakes are not now suffering from acid rain.

He said similar surveys have been done in the other western provinces and will be combined in two or three months to produce a map indicating regional sensitivities to acid rain.

Lechner said the Saskatchewan study showed that except for a band of moderately sensitive lakes south of the pre-Cambrian shield, lakes in the province have a high tolerance for acid rain.

Reprinted from the Regina Leader Post, March 1989, with the permission of the Canadian Press.

North of Sixty

SRC's expertise is available when and where needed. And that often takes our scientists and engineers across provincial boundaries and even around the world.

When the government of the Northwest Territories called with questions about air pollution in the Arctic and the effects of acid rain in a northern environment, SRC's Atmospheric Processes team was able to help. Research scientist Stan Shewchuk heads the group. "Broadly speaking, our area of expertise is air quality monitoring. We work with a variety of industries and government departments to measure the effects of their activities on the air and on land where most airborne emissions fall."

The Northwest Territories is far removed from the heavy industry of southern Canada. Is acid rain being transported to the Territories? Shewchuk's answer is: "We found acid levels in snow and lake water that ranged from measurable amounts right down to nothing above background levels. But we did not find the high levels common in eastern Canada and the U.S.

"Airborne sulphates and nitrates are the source of acid rain. In some cases, their migration has been tracked to sources thousands of kilometres away. Scandinavia, for example, is affected by emissions from the United Kingdom," he says.

"In the Territories' case, emissions from the Tar Sands project in northeastern Alberta and mine smelters in northwestern Manitoba are blown north, on an occasional basis, into the southern areas of the NWT's District of MacKenzie," says Shewchuk.

"That's the area we sampled: six small lakes south and east of Great Slave Lake, all but one in the Precambrian Shield." Using a ski-equipped plane, the crew stopped at each lake to collect snow cores and lake water samples. Shewchuk says the area covered was large enough to be considered a regional study.

"We brought the samples back to our labs and analyzed them for acid levels and major inorganic ions. With that information we produced an ion balance which is a method of showing where the sulphates and nitrates fit into the overall chemistry of the water," he says.

The results of the work were reassuring but Shewchuk found that the potential for adverse impacts from acid rain is quite high in the Northwest Territories. "It's a very fragile environment and the lakes have very low levels of naturally occurring elements like magnesium and calcium. These elements, when present, act as buffering agents and help neutralize acid rain falling to the environment."

In recent work completed for the Saskatchewan Department of the Environment and Public Safety, Shewchuk and Stella Swanson, SRC Manager of Aquatic Biology, looked at the sensitivity of lakes in northern Saskatchewan. "As in the earlier Territories work, we found very low levels of buffering agents. That means our northern lakes don't have a natural ability to withstand acid rain," says Shewchuk.

Shewchuk says that vegetation in the Northwest Territories is also susceptible. "Even a moderate increase in the presence of acid rain would affect the growth of lichen which is a staple food for migrating caribou. The government of the Territories is taking the right approach by monitoring now rather than reacting to problems later, and by looking at the whole ecosystem rather than isolated parts of it."

*Reprinted from **SRC News**, Volume 5 #1 (September 1989), with the permission of the Saskatchewan Research Council.*

Acid aerosols a problem

air pollution pushing up death rates

Ottawa (CP) – There's growing evidence air pollution is pushing up death rates in some North American cities, say researchers.

Studies in several U.S. cities have found a correlation between episodes of high pollution and increased mortality rates, says Mark Raizenne, a scientist with the federal Health Department.

And there's concern air pollution may be a factor in the otherwise unexplained doubling of asthma deaths among Canadians aged 15 to 35 during the last decade, says David Pengelli, a researcher at McMaster University in Hamilton.

Much of the research is focusing on tiny particles known as acid aerosols – less a thousandth of a centimetre in diameter – coated with powerful acids, including sulphuric acid.
Acid aerosols are caused by the same emissions that cause acid rain, but they don't fall to the ground with rain. They remain suspended in the air even on a clear day.

Because of their small size they can penetrate deeply into the lungs when people breathe. They have received little attention until recently because the technology to measure them didn't exist.

The Canadian Lung Association and the Canadian Thoracic Society, along with their U.S. counterparts, issued a warning about acid aerosols last month.

"Recent monitoring data indicate that exposure to acid aerosols is widespread in North America," the associations say in a joint statement published in the August issue of the American Journal of Respiratory Disease.

"Acid aerosols have been linked with a broad spectrum of human health effects ranging from breathing discomfort, to bronchitis, to altered lung function and increased mortality rates."

The statement says a large segment of the population of the United States and Canada is chronically exposed to acidic air pollutants. Children, asthmatics and those who exercise outdoors are at greatest risk.

Areas of highest concentration in Canada are in southern Ontario, New Brunswick and Nova Scotia.

Studies involving animals have shown that acid aerosols cause narrowing of the breathing airways in some species. Clinical studies with volunteers have shown the same effects in humans, says the statement.

Pengelli participated in a scientific workshop for the Canadian and American lung associations that produced the statement on acid aerosols.

*Reprinted from the **Regina Leader Post**, September 23, 1991, with the permission of the Canadian Press.*

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Note: Please refer also to page 83 of *Science 10: A Curriculum Guide for the Seconary Level*, for other references of interest.

Chemistry 20

Introduction to Chemistry

Unit Overview

This unit is intended to familiarize students with some essential considerations of laboratory safety. For some students, this may be a review. For others, it will be new. It is prudent to assume that all students will profit from this discussion.

The learning objectives are general safety precautions that students should be familiar with. Other more specific precautions will arise during laboratory activities, and they should be brought to the students' attention at that time.

In addition,students should develop an understanding of the importance of chemistry in society, as well as how society influences the development of chemistry. The modes of thinking sanctioned by a society guide what members of that society look for and how what is seen is interpreted. What is searched for and how what is found is interpreted are key principles in how science and technology develop.

Students can investigate the societal implications of contemporary issues related to chemistry.

Although we think of science as being universal, science and the applications of science are both influenced by culture. How changes in chemical technology and products affect one society might be very different from how they affect another society or culture.

These principles are important to keep in mind throughout the study of chemistry.

Factors of scientific literacy which should be emphasized

A2 historic
A3 holistic
A7 unique
A9 human/culture related

B1 change
B2 interaction
B10 cause-effect

C3 observing and describing
C6 questioning

D2 scientists and technologists are human
D4 science, technology, and the environment
D5 public understanding gap
D6 resources for science and technology
D7 variable positions
D8 limitations of science and technology
D9 social influence of science and technology
D11 science, technology, and other realms

E3 using equipment safely
E7 manipulative ability

F1 longing to know and understand
F2 questioning

G1 interest
G5 avocation
G7 vocation

Foundational Objectives for Chemistry and the Common Essential Learnings

Recognize safe practices and explain the reason for each practice.

- Report to the teacher if contact lenses are worn.
- Report any allergies to the teacher.
- Identify the location of the fire blanket, fire extinguishers, eye wash station, and any other safety equipment.
- Know how to use the safety equipment in the laboratory.
- Restrain any loose clothing, jewellery, or hair.
- Wear eye protection whenever it is prudent or required.
- Maintain a clean, uncluttered work area.
- Gather and promptly dispose of any broken glass.
- Comply with fire drill regulations.
- Check procedures before carrying them out.
- Follow accepted principles for dispensing, handling, and disposing of chemicals.
- Recognize and minimize the hazards of toxic and corrosive chemicals.
- Treat all chemicals as if they were hazardous.
- Refrain from pipetting by mouth.
- Use care when operating a burner.
- Neither bring food into the laboratory, nor consume food while in the room.
- Wash hands after chemicals have been handled.

Identify and explain how chemistry affects us.

- Discuss how advances in chemistry have led to the development of new products.
- Outline the societal impact of new chemical products.
- Recognize that advances in chemistry are often driven by societal needs.
- Explain the relationship between science and technology.
- Identify some issues or problems for which a knowledge of chemistry is important in identifying causes and solutions.
- Recognize that some problems can not be solved by science.

Use a wide range of language experiences for developing knowledge of the importance of chemistry. (COM)

- Show understanding by providing an alternative rephrasing, drawing a diagram or making a model.
- Synthesize ideas gleaned from a variety of sources and media.
- Identify critical issues in factual and editorial argumentative messages from both print and non-print media.
- Create questions as tools to further understanding of concepts.

Develop an understanding of how knowledge is obtained, evaluated, refined and changed within chemistry. (CCT)

- Focus attention on personal knowledge, and gaps in that knowledge.
- Reflect upon how knowledge is created, refined and applied in chemistry.

Come to a better understanding of the personal, moral, social, and cultural aspects of chemistry. (PSVS)

- Understand how application of chemical principles through technology influences the natural environment.
- Establish arguments based on human rights, human needs or the needs of the environment with respect to the use of knowledge about chemical principles.
- Explore how moral principles influence judgements about the application of chemical principles.

Develop a positive disposition to life-long learning. (IL)

- Cooperate with each other in order to enhance understanding through shared information.
- Move from choosing among teacher-directed activities toward creating self-directed activities pertinent to chemistry.
- Develop a willingness to take risks as independent learners.
- Recognize the inevitability of profound change due to technological innovations and changes in society's values and norms.
- Be willing to try to influence change by continuing to learn and apply what is learned.

Suggested activities and ideas for research projects

- Adapt an article from *What's Happening in Chemistry* to use as a case study to introduce the course.

- Use *Organic Chemistry 2: ASA* or *Organic Chemistry 2: Polyethylene* from the **Concepts in Science** series. Although the terminology will be beyond most students understanding at this time, most of the concepts and references will be easily understood. Both videos convey the impact of chemistry and the interrelationships of science, technology, society and the environment.

- From Sections III, IV, V, IX, and X of the Laboratory Safety Checklist on pages 139-144 of the *Science Safety Resource Manual*, create a checklist for students to complete. Take time to discuss the reasons for safety rules and the implications of unsafe practices in the laboratory.

- Chapters 1 and 2 from *Science Process and Discovery* contain an excellent introduction to the nature of science. If these chapters were not already used in grade 10, they are well worth using as an introduction to Chemistry 20. The discussion of these chapters can serve as a focal point or a reference point during the rest of the course.

- "Chemistry of Consumer Products" from *Chemicals in Action* may be a useful way to motivate students to study chemistry. Alternatively, there are some problems or questions from the unit **Consumer Chemistry** in this guide that might be used to introduce the study of chemistry.

- When ethanol (or methanol) and saturated calcium acetate solution are mixed in a 5:1 volume ratio, a gel forms. Simultaneously pouring the liquids into a beaker produces sufficient mixing. The gel can be removed from the beaker and burned on a wire mat. Quantities of 5 mL acetate solution and 25 mL alcohol mixed in a 100 mL beaker are enough for each lab group to investigate.

  What effects are there when the 5:1 alcohol to acetate ratio is changed? What uses are there for this gel? What are some other examples of gels?

- Demonstrate the dehydration of sugar by concentrated sulphuric acid.

  Fill a 100 mL beaker to the 40 mL mark with table sugar (sucrose). Ask students to predict what will happen if 40 mL of water is added. Have them record their predictions, or record class predictions on the board. Mix and observe. Repeat the process (predictions and all) using 40 mL of concentrated (18 M) sulphuric acid instead of water. Since $SO_{2(g)}$ is generated by the reaction between the sugar and the sulphuric acid, do this in a fume hood, a well-ventilated room or outdoors. Concentrated sulphuric acid is extremely corrosive. Handle it with care and have a spill absorbing mixture available. Rinse the carbon column under running water for at least a minute. It can then be disposed of in ordinary garbage.

  Discuss the predictions and the results. Linus Pauling said that seeing this demonstration was the initial spark for his interest in chemistry.

- Create a poster which describes the risks associated with one chemical or one family of chemicals which are found in your school.

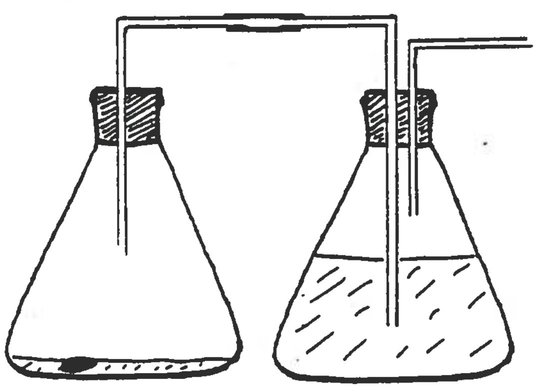
- Search through recent issues of newspapers and magazines. Clip any articles or advertisements which deal with chemicals, the chemical industry, chemical research or chemists. Mount these articles on a poster for display.

- If you could develop a new chemical for some use, what would that use be? (e.g. a chemical additive to rubber tires to prevent them from wearing out) Are there any chemicals now which do similar things? Has there been any research done on a chemical for the purpose you stated?

- Some chemical discoveries have had both positive and negative effects. Pick one chemical which has been synthesized or isolated in the twentieth century and describe its benefits and its drawbacks. Some examples of such chemicals are detergents, ASA, DDT or other insecticides, 2,4-D or other herbicides, vinyl.

- Take a piece of loose leaf paper and draw a vertical line to produce two equal columns. Record observations of the following demonstration in the left hand column. Use a separate point for each observation, and two or three lines between points. When the demonstration is complete, write in the right hand column an explanation for each observation.

Note to teachers: This activity is designed to give students a chance to make observations, interpret them and discuss the difference between an observation, inference and conclusion. Set up the demo as in the diagram.



Put 25 mL concentrated nitric acid into flask A. Fill flask B two-thirds full of water. (Five drops of phenolphthalein and enough 1.0 M NaOH solution to produce a medium pink colour are optional.) Put the stopper into flask B. Gently blow through the delivery tube from the stopper which will go into flask A to make sure that the tube is not blocked.

When everyone is ready to start observing, drop a short piece of copper wire or a penny into the acid in flask A and stopper immediately. NO_2 gas forms. It is very irritating to the eyes, mucus membranes and lungs. Make sure the stoppers are securely in place. The water bath should remove almost all of the NO_2 gas, but have a fume hood handy.

If your classroom configuration is such that not all students have a good view of the flask, consider setting up a closed circuit tv network with the camera at the site of the demo and one or more monitors elsewhere. You might also want to videotape this demonstration. Future classes could be shown the apparatus and then the tape of the demo.
(This activity was adapted from *CHEM13 NEWS*, #192, February 1990, page 4, based on an idea from Judith Putnam of Ellington, CT, reported by Bruce Hemphill of St. Catharines, ON)

Sample ideas for evaluation and for encouraging thinking

- Suppose you have a sister in grade 8. One day she asked you what chemistry is. Write a response to her question.

- List five practices that you and your classmates follow to make working in your laboratories safer.

- List five things you could do to make your work in the laboratory safer than it is now.

- Comment on the quotation "Chemistry is the process of finding out what substances are made of and modifying them for our use."

- How does chemistry affect the way we live?

- "Science is built up with facts, as a house is with stones. But a collection of facts is no more a science than a heap of stones is a house." — Henri Poincaré, a nineteenth century French philosopher and mathematician.

If chemistry is just a matter of remembering a bunch of facts about matter and its structure, and memorizing how to do problems about matter and its changes, then it is like a heap of stones or a pile of brick or a stack of lumber. A house has a structure that is produced by ordered relationships among building materials. Chemistry has a stucture that is produced by ordered relationships among concepts. Matter is made of atoms. Atoms can join together to form molecules. An atom can be manipulated to give up electrons. These are all ideas we believe because of observations that have been made and facts that have been established.

Concept maps or concept webs help us sort out the connection among concepts. So a concept map is one way to express the structure of chemistry as a science, as defined by Poincaré.

Starting with the broad concept **chemistry**, draw a concept map or web which expresses your ideas about chemistry. Once you have drawn it, find a partner. Compare your maps or webs. Explain them to each other. Then put them away until the end of the term. At that time you will draw another map or web. The two can then be compared. Remember that a concept map is never right or wrong, but it expresses what you understand about a topic.

Teacher's note: A concept map has a hierarchical structure. Thus, the map indicates both the priority and specificity of the concepts diagrammed on it. A concept web has a structure which shows relationships among concepts, but does not attempt to indicate any level of either importance or abstraction. For a complete description of concept mapping, see Novak, J and D. Gowin (1984). *Learning How to Learn* . New York: Cambridge University Press.

Laboratory Activities

Unit Overview

This unit is intended to be integrated with the other units in Chemistry 20, rather than being treated separately. The laboratory activities should be spread through the entire course, although one or two units may receive a greater allotment of laboratory activity time than the others. They should also target a wide range of factors within all seven Dimensions of Scientific Literacy.

The 20 hours of laboratory activity should be time that students spend actually performing activities. **Laboratory activities can be considered as having three separate phases: the preparation phase, the activity itself, and follow-up phase.** Demonstrations performed by the teacher should not be counted as part of the time devoted to laboratory activities, unless they involve a significant response and self-directed extension of the experience by the students.

Some of the activities may be more open-ended than others. Students should be encouraged to design and conduct their own investigations, when appropriate. Many activities are correlated to the topics of the curriculum in *Science: An Information Bulletin for The Secondary Level – Chemistry 20/30 Key Resources.*

Consideration should be given to the use of microscale experimentation. In an article in *Chem13 News* on microscale experimentation, Geoff Rayner-Canham, William Layden and Deborah Wheeler wrote:

> There are eight advantages of conversion to microscale.
>
> 1. The low cost of most microscale equipment. Many items are available in bulk from biomedical suppliers.
> 2. A reduction in chemical costs (though there is a short term increase in costs due to the purchase of microscale equipment).
> 3. An almost complete elimination of waste disposal problems.
> 4. A reduction in safety hazards. Not only are smaller quantities likely to present less severe safety hazards, but the use of plasticware precludes the possibility of injury due to broken glass.
> 5. Most experiments can be performed more quickly on the microscale.
> 6. Less space will be needed for storage as the volume of chemicals will be less. Also, the space needed for equipment storage is far less.
> 7. The microscale (twenty-first century) lab can be a clean, odourless, comfortable work environment in contrast to the cluttered, dirty, smelly, and dingy (nineteenth century) laboratory of the past.
> 8. Students really enjoy working with microscale equipment.

(from *CHEM13 NEWS*, #199, December 1990, page 8. Used with permission.)

More information on microscale experimentation can be found in *Chem13 News* February 1989 (#183), March 1989 (#184), January 1991 (#200), February 1991 (#201), and September 1991 (#205).

"Microscale Chemistry Experimentation for High Schools – Part II: Home Made Equipment" by Geoff Rayner-Canham, Deborah Wheeler and William Layden (*CHEM13 NEWS*, #200, January 1991) and "Iron:Copper Ratios, A Micromole Experiment" by Jacqueline K. Simms (*CHEM13 NEWS*, #200, January 1991) are included as Appendix 1 in this Guide.

Teachers should attempt to use a variety of student assessment techniques during the laboratory activities. Included among those should be techniques which can be used to obtain information in the psychomotor and affective domains. Rating scales, observational checklists, anecdotal records, and test stations could be included. If students are performing tasks which can not be done with pencil and paper, then it is not appropriate to base their assessment on the results of pencil and paper tests alone.

Factors of scientific literacy which should be emphasized

A1 public/private
A3 holistic
A4 replicable
A8 tentative
A9 human/culture related

B1 change
B2 interaction
B9 reproducibility of results
B10 cause-effect
B13 energy-matter

C2 communicating
C3 observing and describing
C4 working cooperatively
C5 measuring
C6 questioning
C7 using numbers
C8 hypothesizing
C9 inferring
C10 predicting
C11 controlling variables
C12 interpreting data
C15 analyzing
C16 designing experiments
C19 consensus making
C20 defining operationally

D2 scientists and technologists are human
D3 impact of science and technology
D6 resources for science and technology
D7 variable positions
D8 limitations of science and technology

E1 using magnifying instruments
E3 using equipment safely
E7 manipulative ability
E11 measuring mass
E12 using electronic instruments

F2 questioning
F3 search for data and their meaning
F5 respect for logic
F7 demand for verification

G1 interest
G3 continuous learner

Foundational Objectives for Chemistry and the Common Essential Learnings

Acquire concrete experiences of chemical events which form the basis for abstract understandings.

Gain proficiency in manipulating laboratory equipment.

Strengthen understanding within chemistry through applying knowledge of numbers and their interrelationships. (NUM)

Develop a contemporary view of technology. (TL)

Develop compassionate, empathetic and fair-minded students who can make positive contributions to society as individuals and as members of groups. (PSVS)

Independent Research

Unit Overview

This unit provides students with unique opportunities to do independent research on some topic in chemistry. The topic may be selected from ones provided by the teacher, or students may be given the responsibility of presenting proposals for their own research project. Guidelines for the projects can be developed with the class.

Clear criteria for assessment of the research projects need to be established, so that students can consider them when they are developing their project proposals. The proposals may be submitted in the form of a contract, indicating the work that an individual or a group agrees to complete by a specific date.

The independent research projects may be treated separately, or integrated with one or more of the units. If the projects are integrated, a common theme might be used for all of the projects. All of the research projects might be related to the **Atoms and Elements** unit, or to **Organic Chemistry**, for example. The student projects would then enhance the presentation of those units, providing additional motivation for learning. As a separate unit, students could select from a wide variety of topics. This allows students to direct their own learning needs and investigate topics of particular interest.

The projects can take many forms. These include: a review of the literature on a particular topic, the design of experiments to investigate some phenomenon, or conducting investigative research into an issue of current societal concern in the community. Science Fair projects could be developed. Many other possibilities exist. Not all students need to work on similar types of projects. **The key here is to allow for flexibility and innovation in independent research.**

Collaborative group projects can also be used to complete a project which is more extensive than could be undertaken by an individual, and to make use of the varied talents of the group members so that the product is greater than the sum of the individual efforts of those involved. Such projects require guidelines regarding the responsibilities of individuals within the group.

Plan cooperatively with a teacher-librarian, if available, so that students have the resources to do literature reviews and research. Strive to update the collection of chemistry-related resources in the resource centre. Government agencies, universities and associated organizations, and industries which produce or use chemicals are all sources of information for research projects, as are members of the community.

Factors of scientific literacy which should be emphasized

A1 public/private
A3 holistic
A7 unique

B8 quantification
B15 model

C2 communicating
C4 working cooperatively
C15 analyzing
C21 synthesizing

D1 science and technology
D3 impact of science and technology
D7 variable positions
D9 social influence of science and technology

E3 using equipment safely

F1 longing to know and understand
F5 respect for logic
F7 demand for verification

G1 interest
G2 confidence
G3 continuous learner
G4 media preference
G5 avocation
G6 response preference
G8 explanation preference

Foundational Objectives for Chemistry and the Common Essential Learnings

Investigate problems in chemistry and in the application of chemistry.

Develop abilities to meet own learning needs. (IL)

- Write proposals for individual or group projects, including such things as: a completion date, criteria for assessment, resources to be accessed, preferred method of presentation, suggested audiences for presentation, and meeting dates for review and collaboration.
- Take responsibility for their own learning by setting goals, designing plans, developing proposals, suggesting baseline performance levels, organizing allotted time, managing activities, evaluating success, and reviewing the entire process.
- Demonstrate an ability to access information from a variety of resources.
- Follow guidelines for completing a specific learning task.
- Explore issues or topics which address their interests and concerns.

Develop an understanding of how knowledge is created, evaluated, refined and changed within chemistry. (CCT)

- Participate in scientific inquiry.
- Focus attention on knowledge and gaps in personal knowledge related to a specific topic.

Develop compassionate, empathetic and fair-minded students who can make positive contributions to society as individuals and as members of groups. (PSVS)

- Learn in a climate that is sensitive, flexible and responsive.
- Collaborate with teachers and others to determine and monitor their own learning processes.
- Work cooperatively with others.
- Accept and respond to constructive criticism responsibly.
- Share the results of their research project with other students, teachers, parents, or members of the community.
- Share the results of their research by developing displays, exhibits, performances, presentations, demonstrations, lectures, or other appropriate methods.

Ideas for research projects

Note: Other ideas for research projects may be found in the **Consumer Chemistry** unit. Look for opportunities to link subject areas.

- The mining industry is an important part of the economy of Saskatchewan. What elements and compounds are produced from Saskatchewan deposits? What are the chemical formulas of the ores or raw product for each of the elements or compounds produced? What are the chemical processes used to separate gold and uranium from their ores? Where is the market for sodium sulphate and what is it used for?

- What are plastics? How is natural gas (methane) used in the plastics industry? Could we do without plastics?

- What consequences are there if one eats or drinks while in a chemistry laboratory? Are there instances of poisoning or ill effect due to such activity? Research cases of chemical ingestion while eating, smoking or drinking in a laboratory.

- Create a list of Canadian discoveries and inventions in, or which can be linked to, the field of chemistry. Using one of the items on the list, write a report on the person(s) who made the discovery and how knowledge of chemistry was advanced or applied by the person(s). One source of information is Ainley, Marianne *Despite the Odds: Essays on Canadian Women in Science* (1990), U of Toronto Press. (This activity has been adapted from "Canadian Scientist Study: One Way to Incorporate the CELs" , by Valerie Mitschke, in the *Accelerator*, 16:4 (June 1990).

- How is coffee decaffeinated? What is the caffeine which is removed from the coffee used for? In what class of chemical compounds is caffeine? What are some related compounds? What are the chemical mechanisms involved in the stimulating effect of caffeine on humans?

- What are colligative properties? Why do they have the effect that they do? How is knowledge of colligative properties applied? How could McGyver use a knowledge of colligative properties to his advantage? Design a demonstration or investigation which can help the other students in your class understand what colligative properties are.

- What is the chemical difference between soaps and detergents? What properties of each make them effective for their tasks? What effect does each have on the environment?

- What chemical reactions are involved in the production of warming and cooling effects by commercially available hot-packs and cold-packs? Make a version of each pack. Explain the chemistry and demonstrate the effectiveness of your packs to your class.

- Buildings in Saskatchewan have among the highest levels of radon gas in Canada? What is radon gas? How is it produced? How does it get into buildings? What are its effects on humans? Does it have any effect on other animal life or on plants?

- Organic producers and many others claim we are poisoning ourselves by consuming food which has been treated during production and storage with insecticides, herbicides and fungicides. How much of a hazard is consumption of residual applied chemicals? Compare the risk from applied chemical residues to the risk from natural plant chemicals and toxins produced by microorganisms.

- What is Agent Orange? How was it used in the Vietnam war? What problems does it cause for people who are exposed to it?

- What are some ways that herbicides can be classified? Why do some herbicides affect only broad-leafed plants, some affect grass plants and some affect all plants?

- How do insecticides kill insects?

- One disadvantage of the heavy use of insecticides is that insects resistant to their effects are not killed. When they reproduce, their offspring are also resistant. In this way a large percentage of the population becomes resistant. What are some of the ways insects become resistant?

- How does the ozone layer prevent ultraviolet rays from reaching the Earth's surface?

- What are PCBs? How are they useful? What kind of problems do they cause? How are these chemicals destroyed? What chemical reactions are involved in the destruction process?

- Compare saturated, monounsaturated and polyunsaturated fats. Outline the metabolism of each in the human body.

- Compare the different forms of the periodic table which have been produced? What are the advantages and disadvantages of each? Which seems to you to be the most useful form?

- What produces luminescence in chemicals? What are the similarities between fluorescence and phosphorescence? How do fireflies produce their light?

- Since the Tokyo Olympics, most Canadians have heard of stanozolol. Is it the most commonly used steroid among athletes? What is its chemical formula, and the formulas of other steroids? What steroids are natural body hormones? Why do steroids have the effect on muscle mass which they do?

- The Weyerhauser paper mill at Prince Albert uses many chemicals. Outline the chemical processes involved in converting wood chips into paper. How does the Weyerhauser operation purify the waste water before discharging it into the North Saskatchewan River?

- Canada Day and Victoria Day are two occasions which are traditionally celebrated with fireworks. Explore the chemistry of fireworks. How are fireworks propelled into the sky? How do they explode once they are in the sky? How are the various colours and patterns produced?

- There are many drugs which have been linked to damage to human fetuses: thalidomide; ethanol; diethylstilbestrol (DES). What is the chemical structure of these drugs? To what classes of chemical compounds do they belong? Are there related compounds which are not harmful to developing fetuses? What makes them have the effect that they do? How do they interact with the developing fetus?

- One of the greatest advances in 20th century medicine was the development of the sulfa drugs. What is the characteristic part of the sulfa drug molecule? What are the chemical formulas of some? When were they developed? How do they produce the effect they do? Who were the people involved with their development?

- Of what is photographic film made? What chemical reactions are involved in the exposing and developing of photographic film? What processes are used to recover the solvents and the precious metals which remain after film has been processed?

- Why do substances crystallize in the form that they do? Grow some crystals from a solution prepared with distilled water and AR grade reagent. Grow some crystals from a contaminated (mixed) solution.

- Identify the formulas, sources and effects of those ions and molecules classed as water pollutants.

- Investigate the use of qualitative analysis in forensic science.

- Explore the role of solubility in the deposition, mining and refining of potash in Saskatchewan.

- For what achievement are Banting and Best known? Discuss the chemistry involved in their research.

- Spectrometry is an important area of chemistry. What is the function of spectrometry? Outline the principles which underlie each of the various types of spectrometry.

- How do glues work? Are there different types of glues? Is the bond chemical or physical? What are some of the most common components of glues?

- What chemicals are found in the bath of a chromium electroplating vat? Describe the chemical processes involved in preparing a bumper for rechroming and in doing the rechroming.

- Compare carbohydrates and lipids. How are their chemical structures similar? How are their structures different? In humans, what chemical processes are used to degrade and to synthesize these compounds in the body? A joint project with Biology 30 is possible.

- Write or review science fiction which deals with chemical-related accidents causing strange results: Spiderman, mutant killer tomatoes, the Fly, and so on. How did the Teenage Mutant Ninja Turtles become mutant?

- How do mutagens, teratogens and carcinogens produce the effect they do?

- What is the chemistry behind the toy cars that change colour and shape when their temperature changes? What industrial or medical applications are there for these types of effects?

- Love Canal is possibly the best known toxic chemical dump. What can you find out about what chemicals are causing the problem, the source of the chemicals, whether they were by-products or end-use chemicals and the effects they have on the soil and water?

- Find a toy that uses a chemical or two in a chemical reaction. Write an equation for the chemical reaction involved. Explain how the toy works.

- Some publishers advertise that their books are printed on acid-free paper. How is acid-free paper produced? Why does some paper contain acid? How acidic is 'normal' paper. Why is using acid-free paper an advantage? Can normal paper be converted to acid-free paper after it has been printed on and bound into books?

- What chemistry is involved in the development and manufacture of cosmetics?

- Canada is a world leader in production of aluminum, although there is no bauxite (aluminum ore) mined in Canada. What is the chemical formula of bauxite. What are the reactions involved in reducing the ore to the metal? Are these reactions exothermic or endothermic? How does the energy involved in the refining reactions make Canada a place where this refining can be done? Where in Canada are the aluminum smelters located?

- How does a microwave oven heat the food "from the inside"? How do other frequencies of light affect molecules?

- How do jewellery cleaners work? What are the active chemicals in them? Are there different chemicals in cleaners for different metals (e.g. for gold, for silver, for brass)? Why can't you use the jewellery cleaner on opals and pearls?

- This project involves the communication of images of chemistry through art. Find examples of drawings and paintings in both modern and historical times which depict aspects of chemistry. Egyptian and Greek artists, European artists such as da Vinci, Rembrandt, Durer, and science magazine covers are all sources of examples. The art of video animation is another rich source. Discuss how these works show the artist's ideas about chemistry.

  What current issues and ideas involving chemistry could you select as a basis for your work? Will you focus on past achievements, present work or future possibilities?

  Choose an idea. Select elements of design and painting or drawing techniques which will help emphasize and visually communicate the idea. Consider various strategies which may be useful – juxtaposition, simplification, viewpoint, unity, balance. Discuss your plan with other students.

  Present your completed work to the class. Explain the concept and techniques used.

  (This activity was adapted from *CHEM13 NEWS*, #197, October 1990, page 2, based on an idea contributed by Pamela Slater-Suskind, Vancouver, B.C.)

- Biosphere 2 is a series of domes built in the Arizona desert. It is intended to be sealed off from the rest of the world and home to eight people for two years. What aspects of chemistry are (were) important to this project? How is the O_2/CO_2 balance maintained? What interrelationships are there between the chemistry and the biology of this project? between the chemistry and the physics of this project?

(Many of these suggestions are adapted from ideas submitted by Blaine Barnstable of Loreburn and Al Kabatoff of Saskatoon.)

Atoms and Elements

Unit Overview

This unit establishes an important foundation for much of what will follow in Chemistry 20 and 30. Components and characteristics of atoms are considered. An understanding of the structure of the nucleus provides students with the basis for understanding how the average mass number of an element is determined.

This unit offers an opportunity to consider the descriptive chemistry of the elements, an area of chemistry which was deemphasized in the previous chemistry curriculum. It fits well with the discussion of classification of the elements.

Consideration of the properties of some of the elements leads to a discussion of the organization of the periodic table. Patterns in the periodic table are then examined in more detail.

Students gain a historical perspective, recognizing that many conventions that are in use today have been based on the work of previous scientists. This provides them with an important insight into the nature of science.

Factors of scientific literacy which should be emphasized

A2 historic
A6 probabilistic
A7 unique
A8 tentative
A9 human/culture related

B3 orderliness
B6 symmetry
B9 reproducibility of results
B11 predictability
B13 energy-matter
B15 model
B20 theory
B22 fundamental entities

C1 classifying
C8 hypothesizing
C9 inferring
C10 predicting
C13 formulating models
C15 analyzing
C20 defining operationally

D1 science and technology
D5 public understanding gap
D7 variable positions

E3 using equipment safely
E4 using audio visual aids
E5 computer interaction
E11 measuring mass

F2 questioning
F3 search for data and their meaning
F5 respect for logic
F7 demand for verification

G3 continuous learner
G5 avocation
G6 response preference
G8 explanation preference
G9 valuing contributors

Foundational Objectives for Chemistry and the Common Essential Learnings

Discuss the development of ideas about the structure of matter.

- Outline Aristotle's ideas on the nature of matter.
- Explain the contributions of the early alchemists.
- Summarize the contributions made by Dalton, Lavoisier, Berzelius, Thomson, Rutherford, Milliken, Planck, Bohr, de Broglie, Schrödinger or Heisenberg in developing a model of the structure of the atom.
- Understand how theory is used to explain observations.

Identify the relationships among the components of the atom.

- Identify protons, neutrons, and electrons as constituents of atoms.
- Consider the forces which hold the atom together.
- Draw Lewis diagrams to indicate the valence electron structure of atoms.
- Recognize the terminology used to describe atoms and their isotopes: atomic number; nucleon (mass) number; atomic mass; atomic mass unit: average atomic mass.
- Discuss the concept of the mole.
- Distinguish between isotopes of an element.
- Recognize that there is a difference between mass and weight.
- Calculate atomic mass (atomic weight) values when given the percentage of each isotope of an element.

Examine how elements are described and classified.

- Recognize that elements have characteristic properties.
- Classify elements according to their properties.
- Identify some elements by their properties.
- Describe the development of the periodic table by Mendeleev.
- Explain the basic principles of organization of the periodic table.
- Identify trends and patterns within the periodic table.
- Understand the history of the use of symbols for the elements.
- Use symbols for the elements correctly.
- Use the periodic table to determine the valences of elements.
- Compare several forms of the periodic table and recognize that each has its advantages.

Understand and use the vocabulary, structures and forms of expression which characterize chemistry. (COM)

- Incorporate the vocabulary of chemistry into writing and talk about chemistry.
- Recognize the periodic table as a source of information.

Apply knowledge of numbers and their interrelationships. (NUM)

- Read and interpret information about elements from charts and tables.
- Use numerical data to compare and describe elements.

Suggested activities and ideas for research projects

- What chemical elements are of importance to the economy of Saskatchewan? Report, using posters and a short oral presentation, on one of the elements. Include such information as its symbol, electron structure, chemical family (group), chemical and physical properties, in what forms it is usually found in Saskatchewan, and why it is of importance.

- Ask students to design crossword puzzles with the names of elements. The clues would be the symbols for the elements or descriptions of the physical or chemical characteristics of the elements.

- Assign individuals or groups of two or three to prepare reports on one of the elements. Some of the things which might be included in the report are:
  - natural occurrence
  - historic and contemporary uses
  - origin of name
  - when, how, where and by whom it was discovered
  - characteristic physical and chemical properties.

  The report might be presented to the class orally, in a mixed media presentation, on a poster display, as a written report or in some other way.

- Ask each lab group to brainstorm a list of the characteristics of metals. Make sure each group has a recorder who will write down each of the suggestions.

  Then distribute samples of metals in various forms: aluminum foil, copper foil, silver foil (if your budget can afford it), thin zinc and tin sheet, a penny, a nickel, a dime, cobalt pellets or whatever is available. Let the students examine and explore the characteristics of the metals. Compare what they observe with the list of characteristics they created by brainstorming.

  Put two or three groups together and ask them to compare their results. Ask each combined group to list on a poster the characteristics they have discovered. The poster can be presented to the whole class, or displayed on the bulletin board.

- Place a piece of copper foil over a key (or a nickel, quarter or ...) and rub the foil firmly against the key. What is the effect on the foil? Continue rubbing. Does any of the copper transfer to the key?

- Pick up a set of coded toothpicks and a flame test kit with identified chemicals. The flat ends of the toothpicks have been soaked in a salt solution and dried. Your task is to solve the code on the toothpicks. What salt does a red and green stripe represent?

  Note to teachers: To prepare toothpicks for use in this activity, use an elastic band to bundle some toothpicks together, with the flat ends all at the same end of the bundle. Stand the bundle, flat ends down, in about 2 cm of a saturated salt solution. Leave the bundle there overnight. Remove the bundle and allow to dry. Repeat this procedure for as many different salts as you wish.

  Spread the dry toothpicks and code them on the narrow ends using felt tip markers. For example use a single red line to indicate copper chloride, a blue line to indicate copper sulphate and green and yellow bands for copper nitrate. Red and blue might indicate lithium chloride.

  This can also be done with a set of coded spray bottles which the students use to spray a salt solution into the flame of the burner.

- Use a cardboard tube spectroscope to observe the spectra produced by fluorescent tubes, sunlight bouncing off a white wall (don't look directly at the sun), and colours produced when salt solutions are sprayed into burner flames.

  Borrow a spectroscope to observe both blue-white mercury vapour street or yard lights and the orange sodium vapour street of yard lights. Does a full moon produce enough light to create a spectrum in the spectroscope?

  How did Bohr use information from hydrogen spectra to develop his model of the atom?

  Note to teachers: It is possible to have students construct their own spectroscopes using cardboard tubes, poster board and cellophane.

- According to information from the American Gold Institute, 30 grams of gold can be hammered into a gold leaf sheet covering almost 10 m^2. Assume that the area is exactly 10 m^2. How many atoms thick would the gold leaf be?

- If you have a large blank wall in your laboratory, consider creating a giant periodic table in the space. It could be the conventional 18 group rectangular table or the class might choose to depict one of the alternative forms. Do some research to find out about all the forms of the periodic table which have been devised. Each lab group could pick one and make a presentation to the class outlining its advantages from these one could be selected for the large project. (Or possibly two could be done if the space is large enough.) **(This activity was adapted from *CHEM13 NEWS*, #198, November 1990, page 3, based on an idea contributed by Denise Gordon of Fort Worth, TX)**

- A game to play involves spelling names of elements using only the symbols of elements. For example, silicon (element 14) can be spelled using the symbols for silicon, lithium, cobalt and nitrogen. Once you have found a name, you could then give that to another group in scrambled order: what element can be spelled using the symbols of rubidium, nitrogen, oxygen and calcium? This game could be extended to finding other words that can be spelled with element symbols. What word do you get if you put the symbols for lithium, neon and argon in a row?
(This activity was adapted from *CHEM13 NEWS*, #198, November 1990, page 3, based on an idea contributed by Duncan Morrison of Vancouver, B.C.)

- Create element quiz questions. These could be presented in a group as a small research project, or individually, one each day, with a prize or commendations to the person able to find the answer. One source of those questions is from a book *The Elements* by John Emsley (1989), Oxford University Press. **(This activity was adapted from *CHEM13 NEWS*, #197, October 1990, page 5, based on an idea contributed by Reg Friesen of Waterloo, ON)**

- Discuss the two meanings of the term element. It is used to mean both 'non-decomposable substance' and 'type of atom'. The context determines which meaning is intended. Examples of statements in which the usage must be clear are:
  - The element copper has a melting point of 1083°C
  - Most fertilizers contain the element nitrogen.

  In the first statement, element refers to the non-decomposable substance copper. Individual copper atoms do not have melting points. In the second statement, element refers to the type of atom since fertilizers do not contain nitrogen gas, the substance. Make sure that the distinction between the two usages is clear.**(This was adapted from an article in *CHEM13 NEWS*, #197, October 1990, pages 8-9, "Temporary Words for 'Element' Aid Thinking in Molecular Terms" by Jan Hondebrink, Enscede, The Netherlands.)**

- This assignment is a creative library research paper on an element. The importance of chemical elements in our lives can be strengthened by making the description of an element part of the production of an imaginative, creative product.

  First, select an element and gather information about its:
  - discovery, including derivation of its name
  - method of preparation and purification
  - chemical and physical properties
  - uses and applications

  Take the information you have gathered and create an adventure story involving the element. Weave into that story the factual information you discovered in your research into the element.

  Use a word processor to produce your story, so that it can be bound into a collection of short stories titled *Lives of the Elements*. As one of the authors of this book, you will be honoured at a reception announcing the book's release. **(This activity was adapted from *CHEM13 NEWS*, #195, May 1990, page 8, based on an idea contributed by Bekye Dewey, Falls Church VA)**

- What if iron didn't exist? What could be used instead of iron? What effect would it have on our society? How might history have been different?

Pick an element other than iron. Answer the same questions with respect to the element you have picked. **(This activity was adapted from *CHEM13 NEWS*, #192, February 1990, page 3, based on an idea from Michael Kelly, Westford MA and reported by Bruce Hemphill, St. Catharines, ON)**

- Chemical bingo is one way to become more familiar with the symbols for the elements. Prepare bingo cards, but in place of the numbers use symbols. (Use regular bingo cards to prepare the cards. Develop a master key of what symbols are used to replace each number on the cards. Each column could be reserved for a particular group of elements e.g., column B could be used for groups I and II elements, column I could represent elements from group VII.)

  Call out the name of an element. In order to mark the space, students must be able to recognize the correct symbol if it appears on the cards. Tables and charts can be used as aids. Set a time limit before calling out the next element, and set rules regarding the use of reference materials.

  Use regular bingo variations such as: full card blackout, roving kite (any four corner squares plus a diagonal), roving L (any two outside lines sharing a common corner, roving T (any outside line with a centre line), 8 around the free (all eight squares around the free square in the centre), wee house (8 around the free, plus the square in the top centre of the top row), etc.

- Design an advertising campaign for an element. Pick an element. Create a fact sheet listing the physical and chemical properties of the element, along with any interesting facts about the element. Then produce a poster with a logo for the element and promoting its use. As a final part of the advertising package, an audio or video taped commercial for the element should be produced.

  Note to the teacher: This project can be evaluated by the students. The students could produce a list of common criteria on which they will base their evaluation. Each package could be given to five students to evaluate. The average mark given by the student graders could form the mark for the project. As a wrap-up, you might show a copy of "The Ball of String" sketch from Monty Python's Flying Circus tv series, in which an advertising campaign to sell bits of string in four inch lengths is devised.
  (This activity was adapted from *CHEM13 NEWS*, #192, February 1990, page 3, based on an idea from Michael Kelly, Westford MA and reported by Bruce Hemphill, St. Catharines, ON)

- What is the origin of the term 'mole' to describe Avogadro's number of particles?

- Demonstrate atomic spectra as a result of electron transition. You will need a flashlight, red confetti, a lab coat, a sturdy chair and a sturdier table or demonstration desk. Ask the students to gather closely around the table so they can see.

  Put the lab coat on, with the red confetti in one pocket. Ask a student to shine the flashlight on you while you stand on the floor. Explain that you represent the electrons of a whole bunch of hydrogen atoms and the floor is your ground state. Energy input (in this case light from the flashlight because heat from a bunsen burner is too risky!) can cause electrons to become excited and move to higher energy levels.

  Those higher levels are quantized, and you can't be in between them. Step up on the chair and start to move a little to represent the second energy level. Then step up to the table to represent the third energy level and start to do a little dance to represent lots of energy.

  Then mention that electrons can't stay in the excited state indefinitely so they will go back to ground state. Point out the two ways of getting to ground state. Ask what happens to the energy when the electrons go back. Hopefully, someone will say that the energy they absorbed is emitted.

  If not, you say it as you step back down onto the chair, reaching into the pocket containing the red confetti and throwing a handful out over the students' heads. Each piece of confetti represents one photon of light (why is the light monochromatic?) which was the energy emitted by one electron going from energy level three to energy level two.
  Since the electrons have not yet returned to the ground state, ask what will happen when they go down the last step. This time someone should say that energy will be released. As you step back to the floor, reach into an empty lab coat pocket and throw some imaginary confetti on

them. This represents invisible ultraviolet light.(**This activity was adapted from *CHEM13 NEWS*, #190, December 1989, page 11, based on an idea contributed by Jerry Sears of Wayne, MI)**

- What colour is pure copper? To find out, hang a strip of copper in a 250 mL beaker so that the bottom of the strip comes within 1 cm of the bottom of the beaker. Put methanol or propanone in the beaker to a depth of about 0.5 cm so that the copper is not touching the liquid.

  Remove the copper from the beaker and heat in a burner flame. Make sure the burner is at least 1 m from the beaker, since both methanol and propanone are flammable. If the liquid does catch on fire, gently cover the mouth of the beaker with a notebook. This will smother the fire.

  Bring the red hot copper back to the beaker and suspend it above the liquid. The hot copper should oxidize the vapours of the liquid, thus itself being reduced to pure metallic copper. If it doesn't work the first time reheat the copper. What accounts for the 'copper colour' of copper? **(This activity was adapted from *CHEM13 NEWS*, #188, October 1989, page 16. The *Journal of Chemical Education* (May 1989, page 400) was cited there as the source.)**

- Create a wordsearch on a 20 by 20 grid, using the names of elements 1 to 103. Create a 'score' for the wordsearch by adding the atomic numbers of the elements in the puzzle. Who can create a puzzle with the highest score? Bind the puzzles from your class into a book. Copies of the book could be given to a grade six teacher for use with students at that level who are just starting to learn about atoms and elements. **(This activity was adapted from *CHEM13 NEWS*, #192, February 1990, page 3, based on an idea from Michael Kelly, Westford MA and reported by Bruce Hemphill, St. Catharines, ON)**

- What causes the *aurora borealis*? Where does the light come from? Do you think Hendrik Lorentz knew how they were produced? Why?

- Select one of the elements from group IA to group VIIIA (or groups 1,2, 13-18). Find out the physical and chemical properties of that element, in what form it is found, how it is extracted or purified and where and how it was discovered. Submit a written report containing what you have found out about your element.

  After the reports have been returned, group yourself with students who have elements which are in the same group (family) of the periodic table. Create a list of common properties and trends in properties among those elements.

  Find a creative way to present this information about your chemical family to the rest of the class. The presentation should last from three to five minutes. Possibilities for reporting are a poster presentation, part of a tv quiz show or talk show, raps, plays, poems, stories, interviews or videos. Also prepare a summary sheet with important information about your family to distribute to everyone in the class.

  Split your family into two groups to do the lab activities assigned by your teacher.

  Note to teachers: Have students select elements by drawing from a hat or some other way which will randomize the groups when they are formed. The lab activities assigned can be any which examine the properties of the elements. Choose these activities from among those listed in this guide or from other sources. **(This activity was adapted from *CHEM13 NEWS*, #206, October 1991, page 4, based on an idea contributed by Ken Lyle, Houston, TX)**

- How many different forms of the periodic table have been produced? Select one form other than the standard block form which appears in most books. Explain the basis for its structures, as well as identifying the advantages and disadvantages of the form.

- Select an "Element of the Day" to highlight each day. The name of the element could be posted on the blackboard or on a poster. The elements could be selected randomly or according to some pattern. If there is a pattern the students could be challenged to predict tomorrow's element. The presentation of the element for the day could range from simply displaying its name to display of a sample or picture of a sample, its characteristics, its symbol, common reactions it is involved in, where and in what form it is found, and so on.

  The same idea could be used for a "Molecule of the Day".

Sample ideas for evaluation or for encouraging thinking

- Sodium has only one more proton than neon. How are these two elements different? Why are they so different?
- How can there be so many different forms of the periodic table? Why isn't there one, best, most correct table?
- Which elements are called the transitional elements? What transition do they represent or indicate?
- Scientists now believe that the basic components of matter are quarks and leptons. Ideas about matter have come along way since Aristotle was arguing against Democritus's idea of indivisible pieces of matter he called atoms. Are atoms still a useful concept even though we believe that they are not indivisible?
- When an electric spark forces an electron from its ground level, what attractive force must be overcome? What evidence appears when the electron drops back to its starting place? What kind of waves are produced? At what point does the electron have the greatest amount of energy?
- What must be done to a 2 level electron to make it a 3 level electron? What happens when the 3 level electron becomes a 2 level electron?
- Draw the electron dot (Lewis) representation for phosphorus.
- In most chemical reactions involving lithium, the lithium atom loses an electron and forms an ion. On the other hand, fluorine atoms tend to form ions by gaining an electron. Why do these elements behave so differently in the formation of ions?
- Why do metals have low ionization energies?
- Suppose that energy is released during the addition of an electron to a neutral atom. Which is more stable — the atom or the resulting ion?
- What is similar in the electron structure of each of the noble (inert) gases?
- How similar were the ideas of Dalton and Democritus about matter? How were their ideas different?
- **What fundamental problem with the Bohr model of the atom did de Broglie, Schrödinger and Heisenberg all tackle?**
- **What constraint in analyzing the motion of the electron in the atom did Heisenberg uncover?**
- **How many electrons, protons and neutrons are found in an atom of ^{14}C (carbon-14)?**
- **If the main isotopes of chlorine are ^{35}Cl and ^{37}Cl, how does the average atomic mass come to be 35.5 amu?**
- **What is the relationship between ^{12}C, atomic mass units and the mole?**
- **What are the isotopes of uranium? Which one is most important to Saskatchewan's economy?**
- **Find the element with the following characteristics:**
  - **silvery white metal**
  - **fifth most common element**
  - **can be replaced in its most common nutritional source by a radioactive isotope of strontium**
  - **important component of the structure of human bone**

  Make up some more of these to share with your classmates.
- **What is a major source of radioactive strontium ions in the environment?**
- **What properties do all halogens have in common?**
- **What do elements found in groups IIA and IIB (or groups 2 and 11) have in common?**
- **Using the ionization energies for all members of period 2 of the periodic table, draw a line graph showing the relationship between atomic number and ionization energy? Which is the dependent variable in these data?**

  Predict the shape of the line graph for the ionization energies of the period 3 elements plotted against the atomic numbers? How about for period 4?

- How is a decomposition reaction different from a synthesis reaction?

- Can an element be decomposed in a chemical reaction? Is ozone an element? Discuss the differences between elements and the atoms they are composed of.

- Silicon is sometimes called a metalloid. It is also described as a semiconductor. Why does it not fall into the class of either metals or nonmetals? Are there other elements which are similar to silicon in this respect? Are all members of Group IVA (group 14) also semiconducting metalloids?

- What tests could be done to determine if a piece of solid was metallic?

- The most common element in the earth's crust is oxygen. Why isn't this oxygen available for breathing?

- Aluminum is the third most common element in the earth's crust. Over 8% of the crust is aluminum. Yet bauxite, the ore from which aluminum metal is refined is quite rare. Why?

- Clues to the Greek and Latin roots of the names of elements are given in the statements below. Try to identify the elements for each group of clues.
  - Some elements are named for a colour. Which elements correspond to greenish-yellow, rose, violet, indigo, deepest red, sky blue, the rainbow, and colour itself.
  - These have Scandinavian origins: a goddess; a god of war; a heavy stone; the earliest name for Scandinavia.
  - Which elements have names arising from "liquid silver", a magnet, a green twig, a stone, flint, and a smell?

  (This was adapted from *CHEM13 NEWS*, #182, January 1989, page 10, based on an article contributed by R.J. Friesen, Waterloo, ON.)

Molecules and Compounds

Unit Overview

Chemical bonds, the nomenclature system, and properties of compounds are essential concepts in chemistry which are highlighted in this unit.

This unit presents an opportunity to use a variety of instructional methods. For a description of the range of instructional methods, see *Instructional Approaches: A Framework for Professional Practice*, pages 15-19.

In order to understand how chemicals react, one must understand how molecules form.

The way that molecules aggregate determines the properties of the compound. Both these concepts can be developed through model making and through comparison of and experimentation with variety of compounds. These are two key instructional methods.

To a certain extent, this unit can be integrated with the units dealing with chemical reactions and stoichiometry, since the formation of molecules depends on the occurrence of a reaction, and elements combine in stoichiometric ratios.

Factors of scientific literacy which should be emphasized

A2	historic
A4	replicable
A5	empirical
A8	tentative
B1	change
B2	interaction
B3	orderliness
B8	quantification
B9	reproducibility of results
B10	cause-effect
B13	energy-matter
B15	model
B16	system
B20	theory
B21	accuracy
B22	fundamental entities
B23	invariance
B29	gradient
C1	classifying
C6	questioning
C8	hypothesizing
C9	inferring
C10	predicting
C11	controlling variables
C12	interpreting data
C13	formulating models
C14	problem solving
C15	analyzing
C16	designing experiments
C17	using mathematics
C20	defining operationally
D1	science and technology
D4	science, technology, and the environment
D10	technology controlled by society
E1	using magnifying instruments
E3	using equipment safely
E5	computer interaction
E7	manipulative ability
E12	using electronic instruments
E13	using quantitative relationships
F2	questioning
F5	respect for logic
G2	confidence
G3	continuous learner
G5	avocation
G6	response preference
G7	vocation
G8	explanation preference
G9	valuing contributors

Foundational Objectives for Chemistry and the Common Essential Learnings

Use the formulas and names of compounds fluently.

- Recognize the component atoms, simple ions, or polyatomic ions in a molecule.
- Use both the periodic table and a table of common ions to aid in determining the formulas of binary and other simple compounds.
- Use a table of common ions in determining the formulas of compounds containing one or more polyatomic ions.
- Write the formula of an inorganic compound, given its name.
- Use the oxidation state notation to describe the valence of polyvalent elements, e.g. Fe(III).
- Write the name of an inorganic compound, given the formula.
- Recognize the pattern in the names of the alkane and alkene series.
- Apply the general formula C_nH_{2n+2} for alkanes and C_nH_{2n} for alkenes to write formulas for members of those series.

Discuss the mechanics of bonding between atoms in a molecule.

- Recall the structure of the atom.
- Understand the importance of the interaction of electrons when two atoms or ions approach each other.
- Contrast the bonding produced by shared pairs of valence electrons and by transfer of electrons to form ions.
- Apply the octet rule to determine the number of covalent bonds which form or the charge of the ion which forms.
- Draw Lewis structures for molecules.
- Use VSEPR theory to predict shapes of simple molecules.

Examine the bonding between molecules or atoms in solid and liquid phases.

- Describe the physical properties of ionic, metallic, covalent (molecular), covalent (network), and van der Waals solids.
- Relate the properties of compounds to the uses which those compounds have.
- Compare the properties of some alkanes to the properties of their derivative alcohols, e.g. methane-methanol, propane-propanol, octane-octanol.
- Explore the relationship between the strength of the forces holding solids and liquids together and the magnitude of the melting and boiling points of those substances.

Investigate the factors which influence solubility.

- Recognize the importance of water as a solvent.
- Use the terminology related to solubility.
- Compare the solubilities of several solute/solvent combinations.
- Recognize how the addition of a solute changes the properties of a solvent.

Use language (listening, speaking, reading, writing) for different audiences and purposes. (COM)

- Share in own words ideas which are heard, read, viewed or discussed.
- Outline information for reporting, discussing or sharing.
- Clarify, refine, restate, adapt, change, give examples, make analogies, summarize a message when another does not understand.

Promote both intuitive, imaginative thought and the ability to evaluate ideas, processes, experiences and objects in meaningful contexts. (CCT)

[illegible] ie
[illegible] new
[illegible], heard
[illegible] g.
[illegible] is
[illegible] lual
[illegible] evidence, truth and the views of others when engaging in rational discussions.

- Recognize the value of school rules and norms which support the consistent and respectful treatment of all.

Suggested activities and ideas for research projects

- Methane oozes out of the mud in the bottom of swamps and escapes from the digestive tracts of animals. How is the methane formed in these situations? How does the methane we extract from the ground as natural gas form and accumulate?

- Methanol and ethanol can be used as fuels. Why are they considered to be cleaner burning than gasoline or diesel fuel? How are they produced for fuel use?

- Cyclohexane both freezes and boils somewhere within the range from 0°C to 95°C. Design a procedure to determine the freezing point and another to determine the boiling point of cyclohexane. Submit your written procedures to your teacher. Modify the procedures as suggested and then do them. How many trials must be done to ensure that your estimate is accurate?

  Note to teachers: If you are concerned about the fumes of cyclohexane (which are rated as less of a hazard than fumes of dichlorobenzene) consider suggesting a boiling point determination apparatus with a two-holed stopper venting vapours into an ethanol trap. Since cyclohexane is very flammable do not allow designs which involve heating a hot water bath with an open flame. Cyclohexane's boiling point is 81°C. Pose that as a problem to the students – to produce a hot bath which will still be above 90°C after five minutes.

- Oleic acid, the primary component of olive oil, will form a slick on the surface of water. Depending on conditions, the slick may be only one or two molecules thick. What are some of the conditions which may affect the thickness of the layer? To estimate the thickness of the slick is a good exercise in both indirect measurement and in helping to comprehend the dimensions of atoms and molecules.

  Get a large pan, fill it with water to a depth of about 2 cm and let the water become as still as possible. When still, sprinkle just enough talc or lycopodium powder (spores of a type of moss) on the surface so that the surface looks slightly hazy.

  The oleic acid has been diluted in alcohol so drop a drop of pure alcohol onto the surface of the water. Record the effect. Then put a drop of the oleic acid solution at the centre of the pan. measure the diameter of the slick that forms and estimate its area.

  By estimating the volume of oleic acid in one drop of the solution and the area of the slick, you can calculate the thickness of the slick.

  Note to teachers: Dilute the oleic acid to 0.5% by volume. Circular pizza pans with a diameter of 40 cm work well for this activity. Check around your storage spaces to see if any of this equipment remains from when it was used in the IPS Science program.

  Another exercise in indirect measurement is to calculate the thickness of aluminum foil or of stretchable plastic wrap.

- Microscale decomposition of water into its component gases can be done with a 9 volt battery in a 500 mL beaker.

  Half fill the beaker with a 0.10 M Na_2SO_4 or $MgSO_4$ solution and enough universal indicator solution to give a strong green colour. Fill two 13 by 100 mm test tubes with the solution and invert them in the beaker so that no air is trapped in them.

  Lower a 9 volt battery, with the terminals up, into the beaker and stand it on the bottom near one side. Ensure that there is enough solution in the beaker to cover the battery by 5-7 cm. Bring one test tube over and cover one of the terminals. Lean the tube against the wall of the beaker for support. Repeat this procedure to cover the other terminal with the other test tube. Collect the gases by downward displacement of water.

  Record observations.

  Repeat the activity using different salt solutions (NaCl, KI, NaBr) or different indicators (bromothymol blue, red cabbage juice). What would happen if H_2SO_4 solution were used instead of a salt solution? **(This activity was adapted from *CHEM13 NEWS*, #201, February 1991, page 7, based on an idea contributed by Marie C. Sherman of St. Louis, MO)**

- List the melting points of the metals. Are there any generalizations you can make or trends you can deduce?

- What are some examples of alloys? Are alloys compounds? How do the properties of alloys differ from the properties of their components? Is steel classified as an alloy? Where did the term karat to describe the alloys of gold come from? Why is 24 karat gold pure gold? (Why not 100 karat gold for pure gold?)

  Pick a chemical compound used in some aspect of your life: food; clothing; medicines; housing; fuels; etc. Create a poster or video clip report of the chemical. Information about the name and formula, the properties and uses, the sources, how it is produced from its raw materials, and the value to society of the chemical should be included. **Adapted from an article "Worldly Chemicals" by Larry Mossing, in *The Accelerator* (June 1990).**

- What characteristics of solid carbon dioxide (dry ice) and solid paradichlorobenzene (moth crystals) permit them to go directly from the solid phase to the gaseous phase. Do other solids such as ice or iron do this?

- Below is the ingredients list taken from the back of a package of eye shadow. Determine the chemical formulas and the purpose in the eye shadow for as many of the chemicals as possible.

  Contains: talc, mineral oil, zinc stearate, lanolin, alcohol, urea/formaldehyde resin, octyl palmitate, calcium silicate, ozokerite, jojoba oil, methylparaben, imidiazolidinyl urea, propylparaben, aloe, BHA. **May contain:** iron oxides, mica, titanium dioxide, carmine, bismuth oxychloride, manganese violet, ultramarine blue, ultramarine pink, ultramarine violet, chromium hydroxide greens, bronze powder, aluminum powder, ferric ferrocyanide, ferric ammonium ferrocyanide.

- Some students enjoy making and using flash cards. Put a formula for a molecule or ion on one side of the card and the name of the species on the other.

- Make 3-D models of molecules or ions to hang from the classroom ceiling. These models can be made from commercial kits or be homemade. A label including the name and formula of the species can be strung on the string which supports the model. A poster for each model, with a 2-D sketch of the species and some information (Lewis structure, chemical properties, where it is found) about it can be made for the classroom walls. It is useful to have students start to associate the 2-D representations with the 3-D representations of the species. The posters could be colour-coded to indicate correspondence between poster and model or they could be left for the viewers to figure out.

- Select and promote a "Molecule (or Compound) of the Day". See the "Element of the Day" activity in the previous unit for ideas.

- SCI-TEC Instruments in Saskatoon produces an instrument called the Brewer Ozone Spectrophotometer. It is used in more than 20 countries to measure the levels of ozone, sulphur oxides and nitrogen oxides in the atmosphere. How do such machines detect what molecules are in the air?

Sample ideas for evaluation and for encouraging thinking

- How is separation of whole milk into skim milk and cream different than the separation of water into hydrogen and oxygen?

- For each of the substances in the list, find the chemical formula.

-hematite	-limestone
-muriatic acid	-table salt
-ethanoic acid	-quartz
-galena	-cellulose

- The following are formulas of gems. Match the gem to the formula.

-emerald	-$(AlF)_2SiO_4$
-lapis lazuli	-Al_2O_3
-ruby	-$Be_3Al_2(SiO_3)_6$
-spinel	-$Mg(Al_2O_4)$
-topaz	-$Na_4(NaS{\bullet}Al)Al_2(SiO_4)_3$
-zircon	-$ZrSiO_4$

  What are some formulas of other gems? Memorize the formula for diamond as a test of the ability of your memory.

- Using only a periodic table for aid, write the formulas for the molecules in the list.

-carbon dioxide	-calcium carbide
-rubidium bromide	-silicon tetrachloride
-hydrogen sulfide	-water

- Write instructions so that someone who knew nothing about chemistry could come into this lab and do each of the tasks below. (You may advise the person to use tables or charts on the walls or in the reference books, give the person page references for the books or any help short of giving the answer.)
  - Find the symbol for beryllium and silver.
  - Find the weight of one mole of NaCl.
  - Determine the names of the elements in $CaCO_3$.
  - Find the chemical formula for sucrose.

  Give your instructions to a partner for testing. When you are testing instructions, pretend that you don't know a lot of chemistry and see if the instructions alone are enough.

Chemical Reactions

Unit Overview

Observing, investigating and inquiring about a wide variety of reactions — rusting automobiles, crumbling concrete, burning paper, electricity from a dry cell, and reactions with chemicals in the laboratory — makes concrete the concept of a chemical reaction.

The importance of chemical reactions in maintaining life, in developing new substances, and in the impact of those substances on the environment make it essential that students understand what chemical reactions are and how pervasive they are.

Topics from this unit can support the development of students' concept of molecules and compounds. By integrating this unit with the stoichiometry unit, students simultaneously can develop their concepts of what chemical reactions are, and how we measure them. To some extent the units **Molecules and Compounds, Chemical Reactions**, and **Mole Concept and Stoichiometry** can be treated as one.

Factors of scientific literacy which should be emphasized

A1 public/private
A4 replicable
A5 empirical
A7 unique

B1 change
B2 interaction
B3 orderliness
B8 quantification
B10 cause-effect
B11 predictability
B13 energy-matter
B20 theory
B21 accuracy
B23 invariance

C1 classifying
C2 communicating
C3 observing and describing
C5 measuring
C8 hypothesizing
C9 inferring
C10 predicting
C11 controlling variables
C12 interpreting data
C14 problem solving
C15 analyzing
C16 designing experiments
C20 defining operationally
C21 synthesizing

D3 impact of science and technology
D4 science, technology, and the environment
D8 limitations of science and technology
D10 technology controlled by society

E1 using magnifying instruments
E3 using equipment safely
E7 manipulative ability
E9 measuring volume
E10 measuring temperature
E11 measuring mass
E12 using electronic instruments

F1 longing to know and understand
F3 search for data and their meaning
F4 respect for natural environments
F7 demand for verification
F8 consideration of premise

G1 interest
G2 confidence
G5 avocation
G7 vocation
G9 valuing contributors

Foundational Objectives for Chemistry and the Common Essential Learnings

Appreciate the importance of chemical reactions.

- Identify changes which indicate that a chemical reaction has taken place.
- Identify chemical reactions that help maintain living organisms.
- Identify chemical reactions that harm living organisms.
- Identify chemical reactions that affect the environment.
- Recognize how chemistry has been involved in product and process development in the last thirty years.

Acquire ability to communicate chemical information through equations for reactions.

- Write an equation representing a chemical reaction using chemical formulas for the species involved.
- Recognize that chemical equations need to be balanced for number of atoms and for charge.
- Balance chemical equations for number of atoms and for charge.
- Apply the Law of Conservation of Mass to writing balanced chemical equations.
- Develop net ionic equations.
- Recognize that an energy term is often shown in a chemical equation.
- Place the energy term on the correct side of an equation, depending on whether a reaction is exothermic or endothermic.
- Develop a balanced chemical equation from a word equation, experimental evidence, or a description of a chemical reaction taking place.

Use a wide range of language experiences to develop understanding about molecules and their reactions. (COM)

- Record, discuss and compare their observations of reactions with others.
- Present findings about reactions by using diagrams, models, analogies or other devices.
- Evaluate readings and videos about reactions in the context of concrete experience with reactions.

Develop an understanding of how knowledge is created, evaluated, refined and changed within chemistry. (CCT)

- Strengthen perceptual abilities through concrete experiences with chemical reactions.
- Reflect upon how the technology available to measure reactions influences the concept of how a reaction occurs.
- Recognize how basic concepts of chemistry change with changing perspective and new information.

Suggested activities and ideas for research projects

- A good series of reactions to illustrate both a variety of chemical reactions and some of the principles of stoichiometry begins with copper(II) chloride. The series of reactions here may be done either qualitatively or quantitatively.

  Since all copper compounds are skin irritants, avoid contact with the skin and wear eye protection at all times. If the compounds do contact the skin, wash with lots of running water.

  Obtain a sample of anhydrous copper(II) chloride. Transfer some of the sample (about the size of a dime) to a dry watch glass. Record a description of the compound, and then put the watch glass aside until the end of the period.

  At the end of the period, look for any changes to the cooper(II) chloride. Label the watch glass and store it until the next class. At the beginning of the next class again examine the copper(II) chloride for evidence of change. Record your observations. Dispose of the compound as instructed.

  Add the remainder of the sample to about 150 mL distilled water in a 250 mL beaker. Describe what occurs when the compound is added to the water. Stir the mixture gently until a solution is formed.

  Over a low heat, raise the temperature of the solution to 70°C or so. Add a piece of aluminum metal and describe the reaction which ensues. How can you tell when the reaction is complete?

  Separate the copper metal from the aluminum metal. Which component was the limiting factor in this reaction? Wash and dry the copper.

  Put the copper metal in a labelled 500 mL beaker. Add 50 mL of dilute nitric acid. Put a watch glass over the top of the beaker and watch the formation of nitrogen dioxide gas until the beaker is half full of the gas. Then move the beaker and watch glass to the fume hood until the reaction is complete and the nitrogen dioxide has diffused from the beaker.

  Test a sample of sodium hydroxide with pH paper. Also test the blue copper(II) nitrate solution. Add 25 mL samples of the sodium hydroxide solution to the copper(II) nitrate solution, stirring gently as the addition is made, until the mixture has the same pH as the sodium hydroxide.

  Let the bluish-white copper(II) hydroxide precipitate settle and decant as much of the sodium nitrate solution from it as possible without losing any of the solid.

  Add enough water to bring the volume to 200 mL and heat until the copper(II) hydroxide has been converted to black copper(II) oxide. Let the mixture settle and decant the solution, which still contains sodium nitrate. Add a 50 mL portion of distilled water and swirl gently. Decant and repeat the process twice more, with 50 mL distilled water each time.

  Finally, to the copper(II) oxide, add dilute sulphuric acid drop by drop, swirling after each addition, until all the copper(II) oxide is dissolved.

  Allow the solution to evaporate, producing crystals of copper(II) sulphate. After the crystals have been examined and described, transfer them to test tube and heat them gently. What change is happening to the crystals? Dump the dried crystals from the test tube onto a piece of paper. Add a drop of water to the pile. Record the results.

  From the paper transfer the copper(II) sulphate back to a 250 mL beaker. Add enough water to dissolve the solid. Add some zinc metal and heat gently. How can you tell when this reaction is complete? Pour the solution which remains into an evaporating dish and evaporate at room temperature. How do the crystals formed on this step compare with the copper(II) sulphate crystals? What happens if you heat these crystals? What is the name of these crystals?

  Write word or formula equations for each of the reactions in the activity. Use molecular models (ball and spring, space-filling, etc.) to illustrate each reaction. Perhaps each lab group could be responsible for creating a poster with an equation of one of the reactions, a description of what was observed during the reaction and an example of a similar reaction which is used in some mining, manufacturing or industrial process. If there are more than six lab groups, perhaps some of them could be merged for the purpose of this activity since there are only six reactions.

Each group could make an oral presentation to the class, using the poster for illustration. The posters could be posted on a bulletin board in the order the reactions occur in the activity.

- Mix 1.7 g iron filings and 1.0 g powdered sulphur in a crucible. Heat the crucible with a low flame for three minutes and then for five minutes with a hot flame. Compare the characteristics of the product (after it has cooled) to the characteristics of the reactants.

- Get a Material Safety Data Sheet (MSDS) for one of the chemicals which is used in your laboratory. Study the type of information that is presented on the sheet. From a list of chemicals provided by your teacher, select one chemical and prepare an MSDS for it. **(This activity was adapted from *CHEM13 NEWS*, #195, May 1990, page 12, based on an idea from H.E. Pence of Oneonta, NY)**

- Here are three quick ways to generate gases for illustrating tests. They are demonstrations which Michael Faraday did in annual Christmas chemistry lectures for children.
  - A half glass of soda water (or vinegar with baking soda) will produce enough CO_2 gas in the top part of the glass to extinguish a candle flame or burning splint thrust into that space.
  - Oxygen gas can be generated in another glass by adding a pinch of $CoCl_2$ (cobalt(II) chloride) to household bleach. Alternatively, 3% H_2O_2 (hydrogen peroxide) and a pinch of MnO_2 (manganese dioxide) can be used. A glowing splint will burst into flame when inserted into the top part of the glass.
  - Generate H_2 gas (hydrogen gas) by adding a small piece of aluminum foil to about 2 mL of 3.0 M NaOH solution (sodium hydroxide, or lye) in a 13 x 100 mm test tube. A burning splint held at the mouth of the test tube will produce a 'pop'. A glowing splint quickly inserted into the test tube will go out.

What are the equations for the reactions in each case? **(This activity was adapted from *CHEM13 NEWS*, #205, September 1991, page 9, from an article contributed by John Fortman, Dayton, OH)**

- A microscale procedure for the collection of O_2 gas (oxygen gas) by the displacement of water is described in *CHEM13 NEWS* #183, February 1989, page 13.

- A colour video camera equipped with lenses and adapters designed to fit student microscopes gives students a chance to view a variety of microscale reactions in great detail. If you can borrow some binocular dissecting microscopes from the biology department, this activity also works well when the reactions are observed under those instruments. Porcelain or plastic spot plates are used as the reaction vessels.

Place a small pinch of iron filings in a depression of the spot plate. Observe and describe the filings. Add 1 or 2 drops of 0.1 M $CuSO_4$ (copper(II) sulphate) solution. Record your observations. Write an equation for the reaction which is occurring.

Repeat the procedure twice more, substituting zinc metal and lead metal for the iron filings.

Place a few strands of copper turnings or a few copper shot in a depression. Observe the copper metal. Then add 1 or 2 drops of 0.1 M $AgNO_3$ (silver nitrate) solution. Write an equation for the reaction which is occurring.

Repeat this procedure twice more, substituting iron filings and lead metal for the copper.

To some granular zinc in one of the depressions, add 1 or 2 drops of 1.0 M HCl (hydrochloric acid) solution. Record observations. What do the bubbles indicate? Now add one drop of 6.0 M HCl solution. Observe. Write an equation for the reaction.

Repeat the procedure, using a short piece of magnesium ribbon instead of zinc. **(This activity was adapted from *CHEM13 NEWS*, #199, December 1990, page 14, based on an idea from Norm Hoekstra of Holland, MI as reported in *Periodic Reports and Retorts* (March 1990).)**

- Compare the textures of Plaster of Paris and PolyFilla™. How does each behave when water is added? How does the proportion of water to powder to produce a usable mixture compare? How long does each take to set? What are the chemicals in each? What chemical reactions occur when the powder is mixed with water? Are chemical reactions with the air involved in the curing process? **(This activity was adapted from *CHEM13 NEWS*, #197, October 1990, page 1, based on an idea contributed by David Banks, Gloucester, ON)**

- In a 1.0 litre ziplock bag, put 5.0 g of solid $CaCl_2{\cdot}2H_2O$ and 5.7 g of solid $NaHCO_3$. Squeeze the air out of the bag and then seal it so that there is a minimum of air in the bag. Record your observations of the system.

  Open the corner of the bag and add 10 mL of phenol red indicator solution. Reseal the bag quickly and record your observations.

  What are the chemical reactions involved in this system? What causes the heat effects, the colour changes and the evolution of gas? **(This activity was adapted from *CHEM13 NEWS*, #192, February 1990, page 2, based on an idea from Linda Woodward of University of Southwestern Louisiana. She attributes the idea to Mickey and Jerry Sarquis of Oxford, OH.)**

- Remove the grease from some steel wool. (Dipping in acetone or washing in warm soapy water will do this. Why does most steel wool which you buy have a thin coating of grease?) Dry the steel wool completely before use. Record all observations during this activity. (What do you see? Is there anything you can measure?)

  Put the steel wool in a test tube or small jar. Add enough warm vinegar to cover the steel wool. If a microwave oven is available, warm the mixture in it to just about boiling temperature. Alternatively, warm the container in a warm water bath for about 30 minutes. Then let the mixture sit for a day. Make up a strong solution of tea. Put it aside until the next day.

  Decant the liquid from the vinegar/steel wool mixture. Mix equal volumes of the tea and vinegar solutions in another container. Stir briefly and the use the mixture to write your name on a sheet of paper. Use a small paint brush or a wooden splinter to do this. Set the paper and the container aside where they will not be disturbed. Observe once an hour for the rest of the day and then again on the next day.

  Interpret your observations. Write word equations and formula equations for any reactions which you believe have occurred.

Sample ideas for evaluation and for encouraging thinking

- "Water is the solvent, the medium, the participant and the catalyst in most of the chemical reactions occuring in our environment." Comment on this quotation, taken from *Fact Sheet #1: Water – Nature's Magician* (Environment Canada, 1990).

- Crushed limestone is used in the blast furnaces which reduce iron ore to iron. What is the purpose of the limestone? What chemical reactions is it involved in?

- Identify the chemical processes which are used in drinking water treatment and in waste water treatment. Chlorine gas is commonly added to the water. Is the chlorine involved in any chemical reactions?

- Why do rockets carry tanks of liquid oxygen?

- Why do the alkali metals all react similarly with water?

- A metal can made of iron left half buried in the ground will corrode to leave only a crumbled shell in a few years. A can made of aluminum half buried will last indefinitely. Why is there such a difference? What metals would corrode more quickly than iron?

- As copper weathers, it turns a dark brown and then various shades of green. What reactions are responsible for these colour changes?

- In their solid phases, aluminum conducts electricity and sodium chloride does not. As liquids, both conduct electricity. What is the reason for this difference in behaviour? Are there some substances which conduct in their solid phase but not in their liquid phase?

Mole Concept and Stoichiometry

Unit Overview

In this unit, the concept of the mole is developed. That concept, together with the concepts of ratio and proportion, relative masses of the atoms, and conservation of mass, is key to understanding the analysis of molecules and chemical reactions.

Use concrete examples, analogies and models as much as possible, to enable students to become abstract thinkers in stoichiometric analysis.

Factors of scientific literacy which should be emphasized

A1 public/private
A3 holistic
A5 empirical
A6 probabilistic
A8 tentative

B1 change
B3 orderliness
B8 quantification
B9 reproducibility of results
B10 cause-effect
B11 predictability
B13 energy-matter
B15 model
B20 theory
B21 accuracy
B22 fundamental entities
B23 invariance

C2 communicating
C4 working cooperatively
C5 measuring
C6 questioning
C7 using numbers

D3 impact of science and technology
D4 science, technology, and the environment
D7 variable positions

E1 using magnifying instruments
E3 using equipment safely
E4 using audio visual aids
E5 computer interaction
E9 measuring volume
E10 measuring temperature
E11 measuring mass
E12 using electronic instruments
E13 using quantitative relationships

F1 longing to know and understand
F3 search for data and their meaning
F5 respect for logic
F7 demand for verification

G1 interest
G3 continuous learner
G6 response preference
G9 valuing contributors

Foundational Objectives for Chemistry and the Common Essential Learnings

Explore the concepts which relate to Avogadro's number.

- Use an atomic mass (atomic weight) table to compare the relative masses of atoms.
- Realize that the absolute mass of an atom is very small.
- Describe how Avogadro's number is obtained.
- Explain the concept of a mole.
- Calculate the number of moles in a given mass of atoms or molecules.
- Calculate the masses of various numbers of moles of atoms and molecules

Apply knowledge about atomic mass to calculations dealing with molecules.

- Calculate the percentage composition of elements, by mass, in inorganic and organic molecules from molecular formulas and from mass measurements.
- Calculate the empirical formulas for molecules from data on percentage composition and from mass measurements.
- Calculate the concentrations of solutions in $mols \cdot L^{-1}$.

Perform stoichiometric calculations.

- Extract qualitative and quantitative information from balanced chemical equations.
- Use balanced chemical equations to determine the relative number of moles of reactants and products.
- Manipulate the relationship among molar mass, number of moles and mass of chemicals to solve stoichiometric problems.
- Manipulate the relationship among concentration, number of moles and volume of solution to solve stoichiometric problems.
- Identify limiting reagents in chemical reactions involving non-stoichiometric masses of reactants.

Strengthen understanding within chemistry through applying knowledge of numbers and their interrelationships. (NUM)

- Read and interpret charts and tables.
- Collect, organize and analyze quantitative information from activities.
- Appreciate value of being able to calculate required masses of reactants or anticipated quantities of products.

Develop an understanding of how knowledge is created, evaluated, refined and changed within chemistry. (CCT)

- Make careful observations during active involvement in constructing knowledge.
- Discuss observations, hypotheses, predictions and generalizations with others.
- Recognize how mathematical skill and logical thinking ability are critical to constructing models of how chemical reactions work.

Suggested activities and research project ideas

- Some examples which illustrate the size of Avogadro's number:
  - a mole of sheets of ordinary paper, divided into a million equal piles, is enough so that each pile would reach from the earth to beyond the sun.
  - a mole of pennies, placed side by side would stretch for a million light years.
  - Avogadro's number of grains of sand would cover an area approximately the size of Ontario, Manitoba, Saskatchewan, Alberta, British Columbia, Yukon and the Northwest Territories) to a depth of 2 m.
  - a Cray S-1 supercomputer running at 1 000 MIPS (million instructions per second) would take 1.9 million years to execute Avogadro's number of steps. **(These are taken from the article "A Mole of Heartbeats" by Arthur Last, Athabasca AB in *CHEM13 NEWS*, #195, May 1990, page 6)**

- Here are some ideas for raising awareness about moles in particular and the chemistry program in general.
  - Celebrate Mole Day from 6:02 a.m. to 6:02 p.m. on October 23rd.
  - Make an display small stuffed moles. (Pattern in *CHEM13 NEWS*, #205 (September 1991).
  - Buy and wear a mole t-shirt. (#T27 from Chemsmiles, Box 411, Waterloo N2J 4A9 — $13.00 plus $1.50 postage for one shirt. Postage is 15% of total if more than one shirt is ordered.)
  - Make and wear mole buttons. Give them to other teachers.
  - Make Mole Day posters and post them around the school.
  - Make Mole Day certificates to present to people for various reasons on Mole Day.
  - Join the National Mole Day Foundation. $10 US to NMDF, Box 373, Prairie du Chien, WI 53821.
  - Contact The Mole Company, 1012 Fair Oaks Avenue, #356, Pasadena, CA 91030 for a catalog. **(This activity was adapted from "Mole Day, October 23" in *CHEM13 NEWS* (#205, September 1991, page 8.)**

- Have the students record their predictions, observations and interpretations of the following demonstration:

  Onto the sidearm of each of two 500 mL sidearm flasks, fit a #4 one hole stopper, with the small end of the stopper toward the flask.

  Blow up two large (20 cm diameter) round balloons. Remove the air from them and reinflate several times, so that they will inflate easily during the demonstration. Then place the mouths of the deflated, stretched balloons over the ends of the #4 stoppers.

  Add 200 mL of 6.0 M HCl solution to each flask. Into one flask, place one 2.5 cm by 30 cm strip of aluminum foil. Stopper the flask immediately. Add two strips of foil to the other flask. Stopper it.

  Ask the students to predict which balloon will become larger. Compare the balloons' diameters when the reaction is complete. How do their volumes compare?

  Twist the stem of the balloons, remove them from the stoppers and tie them. Use a candle taped to a metre stick to explode the balloons.

  What gas is produced? What is the limiting reagent? Why does the reaction start slowly and then speed up? What is the relationship between the amount of hydrogen produced and the amount of aluminum used? Would a definite mass of aluminum give a definite volume of hydrogen? **(This activity was adapted from *CHEM13 NEWS*, #199, December 1990, page 6, based on a demonstration contributed by Kerro Knox, Amherst, MA)**

- Use the displacement of copper from copper chloride by zinc to determine which sample provide is copper(I) chloride and which is copper(II) chloride. (Hint: zinc should be used as the limiting reagent in this reaction. Why?)

  Devise a procedure to accomplish this task. Include a sketch of the apparatus and an outline of the data analysis. During a class discussion of the various designs proposed by you and your classmates, be prepared to defend and modify your design.

Teacher's note: Copper(II) chloride absorbs water from the air to form a bright blue hydrated form. Using the brown anhydrous form will simplify the analysis in this activity. Anhydrous copper(II) chloride can be produced by heated the hydrated crystals in a lab drying oven or under a heat lamp. A subsidiary investigation might be to determine the value of *n* in the hydrated crystal $CuCl_2 \cdot nH_2O$.

- **Devise a procedure to determine the percentage of oxygen in the air you exhale. Draw a diagram of the apparatus you would use to discover this, and outline the calculations which would be needed.**

Sample ideas for evaluation and for encouraging thinking

- A class or small group discussion on the significance of the Law of Conservation of Mass can centre about the students' own bodies. Every atom in every cell – skin, muscle, bone. etc. – has come from somewhere else.

  Trace the origin of the component atoms of the students' bodies back to plants and then to the air, the soil, and the water. A source of information to get the discussion going might be a list of the elements in a human body. Students could prepare posters or charts which indicate from which foods each of the elements come. This could be related to the **Ecological Organization** unit in grade 11 biology.

  The discussion can be extended to consider the matter of recycling. **This has been adapted from an article "The Law of Conservation of Mass Revisited – With a Look to STSE" by Warren Wessell in June 1990 issue of *The Accelerator*.**

- Balance these equations.

  $FeS_{(S)} + O_{2(g)} \rightarrow Fe_2O_{3(S)} + SO_{2(g)}$

  $Na_{(S)} + H_2O_{(\ell)} \rightarrow NaOH_{(aq)} + H2_{(g)}$

- $CrO_4{}^{2-}{}_{(aq)} + H^+{}_{(aq)} \rightleftharpoons Cr_2O_7{}^{2-}{}_{(aq)} + H_2O_{(\ell)}$

  Balance this equation. In the reaction represented by the equation above, why must there always be 2 moles of $H^+{}_{(aq)}$ which react for every 1 mole of $Cr_2O_7{}^{2-}{}_{(aq)}$ which forms? (What is the $H^+{}_{(aq)}$ species doing during the reaction?)

- One mole of nitrogen gas reacts with three moles of hydrogen gas to form two moles of ammonia. Write the balanced equation for the reaction and determine what mass of ammonia can be formed if 56.0 grams of nitrogen gas react.

- **When coal is burned, sulphur impurities in the coal also burn. The sulphur oxides which form react with oxygen and water vapour in the air to form acids. If the major oxide of sulphur which forms is $SO_{2(g)}$, write a balanced equation for the production of sulphuric acid from this oxide.**

  What are some other formulas of sulphur oxides? Why would $SO_{2(g)}$ be the most common oxide produced when coal is burned as a fuel?

  Assume that the average sulphur content of Western Canadian coal is 0.4% by mass. (The range is from 0.2% to 1%.) What volume of 1.0 $mol \cdot L^{-1}$ $H_2SO_{4(aq)}$ could be made from the $SO_{2(g)}$ produced when 1 tonne of coal is burned in an electrical generation plant?

  Approximately 11 million tonnes of coal are burned in Saskatchewan to supply 76% of our electrical supply. Assuming that the average sulphur content is 0.4%, how many tonnes of sulphur are found in the Saskatchewan coal burned each year. How many moles of sulphur is this? How many litres of concentrated (18 $mol \cdot L^{-1}$)could be made from this sulphur if it were all captured as $S_{8(s)}$?

  How is sulphur removed from coal before the coal is burned? How are the sulphur oxides removed from the flue emissions after the coal is burned?

Optional: **Behaviour of Gases**

Unit Overview

There are a variety of investigations which can contribute to students' understanding why gases behave as they do — examining some of the properties of gases, collecting data and analyzing the results, searching for trends and relationships. Students can recognize that macroscopic properties of gases can be explained by events that might be taking place at a molecular level.

From relationships deduced from observations about the properties of gases, students can develop an understanding of how the mathematical expression of various gas laws are developed. This unit should not be treated only as an opportunity to do mathematical manipulations. The basis of such calculations should be established through experimentation.

Students should become acquainted with the new definition of standard state pressure, referred to as SATP. They should recognize both STP and SATP while the transition to use of SATP is being made. An article on this topic is "The New Pressure Standard in Chemistry" by Geoff Rayner-Canham in *CHEM13 NEWS*, #192, February 1990, pages 1-2.

Factors of scientific literacy which should be emphasized

A2 historic
A4 replicable
A5 empirical
A6 probabilistic
A8 tentative

B1 change
B2 interaction
B7 force
B8 quantification
B9 reproducibility of results
B10 cause-effect
B15 model
B16 system
B21 accuracy
B33 entropy

C5 measuring
C7 using numbers
C8 hypothesizing
C9 inferring
C10 predicting
C11 controlling variables
C12 interpreting data
C13 formulating models
C14 problem solving
C15 analyzing
C16 designing experiments
C17 using mathematics

D3 impact of science and technology

E1 using magnifying instruments
E3 using equipment safely
E5 computer interaction
E7 manipulative ability
E9 measuring volume
E10 measuring temperature

F2 questioning
F7 demand for verification

G2 confidence
G6 response preference
G8 explanation preference
G9 valuing contributors

Foundational Objectives for Chemistry and the Common Essential Learnings

Apply kinetic molecular theory to understand the properties of gases.

- Compare the behaviour of solids, liquids, and gases.
- Investigate the behaviour of several gases while varying the temperature, pressure, volume or number of moles.
- Use the kinetic molecular theory to make sense of observations about the behaviour of matter.

Recognize how knowledge about gas behaviour is used in science and in technology.

- Consider the importance of Avogadro's hypothesis.
- Identify industrial use and application of gases and their behaviours.
- Recognize why particular conditions have been defined as standard temperature and pressure (SATP and STP).
- Discuss the concept of molar volumes of gases.
- Identify the SI units used to measure temperature, pressure, and volume.

Describe gas behaviour with mathematical equations.

- Sketch graphs which express the relationships among temperature, pressure, volume and number of moles of gas.
- Examine the link between the graph and the equation for a relationship.
- Discuss the concept of an ideal gas.
- Solve problems relating to the gas laws.

Strengthen understanding of gas behaviour by using knowledge of numbers and their interrelationships. (NUM)

- Read and interpret graphs to deduce the relationships between the variables.
- Develop and use their understanding of quantitative information through graphical analysis.
- Understand the uncertainties inherent in measurement and in inductive logic.

Understand and use the vocabulary, structures and forms of expression which characterize chemistry (COM)

- Incorporate the vocabulary of chemistry into talking and writing.
- Use graphs and equations to explain to others about gases and gas behaviour.

Develop an understanding of how knowledge is created, evaluated, refined and changed within chemistry. (CCT)

- Control variables, record experimental data, and analyze those data for patterns and relationships.
- Understand the relationship between observations and measurements and their abstract expression as mathematical formulas.
- Recognize the importance of mathematical expression to the ability to generalize and predict.

Suggested activities and ideas for research projects

- **Set a tube create from three clear plastic straws on a horizontal, dark background. Put a drop of concentrated $HCl_{(aq)}$ on one Q-tip and a drop of concentrated $NH_4OH_{(aq)}$ on the other.**

  Insert the Q-tips simultaneously into opposite ends of the tube. Record the time it takes for the vapours to diffuse and meet in the tube. Watch closely so that you will be able to tell when they meet. What is the formula of the white product formed? How far did each gas travel before they met? Is there a relationship between the mass of the gas molecules and the distance they travel. Can you express this relationship mathematically.

  Note to teachers: The diffusion of ammonium hydroxide and hydrogen chloride through a glass tube forming a visible ammonium chloride front where they meet, most often done as a demonstration, can be done as a microscale activity. This makes it easy for each lab group to do the activity.

  Clear plastic drinking straws substitute for a glass tube. Two or three straws spliced together give a long enough tube. Q-tip cotton swabs can be used to introduce the reactants into the tubes. One drop of concentrated reactant on each swab is enough.

  A Q-tip, pulled through the tube with some thread or dental floss, will clean out the tube well enough for it to be used for second, third, and fourth trials. **(This activity was adapted from *CHEM13 NEWS*, #203, April 1991, page 10, based on an idea contributed by Larry Benton Collins of Arlington, TX)**

- Get a short piece of plastic pipe which can be used to join two balloons together. Blow one balloon to about two thirds of its capacity and the other to about one third capacity. While holding the stems to prevent air loss, attach each of the balloons to the pipe. Predict what will happen when the stems of the balloons are released. Create an explanation of this phenomenon.

Sample ideas for evaluation and for encouraging thinking

- Why is there a particular volume which one mole of any gas measured at some stated temperature and pressure occupies? Is there a volume which one mole of any metal measured at a stated temperature and pressure occupies?

- V=kT is sometimes referred to as Charles's Law and sometimes as Gay Lussac's Law. PV=k is sometimes referred to as Mariotte's Law and sometimes as Boyle's Law. Why are there double names for these realtionships?

- In the relationship V=kT, what are the units of the constant *k*? Why do constants appear in all gas law expressions, or indeed in any mathematical expressions which express the relationships of physical or chemical measurements?

- Scuba and deep-sea divers take precautions when surfacing to avoid problems caused by dissolved gases in their blood and the gases in the alveoli of their lungs? What precautions do they take? What makes these precautions effective? What properties of gases make caution when diving essential?

- Suppose a grade six student came to you and asked you to explain why balloons get larger when they are heated. Construct an explanation for the student. Describe any models, analogies or diagrams you would use during the explanation.

- Suppose a grade six student came to you and asked you why hot air balloons rise when they are heated. Construct an explanation for the student. Describe any models, analogies or diagrams you would use during the explanation.

- A motorist checking the tires of his car before starting out on a trip from Biggar to Kyle noticed that one tire was a bit low. Its pressure was 180 kPa, but he decided to go anyway. When he got to Kyle his sister pointed out that the tire was low. He measured the pressure again and discovered it was 205 kPa. What could have caused the change in tire pressure?

  Is 180 kPa a low pressure for tires?

Optional: **Consumer Chemistry**

Unit Overview

How can chemistry help us understand how a product works? Why is a product effective? What chemicals is a product made of? Did the idea for the product originate in a property of a chemical and the search for an application for that property? Did it originate in a perceived need and the search for a chemical or substance to fulfil that need?

One instructional method which may work in this unit is to assign each student or group of students one or more or the questions posed in the **Suggested activities** section of the unit. Each student or group would be responsible for preparing a presentation to the class, reporting the results of their research. Encourage students to use a wide range of reporting techniques. Posters, poems, video reports, and models are some of the options.

Factors of scientific literacy which should be emphasized

A1	public/private
A3	holistic
A7	unique
A9	human/culture related
B12	conservation
B16	system
C1	classifying
C2	communicating
C3	observing and describing
C6	questioning
C8	hypothesizing
C9	inferring
C10	predicting
C12	interpreting data
C15	analyzing
C16	designing experiments
C19	consensus making
D1	science and technology
D2	scientists and technologists are human
D4	science, technology, and the environment
D6	resources for science and technology
D8	variable positions
D9	social influence on science and technology
D11	science, technology, and other realms
E2	using natural environments
E9	measuring volume
E11	measuring mass
E13	using quantitative relationships
F2	questioning
F3	search for data and their meaning
F4	valuing natural environments
F6	consideration of consequence
G1	interest
G3	continuous learner
G5	avocation

Foundational Objectives for Chemistry and the Common Essential Learnings

Investigate the chemical principles involved in the composition, production or functioning of consumer products.

- Identify chemicals in the components of consumer products.
- Classify the components as either structural or functional.
- Discuss how the chemicals selected are suited for their function.
- Suggest alternatives or substitutes for the chemical components in a product.

Describe and discuss the impact of the chemical industry on society.

- Explain the role of chemistry in the manufacture of consumer products.
- Investigate how chemistry has led to advances or innovations in various consumer products.
- Show how the application of chemistry in consumer products has led to changes in health and lifestyle.
- Investigate the impact of chemicals from consumer products on the environment.
- Understand how chemistry can be used to help make informed consumer decisions.

Develop a contemporary view of chemical technology and its influence on our lives. (TL)

- Examine experiences with and contact with chemical technology in the home and community.
- Understand the political, social and consumer demands which create and sustain technological developments.
- Understand how technological developments can create and sustain consumer demand.

Develop a positive disposition to life-long learning. (IL)

- Cooperate with and help each other in order to enhance understanding through shared information.
- Plan investigations into topics in chemistry.
- Develop a willingness to take risks as independent learners.
- Recognize the inevitability of profound change due to advancement in technology and changes in society's values and norms.
- Understand how change can be influenced by those who keep themselves informed.

Suggested activities and ideas for research projects

- 18-carat gold contains 75% gold. The rest is silver and copper in varying proportions. 18-carat gold is harder than pure gold. A 50% solution of antifreeze in water freezes at a lower temperature than either pure water or pure antifreeze. Are these two phenomena related?

- How does adding gallium or arsenic to pure silicon chips allow the silicon to conduct electricity?

- What chemicals are found in cream blushes and in powder blushes?

- It takes approximately 5% as much energy to manufacture an aluminum can from a recycled can as from the bauxite ore. Outline the chemical processes involved in producing aluminum from bauxite. Which of the processes require the greatest energy inputs?

- Investigate the production and recycling of automobile batteries. What are the main chemicals and processes involved?

- What is acid indigestion? What acids are involved? How do antacid tablets combat acid indigestion?

- Cars are one of the worst sources of air pollution in urban North America? What chemical compounds are emitted from cars? By what chemical processes are these compounds formed?

- Home safety books say that one should never mix bleaches with other cleaners. Why?

- How are bleaches which are advertised as safe for all fabrics or as being 'bleach for the unbleachables' different from other bleaches? How effective are they? By what process does each type of bleach work?

- What are some chemicals which can be used as sunscreens? How does each one prevent ultraviolet radiation from reaching the skin? How are do sunblocks work? What chemicals are used as sunblocks?

- What chemicals are involved in acne remedies? Do they act on the cause of the acne, remove the symptoms or mask the symptoms? How do the chemicals affect the skin, the gland ducts and the bacteria?

- What dyes are used in eye shadow? In what medium is the dye suspended? What are the sources of these dyes? What are some other uses of the dyes?

- Compare and contrast the chemicals used in lip gloss, regular lipstick and frosted lipstick.

- What are the active chemicals in hair gels and mousse? Are these the same chemicals which are used in hair sprays? Are these chemicals or similar chemicals used in any other applications?

- How are detergents chemically different from soaps? How does this difference affect their abilities to clean? What are the advantages of each class of product?

- How are a facial soap, a body soap, an anti-bacterial soap and a European bathing gel chemically similar? How are they different?

- Find out how to make soap using lard and lye. Make some soap and devise tests to see how the soap compares to commercially produced soaps. Use caution when using the soap on the skin. The soap may be caustic if not all the lye has been neutralized. Try canola oil or olive oil instead of lard.

- All members of the group of chemicals called alcohols have an —OH group on a carbon chain. How are all steroids similar? What are some steroids which the human body produces? How do steroids such as stanozolol aid muscle growth? How do synthetic steroids compare to natural steroids?

- Most fertilizers contain nitrogen, potassium and phosphorus. What are these nutrients used for in plants? How do they get from the ground into the plant? What other nutrients are needed for plants? Why don't we hear as much about these other nutrients in fertilizers? For each mineral nutrient which a plant needs, identify one natural compound or source in the soil for this nutrient.

- Some fertilizers for houseplants are advertised as 'slow-release' fertilizers. What does that term mean with respect to fertilizers? How are slow release fertilizers produced?

- What chemical compounds are found in pink fibreglass insulation? How is it produced? Can recycled glass be used to make fibreglass?

- Food additives can be used for more than preserving food. How many different purposes can you identify?

- If an apple is dipped in ascorbic acid solution or lemon juice as soon as it is cut, the apple's surface won't turn brown as quickly? What is the chemical reaction which turns the apple brown and how does the citric acid solution prevent this?

- Do chemicals which are used as food additives undergo chemical reactions with the food or are they just mixed in with the food?

- Go to a grocery store and make a list of the ingredients in each brand of ice cream that is sold there. For each brand, make a poster listing each ingredient, its chemical formula or the class of compounds to which it belongs and the reason the substance is used.

- When liquid egg white is dropped on a hot frying pan it turns to a white solid immediately. What chemical reaction is involved in this change? Drop some vinegar or some lemon juice into some liquid egg white. What changes can you observe? Sketch diagrams or create a model to show the chemical reaction which occurs.

- Poisons which affect humans can be classified as either neurotoxins or hemotoxins. Is there a way to classify herbicides based on what part of the plant they affect? How is the way a herbicide affects a plant related to the type of chemical?

- Are herbicides manufactured in Saskatchewan? What raw materials are used in their production?

- Recent reports indicate that drinking some liquids which have been stored in lead crystal containers may be hazardous. What is lead crystal? What is the hazard? What type of liquids cause the problem? Many paints used to use lead-based pigments. Why were lead-based pigments used? What chemicals are found in most paints now? How are these pigments produced?

- Potters often make their own glazes. What chemicals are used in the preparation of these glazes? What hazards are produced when the glazes are fired?

- How is phototropic glass produced? Is the reaction which occurs when the glass turns darker with exposure to light completely reversible? How long does it take the glass to darken? Is there a limit to how dark the glass can become?

- How many different types of plastics can you identify in products in your school and home? Make a poster listing the type of plastic (e.g. high density polyethylene), several uses for that type, the formula of the monomer or dimer and indicate the sites at which the monomer or dimer polymerizes.

  For each product you can identify which is partially or entirely made of plastic, find out what materials were used for that part or product before plastics were developed. If the product has been developed after plastics have become prevalent, and so has never been made of another material, indicate that.

- How does Freon™ produce its cooling effect in refrigerators? What harm does it cause when it escapes into the atmosphere? Write the chemical equations which illustrate the harm it does.

- How many uses are there for hydrogen peroxide? Some first aid books recommend that hydrogen peroxide be purchased in as low concentration and stored at as low a temperature as possible. Why would they make these recommendations?

- How does rust form on metals? How are the paints that are advertised as being rust inhibitors different from other paints?

- If you have a car with an aluminum block, why is it important to buy antifreeze that is 'aluminum compatible'? What would be the chemical effects of using incompatible antifreeze?

- Gasoline, fuel oil, diesel fuel and kerosene (jet fuel) are all extracted or refined from crude oil. What are the differences in the products? Explain in terms of the chemical constituents of each mixture.

- Emergency flares can be purchased to burn at the side of a road behind a disabled vehicle or to shoot from a launcher for fliers or boaters who have been marooned. What chemicals are in the flares to make them burn so brightly? Have you ever had a birthday cake with sparklers on it? What chemicals are used to make those type of sparklers?

- Synthetic fabrics are very common. Make a poster listing the common or trade names of synthetic fabrics and what chemical or compound each is composed of.

- Research into the chemical components of natural fibres. How does a wool fibre differ chemically from a cotton fibre? Why are wool fabrics rough and scratchy while fabrics of silk are smooth and soft? What other natural fabrics are there?

- The labels of many household products have the corrosive, toxic or flammable symbols on them. Make a list of these products, categorizing them by type of risk. Seven groups will be enough to separate them into all possible combinations (toxic and corrosive, etc.). Identify as many noncorrosive, nontoxic or nonflammable substitutes as possible. Consider the advantages and disadvantages of using the substitute products.

- Most people know that the most of the gold used for making jewellery comes from gold mines. Make an inventory of everything in your classroom. Identify the chemical components of each item in your inventory and list the source of that component. How many of these resources are produced in Canada? For example, a Bic ballpoint pen might be analyzed as follows:
  - plastic barrel — polycarbonate plastic from crude oil
  - plastic plug in the end of the barrel — polyethylene from crude oil
  - plastic ink tube — polyethylene from crude oil
  - metal support for ball — alloy of copper and zinc, both from mines
  - ball — nylon, synthesized from organic acids and alcohols derived from crude oil

- How is stainless steel made rust resistant? Why can't cars be made from stainless steel? How are manufacturers attempting to make their cars more rust resistant?

- How is the glass used in stained glass art coloured? What chemicals are used as pigments? Is the pigment on the surface of the glass or does it permeate the glass? Do the pigments react chemically with the glass or do they remain with the glass as a mixture or a surface coating?

- The search for diamonds has come to Saskatchewan. What is the chemical formula of diamond? How are they formed in nature? How are synthetic diamonds formed?

- What are the elements and compounds in the material used to fill cavities in teeth? When are metal fillings used? When are plastic fillings used? Ultraviolet light is used to cure the plastic fillings. What chemical changes does the uv light induce in the plastic?

- Sodium sulphate is a mineral which is produced in several locations in southern Saskatchewan. How is the chemical concentrated and purified? What is the market for sodium sulphate?

- Ceramic tiles are used on the heat shield of the space shuttles. They are also used as flooring and wallcoverings. What effect does the firing process during their manufacture have on the chemical structure of the clay they are made from? Does the glaze react chemically with the clay? What chemical changes occur in the glaze during firing?

- How is a perfume different from a cologne of the same fragrance? Is the type of solvent different? Is the concentration of the fragrance molecule in the solvent different? Is a different fragrance molecule used?

- Some photographic processors are advertising that they use a process which removes heavy metal ions and toxic solvents from the water before it is disposed. What heavy metals are used in photography? What solvents are used in developing film? How are these removed from the waste water before it enters the sewage system?

- Many products we use are welded by electric arc welding. Welding rods normally have a metal core and an outer coating. What metal is the core composed of? What is the function of the core? Does it react chemically with the metals to be welded? What chemicals are used to coat welding rods? What is their function? What chemical reactions are they involved in?

- One form of arc welding is called gas shielded arc welding. MIG and TIG welding are examples of this process. What gases are used in the gas shielding process? What do these gases shield the weld from? How do they shield it?

- How many types of processes are there for home water softening? What are the ions which must be removed from water to make it soft? What chemical reactions are involved in removing these ions?

- A number of years ago there were several instances of children receiving severe burns when the fleece material of their pyjamas caught fire. Children's pyjamas are now treated with flame retardants. What other fabrics are treated with flame retardants? What chemicals are used to produce the flame retardant effect? How do these chemicals act to inhibit burning?

- Suppose that legislators became concerned about the use of fossil fuels for running private vehicles. What types of laws/recommendations could they make in order to half the amount of fuel use in private vehicles.

- Suppose legislators decided that in order to conserve crude oil and natural gas, the amount of these resources consumed for the production of plastics would be cut by 10% a year for five years. You were appointed to a board which would make recommendations about places where plastic use could be reduced. What are some recommendations you could make?

- Sulphur is a by-product of the natural gas extraction industry. What uses are there for the sulphur removed from sour gas? How is the sulphur extracted from natural gas?

- Coal contains sulphur. What is the impact on the environment if when the coal burns, sulphur oxides escape into the air? Can the sulphur be removed from the coal before it is burned? Can the sulphur oxides be removed from the smoke? What is coal used for? Are there any fuels which could replace coal? What risks or costs are associated with these substitutes? Could coal be used to replace other fuels we currently use?

- Lots of information and ideas for investigations about food additives can be found in the article "Food Additives" in *CHEM13 NEWS*, #207, November 1991, pages 8-9.

Optional: **Organic Chemistry**

Unit Overview

This unit is designed to present students with a broad understanding of organic chemistry. The nomenclature of organic chemistry was introduced in the unit **Molecules and Compounds**.

Here the concepts of functional groups, the importance of structure and the variety of organic compounds and reactions are stressed.

Factors of scientific literacy which should be emphasized

A3 holistic
A4 replicable
A9 human/culture related

B4 organism
B16 system

C1 classifying
C4 working cooperatively
C6 questioning
C8 hypothesizing
C9 inferring
C12 interpreting data
C13 formulating models
C14 problem solving
C15 analyzing
C20 defining operationally

D1 science and technology
D4 science, technology, and the environment
D6 resources for science and technology
D8 variable positions
D9 social influence on science and technology
D10 technology controlled by society

E4 using audio visual aids
E5 computer interaction

F5 respect for logic
F6 consideration of consequence

G1 interest
G2 confidence
G3 continuous learner

Foundational Objectives for Chemistry and the Common Essential Learnings

Consider the characteristics of organic substances.

- Recognize the difference between organic and inorganic substances.
- Name aliphatic or aromatic hydrocarbons using the IUPAC system.
- Distinguish between saturated and unsaturated compounds.
- Compare straight-chain, branched-chain, and cyclic organic molecules.
- Draw structural formulas for hydrocarbons.
- Identify important properties of different types of hydrocarbons.
- Identify some important uses of organic substances.
- Classify organic compounds based on their functional groups.

Develop intuitive, imaginative thought and the ability to evaluate ideas and processes. (CCT)

- Explore the rules which underlie the categories of organic compounds.
- Explore relationships and patterns.
- Design and construct models which illustrate principles and functions.

Suggested activities and ideas for research projects

- To 500 mL of skim milk, add 25 mL of vinegar. Heat the mixture gently while stirring continually. When the milk has curdled, remove from the heat and let the mixture settle. Decant the liquid from the mixture, being careful not to lose any solid. This mixture can also be strained through a coarse cloth, such as cheese cloth? (Why might that type of cloth be called cheesecloth?) Dry the solid.

  Add the solid to about 25 mL water, add about 5 grams of sodium carbonate (washing soda) or sodium bicarbonate (baking soda) and stir to make a paste. Add more water if necessary to make a smooth paste. The paste is a glue called casein glue. Devise some tests to compare its strength to the strength of other glues.

  Why is casein glue called an organic glue? What substances are found in the curds of milk?

- Many organic (carboxylic) acids will react with alcohols to form esters with strong aromas. Mix 1 mL acid with 1 mL alcohol in a 13×100 mm test tube. Add about 10 drops of concentrated H_2SO_4. Heat in a water bath (at about 80°C) for about five minutes. This will produce enough ester to be perceptible to most peoples' sense of smell. If not, pour the reaction mixture into a 250 mL beaker containing about 100 mL of water at about 50°. This should volatize the products.

  Try mixtures of glacial acetic acid and n-pentanol, glacial acetic acid and n-octanol, butanoic acid and butanol, and salycylic acid and methanol.

  Challenge question: What is the purpose of the H_2SO_4?

- Investigate the structures of various complex organic compounds. How are saccharin and sucrose similar? Why are dioxins produced as byproducts during the production or low-temperature combustion of PCBs? How do the structures of natural and synthetic estrogen compare?

Sample ideas for evaluation and for encouraging thinking

- What is the difference between an alkane and an alkene? How is this difference related to the difference between saturated fats, unsaturated fats, and polyunsaturated fats?
- Why are carbon containing compounds called organic compounds? CO_2 is most often classified as an inorganic chemical. What does being classified as an inorganic chemical mean? Construct an arguement for the case that CO_2 should be considered as an organic chemical.
- Alkanes with from one to four carbon atoms per molecule are gases at room temperature. Alkanes with more than four carbon atoms per molecule are liquids or solids at room temperature. Why?
- One process in the refining of crude oil involves the catalytic cracking of long chain carbon molecules to form short chain carbon molecules. Why is this done? What catalysts are used?
- Why is ethene (ethylene) such a useful chemical?

Optional: **Teacher Developed Unit**

Unit Overview

Several approaches may be used for this unit. One would be to use the time to further develop the material in another unit. This allows additional reinforcement, remediation, and enrichment of the unit selected. Further laboratory activities or independent research such as investigations in qualitative analysis could provide opportunities for the teacher to adapt the program to meet the needs of the students.

The **Teacher Developed Unit** could be used to develop a topic not included in the core or optional units. Such a unit might be based on the expressed interests of the students, some special ability of the teacher or some particular community resource or concern.

The unit might also be based on science outreach activities. Guest speakers could be invited into the classroom to discuss a variety of things related to chemistry. Field trips could also be designed to enhance what students have learned in class and add relevance and interest to the topics that have been studied. Careers in chemistry and related occupations could be examined.

Chemistry 30

Review of Basic Principles

Unit Overview

This core unit reviews some of the important concepts developed in Chemistry 20. Students' understanding of key concepts such as safety, atomic theory, periodicity of the elements, nomenclature, the mole, stoichiometry, and bonding should be assessed.

This may be done at the beginning of the Chemistry 30 course, or throughout the course at appropriate times. Either method, or some combination of the two, would be acceptable.

Students may come from a variety of backgrounds and have been away from the study of Chemistry for a long or a short period of time. Giving students a chance to familiarize themselves with the resources, the facilities, and the demands of Chemistry 30 will help to reacquaint them with chemistry.

Factors of scientific literacy which should be emphasized

A1 public/private
A7 unique
A9 human/culture related

B10 cause-effect
B22 fundamental entities

C1 classifying
C2 communicating
C6 questioning
C20 defining operationally

D1 science and technology
D4 science, technology, and the environment

E3 using equipment safely

F1 longing to know and understand
F2 questioning

G2 confidence
G3 continuous learner
G5 avocation
G6 response preference
G8 explanation preference

Foundational Objectives for Chemistry and the Common Essential Learnings

Exhibit an understanding of the language and organization of chemistry.
- Identify protons, neutrons, and electrons as components of an atom.
- Calculate atomic mass (atomic weight) values when given the percentage of each isotope of an element.
- Use the periodic table.
- Write the formula of a compound, given its name.
- Write the name of a compound, given the formula.
- Use a table of atomic mass units (atomic weights) to determine the formula weight (molecular weight, molecular mass, molar mass) of chemical compounds.
- Balance chemical equations for mass and for charge.
- Describe the physical properties of ionic, metallic, covalent (molecular), and van der Waal's solids.

Develop their abilities to meet their own learning needs. (IL)
- Demonstrate an awareness of standard safety precautions that are used in the laboratory.
- Analyze information from graphs and tables.
- Collaborate with teachers and with others to determine and monitor learning progress and processes.

Laboratory Activities

Unit Overview

This unit is intended to be integrated with the other units in Chemistry 30, rather than being treated separately. The laboratory activities should be spread through the entire course, although one or two units may receive a greater allotment of laboratory activity time than the others. They should also target a wide range of factors within all seven Dimensions of Scientific Literacy.

The 20 hours of laboratory activity should be time that students spend actually performing activities. **Laboratory activities can be considered as having three separate phases: the preparation phase, the activity itself, and follow-up phase.** Demonstrations performed by the teacher should not be counted as part of the time devoted to laboratory activities, unless they involve a significant response and self-directed extension of the experience by the students.

Some of the activities may be more open-ended than others. Students should be encouraged to design and conduct their own investigations, when appropriate. A useful strategy with each activity is to ask students as a part of the pre-lab discussion to generate a list of the safety procedures to be followed during that activity. This can be done in a general class discussion or with a general discussion to synthesize suggestions from individual lab groups.

Consult *Science: An Information Bulletin for the Secondary Level – Chemistry 20/30 Key Resources* for a correlation of activities from a number of sources to the topics of the curriculum.

Consideration should be given to the use of microscale experimentation. In an article in *Chem13 News* on microscale experimentation, Geoff Rayner-Canham, William Layden and Deborah Wheeler wrote:

> There are eight advantages of conversion to microscale.
>
> 1. The low cost of most microscale equipment. Many items are available in bulk from biomedical suppliers.
> 2. A reduction in chemical costs (though there is a short term increase in costs due to the purchase of microscale equipment).
> 3. An almost complete elimination of waste disposal problems.
> 4. A reduction in safety hazards. Not only are smaller quantities likely to present less severe safety hazards, but the use of plasticware precludes the possibility of injury due to broken glass.
> 5. Most experiments can be performed more quickly on the microscale.
> 6. Less space will be needed for storage as the volume of chemicals will be less. Also, the space needed for equipment storage is far less.
> 7. The microscale (twenty-first century) lab can be a clean, odourless, comfortable work environment in contrast to the cluttered, dirty, smelly, and dingy (nineteenth century) laboratory of the past.
> 8. Students really enjoy working with microscale equipment.

(from *CHEM13 NEWS*, #199, December 1990, page 8. Used with permission.)

More information on microscale experimentation can be found in *CHEM13 NEWS* February 1989 (#183), March 1989 (#184), January 1991 (#200), February 1991 (#201), September 1991 (#205) and November 1991 (#207).

"Microscale Chemistry Experimentation for High Schools – Part II: Home Made Equipment" by Geoff Rayner-Canham, Deborah Wheeler and William Layden (*CHEM13 NEWS*, #200, January 1991) and "Iron:Copper Ratios, A Micromole Experiment" by Jacqueline K. Simms (*CHEM13 NEWS*, #200, January 1991) are included as Appendix 1 in this Guide.

Teachers should attempt to use a variety of student assessment techniques during the laboratory activities. Included among those should be techniques which can be used to obtain information in the psychomotor and affective domains. Rating scales, observational checklists, anecdotal records, and test stations could be included. If students are performing tasks which can not be done with pencil and paper, then it is not appropriate to base their assessment on the results of pencil and paper tests alone.

Factors of scientific literacy which should be emphasized

A1 public/private
A3 holistic
A4 replicable
A8 tentative
A9 human/culture related

B1 change
B2 interaction
B9 reproducibility of results
B10 cause-effect
B13 energy-matter

C2 communicating
C3 observing and describing
C4 working cooperatively
C5 measuring
C6 questioning
C7 using numbers
C8 hypothesizing
C9 inferring
C10 predicting
C11 controlling variables
C12 interpreting data
C15 analyzing
C16 designing experiments
C19 consensus making
C20 defining operationally

D2 scientists and technologists are human
D3 impact of science and technology

D6 resources for science and technology
D7 variable positions
D8 limitations of science and technology

E1 using magnifying instruments
E3 using equipment safely
E7 manipulative ability
E11 measuring mass
E12 using electronic instruments

F2 questioning
F3 search for data and their meaning
F5 respect for logic
F7 demand for verification

G1 interest
G3 continuous learner

Foundational Objectives for Chemistry and the Common Essential Learnings

Acquire concrete experiences of chemical events which form the basis for abstract understandings.

Gain proficiency in manipulating laboratory equipment.

Strengthen understanding within chemistry through applying knowledge of numbers and their interrelationships. (NUM)

Develop a contemporary view of technology. (TL)

Develop compassionate, empathetic and fair-minded students who can make positive contributions to society as individuals and as members of groups. (PSVS)

Independent Research

Unit Overview

This unit provides students with unique opportunities to do independent research on some topic in chemistry. The topic may be selected from ones provided by the teacher, or students may be given the responsibility of presenting proposals for their own research project. Guidelines for the projects can be developed with the class. There may be opportunities to cooperate with other teachers (biology, physics, social studies, arts education or an English language arts) to produce a project suitable for submission to both classes.

Clear criteria for assessment of the research projects need to be established, so that students can consider them when they are developing their project proposals. The proposals may be submitted in the form of a contract, indicating the work that an individual or a group agrees to complete by a specific date.

The independent research projects may be treated separately, or integrated with one or more of the units. If the projects are integrated, a common theme might be used for all of the projects. All of the research projects might be related to the **Equilibrium** unit, or to **Oxidation and Reduction**, for example. The student projects would then enhance the presentation of those units, providing additional motivation for learning. As a separate unit, students could select from a wide variety of topics. This allows students to direct their own learning needs and investigate topics of particular interest.

The projects can take many forms. These include: a review of the literature on a particular topic, the design of experiments to investigate some phenomenon, or conducting investigative research into an issue of current societal concern in the community. Science Fair projects could be developed. Many other possibilities exist. Not all students need to work on similar types of projects. **The key here is to allow for flexibility and innovation in independent research.**

Collaborative group projects can also be used to complete a project which is more extensive than could be undertaken by an individual, and to make use of the varied talents of the group members so that the product is greater than the sum of the individual efforts of those involved. Such projects require guidelines regarding the responsibilities of individuals within the group.

Plan cooperatively with a teacher-librarian, if available, so that students have the resources to do literature reviews and research. Strive to update the collection of chemistry-related resources in the resource centre.

Factors of scientific literacy which should be emphasized

A1 public/private
A3 holistic
A7 unique

B8 quantification
B15 model

C2 communicating
C4 working cooperatively
C15 analyzing
C21 synthesizing

D1 science and technology
D3 impact of science and technology
D7 variable positions
D9 social influence of science and technology

E3 using equipment safely

F1 longing to know and understand
F5 respect for logic
F7 demand for verification

G1 interest
G2 confidence
G3 continuous learner
G4 media preference
G5 avocation
G6 response preference
G8 explanation preference

Foundational Objectives for Chemistry and the Common Essential Learnings

Develop abilities to meet own learning needs. (IL)

- Write proposals for individual or group projects, including such things as: a completion date, criteria for assessment, resources to be accessed, preferred method of presentation, suggested audiences for presentation, and meeting dates for review and collaboration.
- Take responsibility for their own learning by setting goals, designing plans, developing proposals, suggesting baseline performance levels, organizing allotted time, managing activities, evaluating success, and reviewing the entire process.
- Demonstrate an ability to access information from a variety of resources.
- Follow guidelines for completing a specific learning task.
- Explore issues or topics which address their interests and concerns.

Understand the uses and abuses of mathematical concepts in everyday life. (NUM)

- Read and interpret quantitative information from a variety of resources, and evaluate arguments based on such information.
- Know when and how to make decisions based on visual observation and interpretation rather than on accurate measuring.
- Develop an awareness of the reporting techniques used by special interest groups to increase the impact of data and influence the the uncritical reader, listener or viewer.

Develop an understanding of how knowledge is created, evaluated, refined and changed within chemistry. (CCT)

- Participate in scientific inquiry.
- Focus attention on knowledge and gaps in personal knowledge related to a specific topic.

Develop compassionate, empathetic and fair-minded students who can make positive contributions to society as individuals and as members of groups. (PSVS)

- Learn in a climate that is sensitive, flexible and responsive.
- Collaborate with teachers and others to determine and monitor their own learning processes.
- Work cooperatively with others.
- Accept and respond to constructive criticism responsibly.
- Share the results of their research project with other students, teachers, parents, or members of the community.
- Share the results of their research by developing displays, exhibits, performances, presentations, demonstrations, lectures, or other appropriate methods.

Ideas for research projects

- Each unit of this curriculum guide has ideas for research projects. Especially refer to pages 86-88 and 117-120 of this guide, which are the Chemistry 20 units **Independent Research** and **Consumer Chemistry.** Pages 102-105 of *Science 10: A Curriculum Guide for the Secondary Level* have ideas for research projects. Some of these may be useful in Chemistry 30.

- Another source of ideas is to keep a list of the chemistry-related questions students, school staff members and others ask during the year. Enlist student aid in reorting and recording these questions.

- Eleven of the videos in the *World of Chemistry* series (see *Science: A Bibliography for the Secondary Level – Biology, Chemistry, Physics* or the Media House catalogue) have been listed for use in the Independent Research units of Chemistry 20 and Chemistry 30. These may be viewed with the whole class or by individuals to stimulate ideas for research projects or as an information source for particular projects.

- A very slimey slime can be made with polyvinyl alcohol and sodium borate. What are the proportions for an ideal slime? How does varying the proportions of these components change the characteristics of the slime? How do the characteristics of the slime compare with the characteristics of other 'strange' substances – a 2:1 mixture of cornstarch and water or a 2:1 mixture of liquid laundry starch and white glue with a pinch of salt?

- What gas is used to inflate air bags in cars? Is this gas stored as a compressed gas or liquid, or is it produced as the product of a chemical reaction? If a chemical reaction is involved write an equation for the reaction. What would be some of the advantages and disadvantages of each method of producing the gas required?

Case Study

Unit Overview

There are several ways to initiate a case study program in the classroom. Prepared studies, complete with readings, activities or questions may be used. Students may create their own case studies, selecting a topic from a list provided or from their own research. Case studies may be integrated with other core units in the Chemistry 30 curriculum or treated as a discrete unit. The goal is to provide students with an understanding of the relevance of chemistry as a human endeavour. One case study could be examined by the entire class, or individual or group case studies could be chosen, in collaboration with their teacher, from a selection of available case studies.

The case studies examined could be contemporary issues or topics in chemistry of current interest. Alternatively, the case studies could be ones of historical interest, illustrating how problems and issues in chemistry were resolved within the context of what was known at the time. Laboratory activities could be performed to attempt to replicate some of the work that chemists used to arrive at important findings. A research component can be included, making this core unit suitable for use in conjunction with the core unit **Independent Research**. Depending on which case studies are available, it could also be done concurrently with any other unit.

The case studies provide an opportunity to emphasize many of the Dimensions of Scientific Literacy. In particular, Dimensions A, D, and F can be developed. The case studies should provide students with a better understanding of the nature of science, of science-technology-society-environment interrelationships, and of values that underlie science.

Details of the strategies that will be used in evaluating the case studies should be explained to the students before they actually begin their work on this unit. Teachers might wish to prepare contracts which identify the criteria upon which evaluation will be based, and the products that students will be expected to produce.

Factors of scientific literacy which should be emphasized

A1 public/private
A2 historic
A3 holistic
A5 empirical
A7 unique
A9 human/culture related
B10 cause-effect
B11 predictability
B16 system

C2 communicating
C4 working cooperatively
C6 questioning
C9 inferring
C12 interpreting data
C14 problem solving
C15 analyzing
C19 consensus making
C21 synthesizing

D2 scientists and technologists are human
D3 impact of science and technology
D4 science, technology, and the environment
D8 limitations of science and technology
D9 social influence on science and technology
D10 technology controlled by society
D11 science, technology, and other realms

F1 longing to know and understand
F2 questioning
F3 search for data and their meaning
F5 respect for logic
F6 consideration of consequence
F7 demand for verification
F8 consideration of premises

G1 interest
G2 confidence
G3 continuous learner
G4 media preference
G6 response preference
G7 vocation
G8 explanation preference
G9 valuing contributors

Foundational Objectives for Chemistry and the Common Essential Learnings

Apply knowledge of chemistry to understanding how that chemistry is developed or used.

- Determine the basic chemical principles which were under study or in use in the case.

Appreciate the work and lives of practicing scientists.

Understand how knowledge is created, evaluated, refined and changed within chemistry. (CCT)

- Contribute to creating a climate that is sensitive, flexible and responsive.
- Read and interpret quantitative information from a variety of resources.
- Evaluate arguments based on quantitative information.
- Share the results of research by developing displays, exhibits, performances, presentations, demonstrations, lectures, or other appropriate means.
- Understand that knowledge alone can not produce wisdom, and that wisdom depends upon the interplay of knowledge, experience, and reflection.

Appreciate the value and limitations of technology within society. (TL)

- Explore technological innovations and their implications.
- Assess technological developments in terms of usefulness, economic factors, and public and workers' health concerns.

Develop a positive disposition to life-long learning. (IL)

- Identify learning needs and interests.
- Write proposals for individual or group case studies, including such things as: a completion date, criteria for assessment, resources to be accessed, preferred method of presentation, suggested audiences for presentation, and meeting dates for review and collaboration.
- Take responsibility for learning by setting goals, designing plans, developing proposals, suggesting baseline performance levels, organizing allotted time, managing activities, evaluating success, and reviewing the entire process.
- Demonstrate an ability to access information from a variety of resources.
- Learn through synthesizing understandings and experiences.
- Follow guidelines for completing a specific learning task.
- Work cooperatively with others.
- Accept and respond responsibly to constructive criticism.

Suggested activities and ideas for research projects

- Several movies produced for CBC TV are good case studies in the field of science. Each is excellent for emphasizing the nature of science, the processes and technical skills of science, and the humanness of the people involved in the scientific pursuits. The movies are *The Race for the Bomb* and *Glory Enough For All*. If these movies become available for use in the classroom, they will be excellent teaching aids. Other movies may be available which are useful in the **Case Study** unit or in other units.

Solubility and Solutions

Unit Overview

One of the suggested Science 10 units is titled "Water Quality". That unit deals with environmental issues involving water quality, and with testing aqueous solutions to determine the presence of particular ions. Basic water and waste water treatment is also considered. If students have had this unit in Science 10, it may serve as a jumping off point for an advanced consideration of water chemistry. If the unit was not used in your school, you might consider using some of the ideas from the Science 10 Curriculum Guide to help develop the concepts of this unit in a context familiar to all students.

The emphasis in this unit is on the qualitative description of solubility equilibria. Students should also be able to analyze information from solubility charts, tables, and experimental results. They should be able to determine whether a precipitate is likely to form when two or more different solutions are mixed.

In addition, practice in calculating the strengths of dilute solutions made from solutes and from concentrated solutions is important. Students have been exposed to the use of solutions and the notation for describing their strength during previous courses. The depth with which this topic is considered during this unit will depend on their experiences and understanding.

Factors of scientific literacy which should be emphasized

A4 replicable
A5 empirical

B2 interaction
B3 orderliness
B8 quantification
B9 reproducibility of results
B11 predictability
B12 conservation
B13 energy-matter
B14 cycle
B16 system
B23 invariance
B28 equilibrium
B29 gradient

C1 classifying
C4 working cooperatively
C5 measuring
C6 questioning
C7 using numbers
C10 predicting
C11 controlling variables
C12 interpreting data
C13 formulating models
C14 problem solving
C15 analyzing
C16 designing experiments
C17 using mathematics
C20 defining operationally

D3 impact of science and technology
D4 science, technology, and the environment
D8 limitations of science and technology

E2 using natural environments
E3 using equipment safely

E4 using audio visual aids
E5 computer interaction
E7 manipulative ability
E9 measuring volume
E10 measuring temperature
E11 measuring mass
E13 using quantitative relationships

F3 search for data and their meaning
F5 respect for logic
F7 demand for verification
F8 consideration of premises

G1 interest
G2 confidence
G3 continuous learner
G5 avocation
G7 vocation
G8 explanation preference

Foundational Objectives for Chemistry and the Common Essential Learnings

Calculate concentrations of, and prepare, solutions.

- Express the concentration of a solution in moles of solute per litre of solution (M, moles·litre^{-1} or mols·L^{-1}).
- Manipulate the relationship which links the mass of solute, volume of solution and concentration of solution so that given two, the other can be determined.
- Describe how to prepare standard solutions and serial dilutions in the laboratory.
- Manipulate the relationship which links original concentration, volume of diluent and concentration of diluted solution so that given two, the other may de determined.
- Relate concentrations expressed as ppm or ppb to those expressed as mols·L^{-1} or g·L^{-1}.

Understand the principles of qualitative analysis of solutions.

- Use solubility charts to determine the solubility of various substances.
- Describe how to perform tests on solutions to determine which ions or ion groups are present.
- Describe how to separate ions in solution by selective precipitation.
- Describe how the common ion effect influences the solubility of a solute in a solution.
- Investigate the application of the principles of solubility.

Use numbers and numerical data to strengthen understanding of the concept of solubility. (NUM)

- Read and interpret solubility charts and tables.
- Discuss with others the process of estimation.
- Use the concepts of probability and logic to understand how qualitative analysis is done.

Promote both intuitive, imaginative thought and the ability to evaluate ideas, processes, and experiences in meaningful contexts. (CCT)

- Use metaphoric and analogic thinking to build understanding and create insights.
- Generate and evaluate alternative solutions to problems.
- Analyze data to create hypotheses, predictions and estimates.
- Generate and explore rules underlying categories.
- Propose generalizations which explain relationships.
- Explore the concepts of probability and risk as it applies to levels of pollutants.
- Consider all evidence before drawing conclusions and developing generalizations.
- Withhold judgement when the evidence and reasons are insufficient.

Appreciate the value and limitations of technology within society. (TL)

- Understand the impact of molecular species detection technology on our knowledge of what pollutants are in our environment.
- Use probabilistic reasoning in relation to the analysis of risk related to molecular species detection.

Suggested activities and ideas for research projects.

- Write complete instructions for the preparation of 250 mL of 0.15 M sodium sulfate solution.

- Write instructions for the preparation of a 100 mL sample of 0.01 M sodium sulfate solution from a stock 0.15 M solution.

- (for those of you who still have $AgNO_3$) To 100 mL of 0.01 M $AgNO_3$, add 100 mL of 0.01 M NaCl. Observe the reaction and record a description of it. If the precipitate has started to settle, resuspend it by swirling the container. Divide the suspension into three parts.

  To the first part, add 20 mL of 0.2 M $Na_2S_2O_3$. A reaction will occur immediately. Describe the reaction.

  Heat the second part gently, either in a flame or a hot water bath. Record observations. What happens if this portion is shaken after it is heated?

  Expose the third portion to either strong sunlight or to an ultraviolet source for five minutes. Record observations.

  Devise explanations for each of the effects observed. Investigate the role of the first reaction in the developing of exposed photographic film. **(This activity was adapted from *CHEM13 NEWS*, #81, page 4, November 1976, based on an idea by L. Sibley, St. Catharines, ON)**

- One of the pollution problems which results from potash mining is the spread of the salts from the tailing piles and brine disposal ponds. While the Na^+ and K^+ ions are not a problem, the Cl^- ions may be. A simple test for the presence of chloride ion (Cl^-) in water can be based on the observation that AgCl has a very low solubility in water. Suppose that dilutions of a silver ion (Ag^+) solution are made so that the concentrations of the series are 10^{-1} M, 10^{-2} M, 10^{-3} M, 10^{-4} M, 10^{-5} M and 10^{-6} M. Samples of these dilutions are then used to test water which is suspected of having significant chloride levels in it. What results would lead you to suspect that there was a large amount of chloride in the water? What results would you expect to see if you tested samples of distilled water? How could you estimate the levels of chloride in an unknown sample? What is the negative effect that chloride ions have on the soil and plants?

- What does a report of 8 ppb of PCBs in drinking water mean in terms of absolute amounts present, risk created and possibility of removal before consumption?

- One of the main potash ores in Saskatchewan is sylvanite. Sylvanite is a mixture of halite (sodium chloride – NaCl) and sylvite (potassium chloride – KCl). How is the KCl separated from the NaCl?

- What are the principles which are used in the solution mining of potash at Belle Plaine? Compare solution mining at Belle Plaine with that used at the sodium sulfate mines at Palo, Snakehole Lake or Chaplin?

- Are paints solutions, colloids or suspensions? How are pigments for paints produced? Are paints used by artists different from paints used by house painters? What different solvents are used to produce paints? What types of paints were used by artists during the Renaissance? How are acryllic or latex paints different from alkyd paints? What types of paints were used to do rock paintings?

- At room temperature, prepare a saturated solution of calcium acetate. Gently heat the mixture, over a low flame or in a water bath. What happens to the solution as it becomes hot? Cool the sample and agitate. Record observations and discuss them.

  Cool the calcium acetate to room temperature and mix 5 mL to 10 mL with 9 times the volume of ethanol (ethyl alcohol). Describe the effect. How does varying the 1:9 ratio affect the properties of the gel? Try mixing calcium acetate with other alcohols. (Caution: This gel, similar in composition to products marketed as 'canned heat', is very flammable. Small amounts can be burned by supporting them on a screen.) **(This activity was adapted from *CHEM13 NEWS*, #81, November 1976, page 17, based on an idea contributed by C. McNeill, Savannah, GA. He attributed the idea to Denman Evans.)**

- Gallstone and kidneystone disease involve formation of insoluble stones which block ducts from these organs. The blockage causes severe pain. Are gallstones and kidney stones chemically similar? What is the source of chemicals for their formation in the human body? How do they form?

- Paper chromatography can be used to separate dyes in food colouring and felt tip markers. What solutions are used as solvents to carry the molecules? What determines how effective a solvent will be? Compare the speed and separating ability of several formulations of solvents, including a 0.1% by weight solution of $NaCl_{(s)}$ in distilled water. What are the chemical and physical properties of the solvents, solutes and paper which interact to make this procedure work? **(This activity is based on an article by Peter G. Markow, West Hartford, CT in *CHEM13 NEWS*, #184, March 1989, page 11.)**

- Why does scum form when soap is used in hard water? Write an equation for a typical chemical reaction involving scum formation.

- How do additives such as Calgon™ soften the water? Devise an investigation to measure the effectiveness of softening water with Calgon, as compared to a regular household water softener and to distilled water.

- What chemicals are responsible for hard water in Saskatchewan? Do the chemicals found in hard water vary from location to location in Saskatchewan? Why is some water harder than other water? Do some chemicals in the water cause more severe effects than others? (Severe can be defined as a more noticable effect, an effect more harmful to health, produced by chemicals more difficult to remove, or some other criteria. Since severe is a relative adjective, it must be defined to give it some quantitative meaning.)

- How do water softeners work? What chemical reactions are involved? What is the chemical difference between hard and soft water? What is the chemical difference between distilled water, water sold in the stores as demineralized water, and soft water? How does water become hard? What is the chemical composition of the salt used in water softeners?

Sample ideas for evaluation and for encouraging thinking

- Stones don't dissolve in water very quickly. Propose a method for determining whether they dissolve in water at all.

- How do kidney stones and gall stones form? Can they be dissolved to eliminate them?

- Calculate the strength of a solution made by dissolving 8.05 grams of $MgCl_{2(s)}$ in enough distilled water to make 500 mL of solution. Why is it important to use distilled water for making solutions? Is there a difference between saying "in enough distilled water to make 500 mL of solution" and "in 500 mL of distilled water"?

- How many moles of HCl are there in 25.5 mL of 2.50 mol•L^{-1} $HCl_{(aq)}$?

- Suppose that each time you rinse a 50 mL graduated cylinder, 1 mL of solution is left on the walls of the cylinder. Use your knowledge of serial dilutions to explain why three rinses of 15 mL each is more effective in removing traces of the previous solution than is one rinse of 45 mL.

- A water testing laboratory measured the [Cl^-] concentration in a sample of well water to be 220 ppm. Estmate this [Cl-] expressed as mol•L^{-1}?

- Ca^{2+} and Mg^{2+} ions are often found in Saskatchewan well water. Why are they so common? Use solubility charts to determine if there are any negative ions which could be used to precipitate them from water.

Energy Changes in Chemical Reactions

Unit Overview

This unit provides students with opportunities to understand the enthalpy changes that accompany chemical reactions. The unit should be treated both qualitatively and quantitatively. The use of analogies, models, and kinetic molecular theory may help students to appreciate how energy changes relate to what changes are taking place at the atomic level.

Students need to be able to interpret information from charts, tables, and graphs. They should compare the determination of enthalpy change by use of bond energy data, tables of heats of formation, and the application of Hess's Law, and discuss any discrepancies observed.

The consideration of enthalpy effects in chemical reactions should be clearly linked to the combustion of carbon-based fuels to provide energy for our society. The stability of the CO_2 and H_2O molecules, which makes the burning of hydrocarbon molecules so exothermic and therefore so attractive, and the contribution of CO_2 to global warming should be discussed.

Discussion of the entropy, free energy and the mathematical determination of the spontaneity of reactions is optional.

Factors of scientific literacy which should be emphasized

A3 holistic
A4 replicable
A5 empirical
A7 unique

B1 change
B2 interaction
B5 perception
B8 quantification
B9 reproducibility of results

B13 energy-matter
B33 entropy

C3 observing and describing
C5 measuring
C6 questioning
C8 hypothesizing
C9 inferring

C10 predicting
C11 controlling variables
C12 interpreting data
C15 analyzing
C17 using mathematics

D1 science and technology
D4 science, technology, and the environment
D8 limitations of science and technology

E3 using equipment safely
E5 computer interaction
E7 manipulative ability
E8 measuring time
E9 measuring volume

E10 measuring temperature
E11 measuring mass
E12 using electronic instruments
E13 using quantitative relationships

F3 search for data and their meaning
F5 respect for logic
F7 demand for verification

G3 continuous learner
G6 response preference

Foundational Objectives for Chemistry and the Common Essential Learnings

Examine the relationships between heat energy and reactions.

- Recognize that energy changes are associated with chemical reactions.
- Relate enthalpy change in a reaction to bond energy and stability.
- Differentiate between endothermic and exothermic reactions.
- Compare the energy changes in phases changes and chemical reactions.
- Explain the difference between heat and temperature.
- Identify reactions which are used to produce useful heat.
- Consider the environmental and social effects of the use of heat energy by our society.

Understand the quantitative description of enthalpy change.

- Measure some energy changes in chemical reactions.
- Investigate how tables of standard heats (enthalpies) of formation are created and used.
- Express the enthalpy change of a chemical reactions as a term in the equation for the reaction, or as a heat of reaction (ΔH).
- Use tables, graphs, or diagrams and an application of Hess's Law to infer enthalpy changes in reactions.

Optional: Understand the reasons why entropy and enthalpy effects are important.

- Identify how entropy effects influence chemical reactions.
- Consider the interaction between enthalpy and entropy in determining whether a reaction is spontaneous.
- Use the concept of free energy to express the quantitative relationship between entropy and enthalpy.
- Predict spontaneity of reactions using $\Delta G° = \Delta H° - T\Delta S°$

Understand and use the vocabulary, structures and forms of expression which characterize chemistry. (COM)

- Incorporate vocabulary such as bond energy, enthalpy, endothermic and standard heat of formation into their speaking and writing about energies of reactions.
- Use tables and graphs in interpreting, estimating and explaining the energy effects of chemical reactions.
- Relate the theoretical aspects of the study of energies of reactions to daily, practical experiences with energy produced by and consumed by reactions.

Strengthen understanding of chemistry through applying knowledge of numbers and their interrelationships. (NUM)

- Read, and interpret meaning from, graphs, charts and tables.
- Collect, organize and analyze quantitative information.
- Use graphs, charts and tables to help explain concepts and ideas about energy changes.
- Understand and explain to others (orally or in writing) how temperature change measurements can be used to infer the extent and type of bond rearrangements during a reaction.

Develop an understanding of how knowledge is created, evaluated, refined and changed within chemistry. (CCT)

- Make careful observations of energy effects in reactions, and explain how those effects can be used to make inferences about the atomic and molecular rearrangements.
- Reflect on the importance of theory in creating a framework by which reactions are viewed, and the place of theory with respect to the observations.

Appreciate the value and limitations of technology within society. (TL)

- Explore the distribution and uses in home, school and community of technologies making use of the exothermic or endothermic nature of chemical reactions.
- Assess the benefits and risks accruing from technologies which exploit the exothermic or endothermic nature of chemical reactions.
- Use technological devices to help measure heats of reaction.

Suggested activities and ideas for research projects

- Add a few pellets $NaOH_{(s)}$ to about 50 mL dilute $H_2SO_{4(aq)}$ or $HCl_{(aq)}$. Stir, and note the temperature change.

- Spread about 1 g anhydrous $CuSO_{4(s)}$ in a thin layer on a piece of paper. Anhydrous $CuSO_{4(s)}$ can be formed by grinding bluestone crystals ($CuSO_4 \bullet 5H_2O$) and drying in a 100°C oven or under a heat lamp. Put a small drop of water on part of the layer of chemical. Observe the effect of the water. Describe the differences between the anhydrous CuSO4(s) and the hydrated form.

- Mix $Ba(OH)_2 \bullet 8H_2O_{(s)}$ and $NH_4SCN_{(s)}$ in a 2:1 mass ratio. Stir the mixture, noting the temperature change.

- Use the case study "History of Modern Ideas About Heat" from ***Science: Process and Discovery*** (Field, 1985). 22 questions and problems for investigation accompany the study.

- Brainstorm to produce a list of uses made of the heat effects of chemical reactions. Some are:
  - space heating by combustion of fuels
  - "instant cold" compresses
  - oxidation of glucose in the body to maintain constant temperature

- Identify locations where thermal pollution exists. Analyze sources, effects and reasons why such pollution occurs.

- Consider the local and global environmental implications of burning fossil fuels.

- Pick s chemical reaction. Design a procedure to determine whether that reaction produces heat.

- When equal volumes of 0.10M $HCl_{(aq)}$ and 0.10M $NaOH_{(aq)}$ are mixed, heat is produced. Will twice as much heat be produced if equal volumes of 0.20M $HCl_{(aq)}$ and 0.10M $NaOH_{(aq)}$ are mixed? How about if equal volumes of 0.20M $HCl_{(aq)}$ and 0.20M $NaOH_{(aq)}$ are mixed?

- Identify ways of producing heat other than by chemical reaction. For what purposes is such heat currently used? List places where heat produced by chemical reaction is now used. Could the other sources of heat identified be substituted for heat produced by chemical reaction? Could heat produced by chemical reaction substitute for any of the other sources?

- Using an insulated cup calorimeter, dissolve 3.00 g $KNO_{3(S)}$ in 50 mL of water. Record the temperature change. Rinse the calorimeter and repeat, using 3.00 g $NH_4Cl_{(S)}$ in 50 mL water. Record the temperature change. Compare the two temperature changes. How many grams of $NH_4Cl_{(S)}$ must be mixed with 3.00 g $KNO_{3(S)}$ so that when the mixture is added to water, no temperature change is noticed?

- Determine the molar heat of combustion of paraffin by heating a beaker of water on a stand with a paraffin candle. Use a metal can, open at both ends, with a few vent holes on the side as a chimney to reduce heat loss from the burning candle.

  Based on the mass lost by the burning candle, and the temperature change of the known volume of water, calculate the molar heat of combustion of paraffin.

  Burn a beeswax candle, using the same appartus and procedure, to get data to compare the heat of combustion of paraffin and beeswax.

- Here is a set of reactions which can be used to illustrate Hess's Law. Measure the temperature change of each reaction and use that data to calculate the ΔH for each. Use NaOH pellets which have not been exposed to the air. To know the exact mass of the $NaOH_{(S)}$ is important, but it is not important that it be exactly 2.00 grams. The volumes of solutions and water have been adjusted to give a constant volume of 100 mL.
  2 g $NaOH_{(S)}$ + 100 mL $H_2O_{(\ell)}$
  50 mL 1.0M $NaOH_{(aq)}$ + 50 mL 1.0M $HCl_{(aq)}$
  2 g $NaOH_{(S)}$ + 100 mL 0.5M $HCl_{(aq)}$

- Burning fossil fuels produces most of the heat that we use in North America. What are other sources of heat used? What percentage does each supply? What is the most common fossil fuel? For solid and liquid fossil fuels, compare their efficiency of heat production on the basis of kJ per mole and kJ per gram burned. For gaseous fossil fuels, compare their efficiency of heat production on the basis of kJ per mole and kJ per litre of gas at SATP.

  How much energy does it cost to extract, refine, transport and distribute each fossil fuel? (Express the energy cost in \$ per million kJ.)

Sample ideas for evaluation and for encouraging thinking

- $3C_{(s)} + 2Fe_2O_{3(s)} + 463.1\ kJ \rightarrow 4Fe_{(s)} + 3CO_{2(g)}$
  Rewrite this equation using ΔH notation for one mole of carbon dioxide product.

- How can energy be released when a bond is formed? If energy is released when bonds form, why aren't all reactions exothermic?

- What would happen if energy was released when bonds were broken and absorbed when they are formed? What would happen if energy was released when bonds were broken and formed?

- Why is the law of conservation of energy considered to be valid?

- A plateau in the heating curves of a liquid can indicate the boiling point of the liquid. What becomes of the heat being added to the system during the time period of the plateau, where the temperature doesn't rise?

- $2Fe_{(s)} + 1\frac{1}{2}O_{2(g)} \rightarrow Fe_2O_{3(s)}$ $\Delta H = -824$ kJ/mol Fe_2O_3

  $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$ $\Delta H = -393.5$ kJ/mol CO_2

  Comment on the relative merits of burning $Fe_{(s)}$ and $C_{(s)}$ as fuels.

- $C_3H_{8(g)} + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(\ell)}$ $\Delta H = -2220$ kJ/mol C_3H_8

  $CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(\ell)}$ $\Delta H = -890$ kJ/mol CH_4

  Since propane ($C_3H_{8(g)}$) gives off 2½ times as much heat per mol of fuel, why is natural gas ($CH_{4(g)}$) a more popular fuel?

- To measure the heat of reaction between $Zn_{(s)}$ and $HCl_{(aq)}$, it would be better to use 6.54 grams of zinc and 250 mL of 1.0 M HCl(aq) than to use 6.54 grams $Zn_{(s)}$ and 25 mL of 10.0 M $HCl_{(aq)}$. Why?

- Use charts of thermodynamic data to calculate what percentage of potential heat loss there is when natural gas burns with insufficient oxygen to form $H_2O_{(\ell)}$, and equal mols of $C_{(s)}$ and $CO_{(g)}$, compared to when it burns to form $CO_{2(g)}$ and $H_2O_{(\ell)}$.

  To make this question easier, the equations

  $2CH_{4(g)} + 2\frac{1}{2}O_{2(g)} \rightarrow C_{(s)} + CO_{(g)} + 4H_2O_{(\ell)}$ and $CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(\ell)}$ could be given.

- Energy is absorbed during an exothermic reaction. Where does the energy absorbed come from? Where does it go? Can it ever be recovered?

- How does sweating keep us cool during hot weather or after strenuous exertion? The heat which makes hot weather originates in a nuclear reaction. The heat responsible for heating us during strenuous exercise (and other times too) originates in a chemical reaction. What reactions are involved in each of these cases?

- Why do chemical reactions produce or consume heat as they occur? Where does the heat energy come from? Where does it go when it gets into the air?

Reaction Kinetics

Unit Overview

Gasoline is a hydrocarbon. You want it to burn quickly and smoothly in the cylinder of your car. Vinyl is also a hydrocarbon, used as trim in many cars. You want it to oxidize very slowly. You hope that the steel components of your car also oxidize slowly, so that your car doesn't turn into a large pile of rust. But you hope the lead in the battery oxidizes quickly, to release electrons to run the starter.

This core unit provides students with an opportunity to investigate factors which influence rates of chemical reaction, and a basis for understanding the movement and rearrangement of particles during a reaction. If students see the connection between understanding the principles governing the rates of chemical reactions and understanding how a multitude of applications work, they will have achieved the goal of this unit.

Placing undue emphasis on the mathematical relationships involved in rate laws is unnecessary. Calculating rate laws, determining the order of reactions, or developing equilibrium expressions from rate laws may be of interest to some, but such topics place an unnecessary amount of pressure on students who lack mathematical ability. A descriptive treatment of the unit is preferable.

The use of models and audiovisual aids is practically indispensable in this unit. Many good resources are available. Teachers should attempt to use a variety of them in this unit.

There are several classic rate investigations that may be done. The use of laboratory activities will enhance this unit by making it less theoretical and abstract.

Factors of scientific literacy which should be emphasized

A4 replicable
A6 probabilistic
A8 tentative

B10 cause-effect
B11 predictability
B13 energy-matter
B15 model
B20 theory

C3 observing and describing
C5 measuring
C8 hypothesizing
C9 inferring
C10 predicting
C12 interpreting data
C13 formulating models
C16 designing experiments

D3 impact of science and technology
D4 science, technology, and the environment
D7 variable positions

E3 using equipment safely
E4 using audio visual aids
E5 computer interaction
E8 measuring time
E9 measuring volume
E10 measuring temperature
E12 using electronic instruments

F1 longing to know and understand
F2 questioning
F7 demand for verification
F8 consideration of premises

G1 interest
G2 confidence
G5 avocation
G7 vocation

Foundational Objectives for Chemistry and the Common Essential Learnings

Examine the factors which influence reaction rates in the context of the collision theory.

- Suggest some ways in which the rate of a chemical reaction could be measured.
- Identify some factors which affect the rate of chemical reactions.
- Apply collision theory to account for the factors which affect the rates of chemical reactions.
- Recognize that chemical reactions may occur in successive elementary steps.
- Understand how a series of simple reactions can constitute a reaction mechanism for a complex reaction.

Consider molecular level events in a chemical reaction.

- Discuss the concept of threshold energy.
- Interpret energy versus reaction pathway diagrams.
- Consider the existence of transition states in which activated complexes exist.
- Explain the role of catalysts in chemical reactions.
- Interpret energy versus reaction pathway diagrams for catalyzed and uncatalyzed reactions.
- Describe the use of catalysts in a variety of applications.

Strengthen knowledge and understanding of how to compute, measure, estimate and interpret quantitative data, when to apply these skills and techniques, and why these processses are important in studying chemical energetics. (NUM)

- Recognize whether computed answers are sensible.
- Understand the principles and difficulties of measuring rates of chemical reactions, and inventing suitable procedures for measurement.
- Understand that divergent thinking and reasoning often precede convergent thinking and solutions to problems.
- Distinguish between situations where quantitative precision is required and those where approximations are acceptable.
- Use quantitative problem solving tools such as tables of conversion or equivalence.

Promote both intuitive, imaginative thought and the ability to evaluate ideas, processes, and experiences in meaningful contexts. (CCT)

- Seek alternate ways of responding to activities, projects or assignments.
- Summarize information in a variety of ways.
- Understand that real life problems often have more than one solution.
- Discover relationships and patterns.
- Generate, classify and explore reasons or rules underlying categories.
- Propose generalizations which explain relationships.

Treat themselves and others with respect. (PSVS)

- Work toward improving self-esteem in themselves and others.
- Work cooperatively and contribute positively in group learning activities.
- Demonstrate capacity and ability to act with respect, empathy, sympathy, fairness, loyalty, cooperation and patience for others.

Develop their abilities to meet their own learning needs. (IL)

- Connect what is already known with new experiences.
- Focus on and complete learning tasks.
- Look for associations among items of knowledge and extend identified relationships through additional inquiries.
- Interpret and report results of learning experiences.
- Plan, manage and evaluate own learning tasks.

Suggested activities and ideas for research projects

- To help illustrate the influence that the nature of the reactants has on the progress of a reaction, place about 1 cm^3 of potassium permanganate onto some paper towelling on a fire retardant surface, preferably in a fume hood. Dropwise, add glycerine until the mixture becomes moist. Quickly wrap the towelling around the mixture. After a few minutes the paper towelling will burst into flames. This is a good demonstration of spontaneous combustion.

- Support a paraffin candle in a 50 mL or 100 mL beaker. Measure and record the mass of the system. Light the candle and let it burn for exactly 60 seconds. Reweigh the mass of the system and calculate how much mass has been lost. Repeat three times.

  Use the molecular mass of paraffin to calculate the rate of burning of paraffin. Investigate what variables are important in the rate of burning. Is the length of the wick significant? the diameter of the candle? the ambient temperature? the length of time the candle has been burning? Devise experimental procedures to test these variables.

- Design a procedure to measure the rate at which a gas burner consumes gas.

- Support a sugar cube on a clay triangle. Use a match to ignite it. Describe the rate at which it burns and the characteristics of the flame.

  Remove the cube and extinguish the fire. Get another cube. Rub fine paper ashes or cigarette ashes over its surface. Place this cube on the clay triangle and ignite. Compare the rate and characteristics of the burning.

- Mix a very small (<1 g) sample of $Pb(NO_3)_{2(S)}$ with an equal size sample of $NaI_{(S)}$. Use a glass stirring rod to grind them together. Describe the rate and characteristics of the reaction.

  Get another <1 g sample of $Pb(NO_3)_{2(S)}$ and dissolve in about 10 mL distilled water. Add 1 gram of $NaI_{(S)}$ to this solution. Describe the reaction rate and characteristics.

  Get a third <1 g sample of $Pb(NO_3)_{2(S)}$ and dissolve in about 10 mL distilled water. Dissolve 1 gram of $NaI_{(S)}$ in 10 mL water, and add this solution to the $Pb(NO_3)_{2(aq)}$. Describe the reaction rate and characteristics. Compare results of the three trials.

- Set up three beakers with 200 mL of 15°C water in each. In beaker 1 dissolve 0.5 g $Na_2S_2O_{3(s)}$ (sodium thiosulphate). In beakers 2 and 3 dissolve 1.0 g and 1.5 g $Na_2S_2O_{3(S)}$. Add 200 mL of 15°C 1.0M HCl(aq) to beaker 1 while stirring the mixture.

  Note the time from the addition to the first appearance of cloudiness. Alternatively, set the beaker over an **X** marked on a piece of paper. Looking down through the beaker at the **X**, record the time when the **X** disappears.

  Repeat the addition of HCl to each of the other beakers. Compare the time until cloudiness appears.

  Repeat the experiment using a range of solution temperatures, such as 25°C, 35°C, 45°C, and 55°C. Predict what would happen if 75°C was the temperature of the solutions.

  The equation which represents the dominant reaction when these chemicals are mixed is

  $$S_2O_3{}^{-2}{}_{(aq)} + 2H^+{}_{(aq)} \rightarrow S_{(s)} + SO_{2(g)} + H_2O_{(\ell)}$$

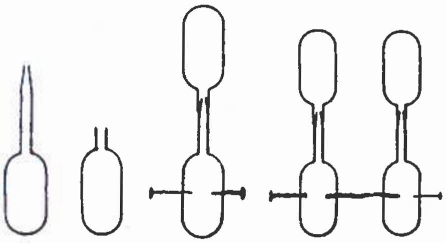
  (This activity was adapted from *CHEM13 NEWS*, #81, November 1976, page 3, based on an idea contributed by L. Sibley, St. Catharines, ON)

- The "clock reaction" is an interesting reaction which can be used to examine the effect of temperature and concentration on the rate of a reaction.

  There are several ways to prepare the chemicals used in this experiment. One method is to prepare three different solutions. Solution A is 0.2 M potassium iodide, solution B is 0.0050 M sodium thiosulphate and starch, and solution C is 0.1 M ammonium peroxydisulphate. Pour 10 mL of solution B into a beaker and vary the amounts of solutions A and C that are added. Add solutions A and C quickly, stirring while they are being added. Begin timing as soon as the solutions come into contact with one another. To keep the total volume constant in each trial, a small amount of water can be added to either solution A or C prior to mixing solutions. Samples can be placed in hot and cold water baths to compare the rates at different temperatures.

A variation of the clock reaction uses two solutions, one of 0.02 M potassium iodate, and another of 0.002 M sodium hydrogen sulphite. Prepare several samples of the iodate solution that have been diluted, so that the total volume of the mixture is 20 mL (i.e., 15 mL KIO_3 and 5 mL of water, 10 mL of KIO_3 and 10 mL of water, etc.). Mix the iodate solution with the sodium hydrogen sulphite solution. Begin timing as soon as the two solutions come into contact. Use a hot and cold water bath for different trails to observe the effect of temperature on reaction rate. (For further details, refer to the "clock reactions" found in a variety of lab manuals.)

- Students can perform microscale explosions using tapered (not thin-stem) Beral pipets. Take two Beral pipets. Cut off the stem of one about 2 cm from the bulb. This is the projectile. Insert a piece of thin copper or iron wire (or straight pins) into each side of the bulb of the other pipet. Leave a suitable spark gap between the inner ends. This is the reaction chamber. For a multiple explosion connect several of these chambers in series.



Draw only one drop of methanol or ethanol into the reaction chamber. Rotate the bulb to coat the walls with the alcohol. Stand the reaction chamber in a test tube rack, bulb down. Securely fit the cut-off pipet over the vertical, tapered end of the reaction chamber pipet. Touch one of the wires with a Tesla coil. **(This activity was adapted from *CHEM13 NEWS*, #184, March 1989, page 3. It is based on an article in the September 1988 *New Jersey Science Teachers Association Newsletter* by George Gross. The experiment was developed by Rob Lewis and Jim Tarnowski at a Butler University workshop in 1988.)**

- Use $Co^{+2}_{(aq)}$ as a catalyst to generate oxygen gas from ordinary laundry bleach. 0.5 mL of 0.1M $CoCl_{2(aq)}$ will provide enough $Co^{+2}_{(aq)}$ to catalyze the decomposition of 2 mL to 5 mL of undiluted bleach.

This system can be used to test the effect of temperature on the rate of a reaction. Some students may want to test the effect on the rate of the reaction of changing the concentration of the bleach used.

This activity also suggests a research project in which the action of catalysts on the rates of reactions is investigated. How do catalysts lower the activation energy of the reaction? Why are metals and metal ions often used as catalysts? What reactions does the catalytic converter of a car promote? Are reaction inhibitors (such as antioxidants, for example) related to catalysts? Do they work by raising the activation energies in their reactions or is there a different mechanism?

- Dissolve 3 grams of sodium potassium tartrate in 50 mL of distilled water and warm to 70°C. Add 2(mL of 3% or 6% hydrogen peroxide. Observe the mixture carefully and record a description.

Add a few crystals of cobalt(II) chloride so that the solution turns pink. Observe the reaction and record a description of what is seen. What evidenc(is there that the cobalt chloride catalyzed the reaction? Are there other salts which will catalyze the reaction in a similar manner? **(This activity was adapted from *CHEM13 NEWS*, #81, November 1976, page 15, based on an idea contributed by J. Huxley, Simcoe, ON)**

- Investigate the production of ozone in the upper atmosphere to form the ozone layer, the mechanisms by which ozone in that layer filters out ultraviolet light, and the issue of catalytic decomposition of ozone by free chlorine atoms.

- How does the Haber process use catalysts? Is the synthesis of ammonia from nitrogen gas and hydrogen gas economically feasible without catalytic assist? What process does the Saferco plant at Belle Plain use to synthesize ammonia? Do all ammonia synthesizing plants in Western Canada use the same process?

- Research the Fischer-Tropsch process. What are the raw materials? What are the products? What catalyst is used? What are the technical details of the process? When was the process first used on a large scale? Why was its use important then? Where is the process used now?

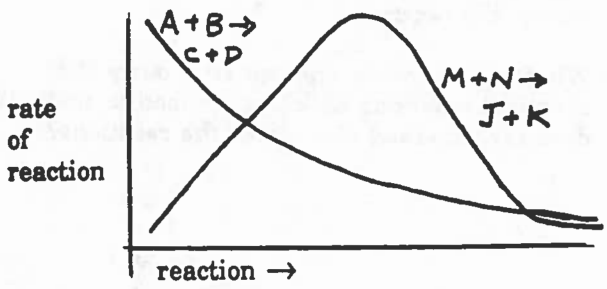
- How many industrial processes can be identified which rely on the use of catalysts to make the process economically viable?

- To demonstrate enzyme catalysis, put some $H_2O_{2(aq)}$ (30% or less) in a petri dish on an overhead projector. Add a drop of blood to one area of the dish, a drop of juice squeezed from a piece of fresh liver in another area, and a drop of juice squeezed from a fresh slice of turnip in a third area. The slight foaming indicating decomposition should be visible on the screen. **(This activity was adapted from *CHEM13 NEWS*, #81, November 1976, page 10, based on an idea contributed by S. Sharpe and D. Humphreys, Hamilton, ON.)**

- Students who would be interested in doing a research project on the treatment of fabrics with flame retardants can be referred to an article by Peter Carty in *CHEM13 NEWS* "Fires and Flame Retardants for Polymers" (March 1989, #184, pages 7-10).

- Use Alka-Seltzer™ tablets to investigate the influence on the rate of reaction of phase (solid and aqueous), amount of surface area (whole tablet versus powdered), and the temperature of the reaction medium (in hot water and cold water).

Sample ideas for evaluation and for encouraging thinking

- 

  Compare the curves which represent the rates of two reactions. What are the similarities in the rates? What are the differences? What factors might cause the differences?

- $Zn_{(s)} + 2HCl_{(aq)} \longrightarrow ZnCl_{2(aq)} + H_{2(g)}$
  Outline three ways that you could measure the rate of this reaction.

- $Zn_{(s)} + 2HCl_{(aq)} \longrightarrow ZnCl_{2(aq)} + H_{2(g)}$
  What would be the effect on the rate of the reaction if
  - a piece of zinc screen were substituted for a piece of solid zinc metal
  - powdered zinc was sprinkled into the acid instead of using apiece of solid metal
  - the strength of the $HCl_{(aq)}$ was doubled
  - the reaction was done in a plastic container instead of a glass beaker

  Explain why the effect indicated for each change would occur.

- Gold is preferable to silver for jewellery because its rate of reaction with oxygen is slower. Why does this make it preferable? Why does it react more slowly with oxygen?

- How is the mechanism of a reaction like the recipe for a cake? Create and explain some other analogies for reaction mechanisms.

- A grade 12 chemistry class was given the task of measuring the rate at which the butane in a disposable lighter burned. Outline a procedure that could be used.

  One group reported the rate they measured was 3.0 grams of butane per minute. Another reported their results as 0.9 mmol•sec^{-1}. A third group reported the rate as 1.3 litres $C_4H_{10(g)}$ at SATP/minute. Are these results equivalent?

- Catalysts are thought to lower the activation energy for a reaction. What are some of the ways which catalysts act to do this?

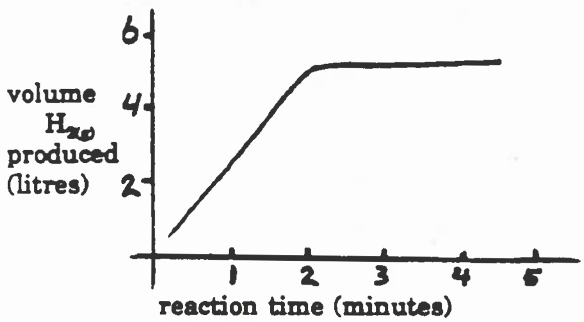
- An increase in temperature of 10°C rarely doubles the kinetic energy of particles and hence the number of collisions of particles is not doubled. Yet this temperature increase alone may be enough to double the rate of a slow reaction? Explain how this can happen.

- Discuss the proper adjustment of the gas supply and air regulator of a gas burner, in terms of the rate of reaction of the burning gas.

- Phosphorus, P_4, burns spontaneously when exposed to air. The product of the combustion is P_4O_{10} and the ΔH is $-2.98 \times 10^{+3}$ $kJ \cdot mol^{-1}$ P_4. Draw an energy diagram (reaction pathway) for the net reaction.

  Calculate how much energy is produced when 20.0 grams of phosphorus burn.

- $Mg_{(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$



  If 10.0 grams of magnesium metal ribbon were put into the acid in this reaction, why would only 5.0 grams of it have reacted?

  If the volume of $HCl_{(aq)}$ used was 200 mL, what was the approximate concentration of the $HCl_{(aq)}$ used?

  What was the rate of the reaction during the first minute? during the time between minute three and minute four of the reaction?

  Sketch a possible shape of the curve if powdered magnesium was sprinkled into the acid instead of using magnesium ribbon.

- Which of the following affects the rate at which a candle burns?
  - temperature of the air
  - shape of the candle
  - % of $O_{2(g)}$ in the air
  - % of $CO_{2(g)}$ in the air
  - length of wick exposed
  - age of the candle
  - composition of the candle

  For each factor briefly discuss why you have ma your decision.

- Name three industrial processes which use catalysts. Identify the catalyst and how each speeds the reaction.

- What are two ways one can slow down the chemical reactions which cause food to spoil? Ho does each method slow down the reactions?

Equilibrium

Unit Overview

Chemical equilibrium is perhaps the most important concept developed in Chemistry 30. The topics solubility, acids and bases, and oxidation/reduction can be treated as examples of equilibrium. Since the establishment of an equilibrium depends on equal rates in the forward and reverse reactions in a system, understanding the factors which influence rates of reaction, and why they influence the reaction, is essential to understand how equilibria become established and how Le Chatelier's principle works. Laboratory activities, independent research, and the case study could all revolve about chemical equilibrium. The study of equilibrium serves as an overall organizing theme for Chemistry 30.

Factors of scientific literacy which should be emphasized

A2 historic
A5 empirical
A7 unique

B1 change
B3 orderliness
B5 perception
B8 quantification
B9 reproducibility of results
B11 predictability
B13 energy-matter
B14 cycle
B16 system
B23 invariance
B28 equilibrium

C1 classifying
C2 communicating
C3 observing and describing
C5 measuring
C6 questioning
C7 using numbers
C8 hypothesizing
C9 inferring
C10 predicting
C11 controlling variables
C12 interpreting data
C13 formulating models
C14 problem solving
C15 analyzing
C16 designing experiments
C17 using mathematics
C20 defining operationally

D1 science and technology
D4 science, technology, and the environment

E3 using equipment safely
E4 using audiovisual aids
E5 computer interaction
E7 manipulative ability
E8 measuring time
E9 measuring volume
E10 measuring temperature
E13 using quantitative relationships

F2 questioning
F3 search for data and their meaning
F5 respect for logic
F7 demand for verification
F8 consideration of premises

G1 interest
G2 confidence
G3 continuous learner
G8 explanation preference

Foundational Objectives for Chemistry and the Common Essential Learnings

Recognize the characteristics and dynamics of equilibrium reactions.

- Observe and describe some reactions which are easily reversible and some which are not easily reversible.
- Consider the implications for a system when the rates of the forward and the reverse reactions that define the system are equal.
- Discuss non-chemical analogies which illustrate or simulate equilibria.
- Distinguish between dynamic equilibria and steady-state processes.
- Discuss the influence of free energy on the spontaneity of reactions.
- Understand why Le Chatelier's principle works.
- Use Le Chatelier's principle to predict how various equilibrium systems will shift in response to external stress.
- Discuss industrial applications of Le Chatelier's principle.

Understand some quantitative aspects of equilibrium systems.

- Write the equilibrium constant expression for a chemical reaction using the general equation:

$$aA_{(aq)} + bB_{(aq)} \rightleftarrows cC_{(g)} + dD_{(aq)}$$

- Recognize that K_{eq} values are dependent upon temperature but are independent of concentration.
- Analyze graphs of the concentrations of reactants and products with respect to time in a chemical reaction which is approaching equilibrium.
- Interpret K_{eq} values to determine whether products or reactants are favoured once equilibrium has been reached.
- Solve problems involving the equilibrium constant expression for a chemical reaction, with concentrations expressed in $mol{\cdot}litre^{-1}$ and kPa.

Use a wide range of language experiences for developing knowledge of equilibrium systems. (COM)

- Show understanding of equilibrium by rephrasing text or classroom definitions and explanations, creating models, drawing diagrams and concept maps.
- Discuss the relationships between the activities and analogies used to illustrate equilibrium and the principles of equilibria.
- Ask pertinent questions (prior questions, contextual questions, evaluative questions) and discuss multiple responses to those questions.

Strengthen knowledge and understanding of how to compute, measure, estimate and interpret mathematical data, when to apply these skills and techniques, and why these processes apply within chemistry. (NUM)

- Use the language of estimation.
- Understand the quantitative nature of equilibria.
- Understand that divergent thinking and reasoning often precede convergent thinking and solutions to problems.
- Verify answers by referring to problem parameters, checking the validity of each step of the method of solution, looking for errors in reasoning and in information and searching for alternative methods of solution.
- Use problem solving tools such as tables and calculators.

Develop a contemporary view of technology. (TL)

- Understand the influence of the underlying values or assumptions of a society on the support of technological development.
- Understand how scientific understanding can support technological developments.

Suggested activities and ideas for research projects

- An oscillating reaction is a good way of illustrating the reversibility of reactions. On a magnetic stirrer, prepare a solution containing 25 mL of concentrated H_2SO_4 in 250 mL of water in a beaker. Add 2 spoons of malonic acid and 1 spoon of $KBrO_3$ (quantities are not critical). Add a pinch of $MnSO_4$.

  Use a white background behind the beaker. The oscillation may continue for a half an hour or longer. **(This activity was adapted from *CHEM13 NEWS*, #81, November 1976, page 9, based on an idea contributed by J. Eix, Toronto, ON)**

- Analogies are useful to reinforce the concept of a dynamic equilibrium. One way to illustrate the concept is with the dual aquaria analogy. Fill one aquarium 3/4 full with water. Leave the other aquarium empty. Alternating turns, a student using a 500 mL beaker pours water from the full aquarium (representing the initial reactants in a reaction) to the empty aquarium. Each student fills the beaker as much as possible without tipping the aquarium. Continue until no further macroscopic changes are evident.

  Before beginning, explain this procedure to the class and ask each student to record a prediction of the final level of water in each aquarium. After "equilibrium" has been reached, discuss general principles regarding equilibrium.

  Repeat the activity, but change the amount of water in each of the aquaria at the starting point. All of the water can be in the second aquarium, or it can be distributed in some proportions in both aquariums. Regardless of the initial volumes in each aquarium, as long as the total amount of water used is the same, when a dynamic equilibrium has been attained the amount of water in each aquarium will be the same.

  Repeat the activity, changing the size of one beaker. This simulates altering the rate of the forward or reverse reaction. Have students predict the effect of this change.

  Once equilibrium is re-established, new "concentrations" of reactants and products will be present (i.e., the level of water in each aquarium remains unchanged, but will be different from what it was initially when different sized beakers were used.) This is a nice way of illustrating LeChatelier's principle.

  Have the students switch beakers and again transfer water. Once equilibrium is re-established, the levels of water in the two aquaria is reversed to what it was before the beakers were switched. This activity also helps to reinforce the idea that at equilibrium, there are not necessarily going to be equal amounts of reactants and products present.

  As a follow-up activity, some students may be able to write a computer program which presents the data in graphical form, showing what happens to the concentrations of "reactants" and "products" as time progresses. A computer program also allows the equations representing the forward and reverse reaction rates to be changed, allowing for rapid analysis without the tedium of recalculating and replotting the data.

  Developing a computer simulation of equilibrium can be a challenging activity that some students may wish to undertake as part of their contract in the independent research section of core unit 3. If a really good program is submitted, obtain the student's permission to use it in other classes. Connect a computer to an overhead projection display system to run the program so that the entire class can see it. (Computers have excellent potential for use in science classes. Consider other ways that their use can be incorporated into the chemistry program.)

- Identify and describe several industrial processes which rely on manipulating the equilibrium point with external stresses to make the processes economically viable?

- When acetic acid (CH_3COOH) and ethanol (C_2H_5OH) are mixed, water and ethyl acetate ($CH_3COOC_2H_5$) form. They reach equilibrium slowly. Devise a way to monitor the progress of this reaction until it reaches equilibrium, and to determine the equilibrium constant of the reaction.

- What is chemical reaction is involved in the Haber process? When was the process developed? What was the urgent social reason for developing the process?

- Medium strength orange pekoe tea (or any other black tea) can be used to illustrate how colour can be used to estimate the concentration of a solution.

Brew a 250 mL beaker of medium strength tea. Put 50 mL into each of two 100 mL beakers. Put the beakers side by side on the stage of an overhead projector. Turn the projector on and compare the colours displayed on the screen. Ask the students to predict what will happen to the colours if water is added to one of the beakers. Add 25 mL water and see what happens. Ask the class to create an explanation for the observation.

Ask the students to predict what will happen to the colours if the volume of diluted tea is reduced to 50 mL. Remove 25 mL of diluted tea and save it. Have the class agree on an explanation for this effect. Return the diluted tea removed to the beaker.

Ask the students to assume that the concentration of the tea in the original beaker is 1.00. What is the concentration of the tea in the diluted beaker

- as estimated by the dilution effect of 25 mL water added
- as estimated by the relative heights of solutions in the beakers

Predict whether the colours will match when the colour from 40 mL of the original strength tea is compared to the colour from 40 mL of a dilution made with 20 mL original strength tea and 20 mL water. Compare the two colours on the screen.

Predict how much tea will have to be removed from the beaker with original strength tea to make the colours match.

Ask the class to identify the two factors which influence the colour on the screen. From this discussion develop the relationships that colour is proportional to the depth of the solution and colour is proportional to the strength of the solution.

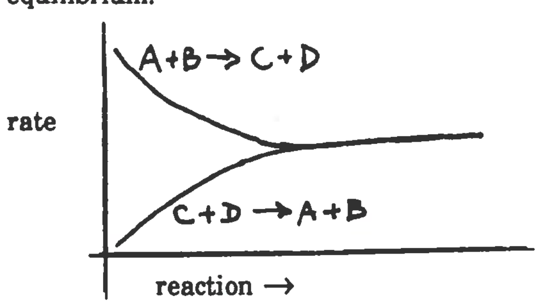
If you have a class which is capable of abstract mathematical expression, create a mathematical expression which includes these two factors: Colour = kCh, where k is a constant, C is the concentration, and h is the height of the solution.

Using the data from the demonstation, test this formula for the cases where a colour match existed ($Colour_1 = Colour_2$).

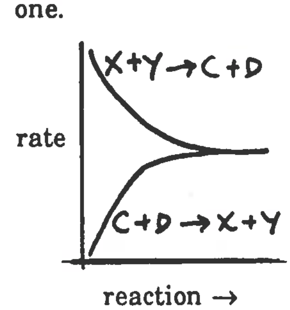
Discuss how this principle is used in qualitative and quantitative analysis. Students might be assigned to find applications of this colour matching technique and report on these applications to the class. **This has been adapted from an activity by Al Kabatoff, Saskatoon.**

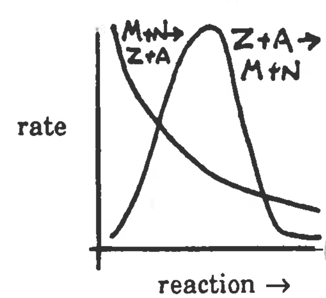
Sample ideas for evaluation and for encouraging thinking

- Given the information on the graph about the system $A_{(aq)} + B_{(aq)} \rightleftharpoons C_{(aq)} + D_{(aq)}$, explain why it is a good inference that the system has reached equilibrium.



- What is equal in a chemical reaction which has reached a state of equilibrium?
- Contrast systems in physical equilibrium, physical steady state, chemical equilibrium and chemical steady state.
- To sustain burning for an indefinite period requires an open system. Why? To maintain a constant vapor pressure above a pool of propanol in a saucer requires a closed system. Why? Which system of the two described would most accurately be classified as a chemical reaction system? Why? Which could be described as a chemical equilibrium system?
- By common agreement, the concentrations of solid components of a reaction system are left out of the equilibrium constant expression. Why is this done?
- Which graph represents what goes on in an equilibrium system? Explain why you picked that one.





Acid-Base Equilibria

Unit Overview

This core unit provides many opportunities to consider environmental issues. Acid precipitation is only one of the applications which could be considered, through case studies, independent research and laboratory investigations. Others may include the production of acids and bases and their use in industrial processes.

Students should observe both physical and chemical properties of acids and bases to help them understand the operational and conceptual definitions those classes of substances. In this unit, students apply the principles of quantitative analysis while considering dissociation, conjugate pairs, the common ion effect (especially with water) and neutralization.

Laboratory activities form the foundation upon which analysis and calculations can be done. **Activities are essential in this unit.**

Factors of scientific literacy which should be emphasized

A3 holistic
A5 empirical
A7 unique

B1 change
B2 interaction
B8 quantification
B10 cause-effect
B11 predictability
B12 conservation
B20 theory
B28 equilibrium

C1 classifying
C2 communicating
C3 observing and describing
C5 measuring
C7 using numbers
C8 hypothesizing
C9 inferring
C10 predicting
C11 controlling variables
C12 interpreting data
C13 formulating models
C14 problem solving
C15 analyzing
C16 designing experiments
C17 using mathematics
C19 consensus making
C20 defining operationally

D1 science and technology
D3 impact of science and technology
D4 science, technology, and the environment
D5 public understanding gap
D8 limitations of science and technology
D9 social influence on science and technology
D10 technology controlled by society
D11 science, technology, and other realms

E3 using equipment safely
E4 using audio visual aids
E5 computer interaction
E7 manipulative ability
E9 measuring volume
E10 measuring temperature
E12 using electronic instruments
E13 using quantitative relationships

F1 longing to know and understand
F4 valuing natural environments
F5 respect for logic
F6 consideration of consequence
F7 demand for verification

G1 interest
G2 confidence
G3 continuous learner
G4 media preference
G5 avocation
G7 vocation
G8 explanation preference

Foundational Objectives for Chemistry and the Common Essential Learnings

Investigate the nature of acids and bases.

- Identify some acids and some bases which are used in common household products.
- Observe some physical and chemical characteristics of acids and bases.
- Construct an operational definition of an acid and a base, using the characteristic properties of those substances.
- Describe the Brønsted-Lowry conceptual definition of acids and bases.
- Identify the conjugate bases formed in acid dissociation.
- Associate acid or base strength with magnitudes of K_a and K_b.
- Identify the conjugate acid of any base.
- Recognize substances which are amphiprotic (amphoteric).
- Compare the strengths of the dissociations in the dissociation series for a polyprotic acid.
- Investigate the nature of the production and use of acids and bases in our society.

Consider how the ionization of water interacts with acid and base dissociations.

- Write the equilibrium constant expression for the dissociation of water.
- Show how the common ion effect influences the equilibrium of water's dissociation when H^+ ions or OH^- ions are added to water.
- Recognize the relationship between the $[H^+]$ and $[OH^-]$ in an aqueous system.
- Calculate the $[H^+]$ in a solution.
- Express the $[H^+]$ as a pH value.
- Explain how a logarithmic scale differs from an arithmetic scale.
- Estimate the pH of solutions, using indicator solutions and indicator papers.

Explore the principles of neutralization.

- State the general neutralization equation:
  acid + base → salt + water
- Write equations for specific neutralization reactions, identifying the nature of each species.
- Solve mathematical problems involving data from titrations.
- Develop skill in doing titrations.

Strengthen understanding of equilibria through quantitative analysis of acid/base reactions. (NUM)

- Collect and organize data in charts and graphs.
- Interpret collected data.
- Read and interpret the scales on buret tubes.
- Discuss with peers how estimates of values are made.
- Use information from K_a tables to calculate pH values in solutions and check results of calculations with indicators.

Develop an understanding of how knowledge is created, refined and changed within chemistry. (CCT)

- Observe and record carefully during experimental or investigative procedures.
- Develop and conduct investigations and research.
- Understand the meaning of theory in science.
- Compare the nature of scientific knowledge with knowledge in other areas of study.

Understand that technology both shapes and is shaped by society. (TL)

- Appreciate how use of the principles of acid/base reactions has influenced our lives.
- Explore how knowledge about acid/base reactions has both explained existing applications and suggested new applications .
- Value the role of technology in studying acid/base reactions.

Suggested activities and ideas for research projects

- Place some 0.001 M HCl in an Erlenmeyer flask. Add universal indicator until the colour is noticeable. Place the flask against a white background, so that the colour changes is most evident.

  Use a magnetic stirrer to distribute NaOH solution dripped into the flask from a buret tube. Open the stopcock to allow the base to drop slowly into the vortex formed in the flask. Observe the colour changes.

  The colour changes can be reversed by adding more HCl from another buret above the flask.

- Obtain a 0.1 M HCl solution. Produce a serial dilution of the acid (at one-tenth concentration decrements). After the samples have been prepared, test each one with chemical indicators. This gives an indication of the colour of the indicators at different pH levels.

  Repeat as above, starting with a 0.1 M NaOH solution.

  Test a variety of solutions with chemical indicators. Determine whether the solutions are acidic, basic, or neutral. Students can determine the approximate pH of each unknown solution with indicators. The serial dilutions prepared previously can be used as standards for comparison.

  Try to react each of the unknown samples with a small strip of magnesium ribbon. Record the results and look for a correlation between the pH and the reactivity with magnesium for each substance.

  Once the standard and unknown solutions have been tested, a variety of household materials can be tested. (Some of these samples, such as oven cleaners, may be corrosive. Caution the students to observe normal safety precautions when handling household chemicals.)

- Place a few drops of phenolphthalein indicator into a beaker of water. Put a small piece of sodium metal on the water. Caution: Use only a very small piece of sodium, and view from a distance.

- What is *aqua regia*? For what purpose was it used?

- What acid is commonly called muriatic acid? What is the origin of that name?

- Place equal amounts of calcium carbonate suspension in two cylinders. Buffer one cylinder with a sodium acetate solution before putting equal amounts of 2 M acetic acid into each. Discuss how the common ion effect alters the rate of the reactions. **(This activity was adapted from *CHEM13 NEWS*, #81, November 1976, based on an idea contributed by C. McNeill, Savannah, GA. He attributed the idea to Denman Evans.)**

- One acid-rain simulation is to burn a small sample of sulfur in a gas jar which contains a small amount of water. Cover the jar and shake. Test the water with chemical indicators. Where does the sulfur dioxide in the atmospere come from. Is the burning of sulfur used commercially to prepare acids from sulfur?

  Another involves collecting automobile exhaust samples and proceeding in the same way. (Caution: Collect the samples carefully to avoid the toxic effects of the exhaust and avoid burns from the tail pipe.) Is the automobile exhaust toxic due to an acid effect of carbon monoxide? Is the "acid rain" produced here a result of a reaction of carbon monoxide with water?

- Burn a strip of magnesium ribbon in air. Place the white, powdery magnesium oxide that results into water. The magnesium oxide reacts with the water to form magnesium hydroxide in water. Test the solution with chemical indicators.

- Are acid-wash jeans really washed in acid? If so, what effect does it have on the fabric? What acid is used in the process?

- Some shampoos advertise that they are low pH. Others advertise that they are pH-balanced. Why do they make these claims? What do the claims mean? Look at advertising to find other claims made about the acidic or basic character of products. Test some shampoos and detergents to determine their pH values.

- Tomatoes can be canned in a hot water bath without fear of botulism developing in the tomatoes. Corn must be canned in a pressure canner at high pressures in order to eliminate the possibiltiy of botulism. Why the difference?

- In July 1991 at St. Lazare, Manitoba, a train carrying acetic anhydride derailed. The chemical spilled and the town was evacuated. What is acetic anhydride? What effect does it have on the environment? How was the spill cleaned up? How would a similar spill be handled if it occurred in your area? Where would the people to organize and carry out the evacuation and clean-up come from?

- How is acid used in uranium milling and refining? What other industrial processes in Saskatchewan use acids?

- Caustic soda is a an important industrial chemical. What is its chemical name? Where and how is it produced? What is its industrial use? What is its domestic use?

- Prepare a "simulated stomach" by placing 5 mL of 2 M HCl into 50 mL of water in a 250 mL Erlenmeyer flask. Add a tablet of an antacid, such as Tums, Rolaids, milk of magnesia tablets, etc. Allow the neutralization reaction to proceed.

  When the fizzing has stopped, complete a titration using 0.2 M NaOH with a phenolphthalein indicator. Calculate the number of moles of acid to begin with, the number of moles of NaOH needed to neutralize the acid, and the number of moles of HCl neutralized by the antacid.

  Compare the results from a variety of brands of antacid tablets. Any claims made by the makers of the antacid tablets can then be subjected to scrutiny, based on experimental evidence. How do these products relieve 'acid-indigestion'? What are the causes and symptoms of acid-indigestion? Discuss the use of models to simulate processes or events. The flask represents the human stomach. How are they similar? How are they different? Are there factors involved in the human stomach which haven't been taken into account by the flask-stomach model?

  As a further extension of this activity, place a universal indicator into the flask containing the simulated stomach acid. Place an antacid tablet into the container. Use a magnetic stirrer if one is available. Observe the changes that occur in the flask as the tablet dissolves and neutralizes some of the acid.

- Prepare a cabbage juice solution by boiling red cabbage in water. Allow the juice to cool. Strain the solution. Add vinegar to the cabbage juice. Note any colour change. Tea also serves as a good chemical indicator. What happens to tea when lemon juice is added to it? Carrot, beet, and blueberry juices also act as indicators. Determine over what range each operates.

- Add sufficient sodium hydroxide solution and universal indicator to water in a 1 000 mL beaker to produce a deep violet colour. Place several pieces of dry ice in another beaker. Pour the sodium hydroxide solution into the dry ice, then continue pouring it back and forth between beakers. The solution undergoes continuous colour changes while this is taking place.

  The dry ice dissolves in the water and forms carbonic acid, which then begins to neutralize the sodium hydroxide. If the solution has turned orange and some dry ice still remains, more sodium hydroxide can be added to repeat the entire process.

- Have students check the pH of their own saliva using Hydrion paper. Make sure that they dispose of the paper immediately after recording the pH. Collect the class data and prepare a graph showing the class results. **(This activity was adapted from *CHEM13 NEWS*, #81, November 1976, page 17, based on an idea contributed by C. McNeill, Savannah, GA.)**

- Perform a titration to neutralize a standard solution of a strong base with a strong acid. If a pH meter is available, collect data as the titration proceeds. Use the data to plot a titration curve.

- The susceptibility of the soils and lakes of Saskatchewan to the effects of acid rain can be demonstrated with a microscale activity. Each lab group will need a 12 by 8 well micro-spotplate, a one litre ziplock bag, some chalk fragments, a supply of universal indicator, a micropipet and a 15 mm piece of plastic drinking straw. The plate can be trimmed to produce a trapezoidal plate which is 6 wells wide at one end and eight wide at the other to more closely resemble the shape of Saskatchewan.

  Assuming that the rows of the spotplate are labelled from the top with the letters A through L and the columns are labelled from the left with numbers 1 through 8, place a small fragment of chalk ($CaCO_{3(s)}$) in the wells E1, F2, F3, F4, G5, F6, G7, H8 and in all the wells below that line. Half-fill each well but F1 with universal indicator solution.

  In well F1 place a 15 mm length of plastic drinking straw as a smoke stack. Add two drops of

$6.0\ M\ HNO_{3(aq)}$ to well F1 and carefully place the plate into a one litre ziplock bag. Drop a 1 mm piece of #14 copper wire (ordinary house wiring gauge) into the stack in well F1. Immediately seal the bag.

What effects are noticed? What does the spotplate represent (if you haven't told them)? What is the purpose of the chalk in some of the wells? Why were those wells selected to have chalk in them?

Add 300 mL of water to the bag to sufficiently dilute any remaining nitric acid. The plate, bag, straw and copper wire can all be reused after rinsing and drying. The chalk fragments can be discarded.

This activity could also be demonstrated on an overhead projector. **(This activity was adapted from *CHEM13 NEWS*, #207, November 1991, page 7, based on an idea contributed by Denise Gordon of Fort Worth, TX. She adapted the idea from an activity designed by Donna Bogner.)**

- How many foods can you identify which contain acids? For each food, list the name(s) of the acid(s).

- Find a recipe for sauerkraut. Use the bottom two-thirds of a clear plastic 2 L pop bottle to produce the sauerkraut. A plastic petri dish cover will fit into the bottle as a press for the top of the mixture. The clear plastic will let you monitor the production. Measure the pH of the liquid each day until the sauerkraut is finished. What acid is produced? What gas is produced? Where does the liquid come from? What chemical reactions are occurring? What causes these reactions to occur?

- The activity "Deadly Skies" from the *Project WILD Activity Guide* (page 319) could be used during this unit. It involves a simulation and discussion of the effects of acid rain.

Sample ideas for evaluation and for encouraging thinking

- When a thermometer dipped in water is inserted into a jar of dry $HCl_{(g)}$, the temperature rises. When a thermometer dipped in $CCl_{4(\ell)}$ (carbon tetrachloride) is inserted into an identical jar of dry $HCl_{(g)}$, the temperature does not rise. Why?

- Why is vinegar useful for cleaning electric kettles and steam irons?

- The toxin in bee stings is acidic. The toxin in wasp stings is basic. What implications does this have for treatment of reactions to these toxins?

- Why are lakes in Southern Saskatchewan less susceptible to acid precipitation than are lakes in Northern Saskatchewan?

- Why is NaOH an essential ingredient in making soap from fats and oils?

- Sulphuric acid dehydrates sucrose ($C_{12}H_{22}O_{11}$ or $C_{12}(H_2O)_{11}$) to leave a carbon network. Where does the water removed by the acid go? Predict the effect of putting a drop of concentrated (18M) H_2SO_4 on a crystal of $CuSO_4\cdot 5H_2O$.

- Write an equation for the dissociation of $CH_3COOH_{(aq)}$. The value of K_a for $CH_3COOH_{(aq)}$ is 1.8×10^{-5}. What percentage of the acid molecules (CH_3COOH) are ionized in a 1.0 $mol\cdot L^{-1}$ solution?

  Use Le Chatelier's Principle to predict how the addition of CH3COO- ions to a CH_3COOH solution at equilibrium would affect the pH at the new equilibrium?

- Calculate the $[NaOH_{(aq)}]$ if 34.7 mL of 0.100 $mol\cdot L^{-1}$ HCl(aq) is required to neutralize 15.0 mL of the $NaOH_{(aq)}$.

- The term amphiprotic is used to describe a substance which is capable of acting as an acid or a base, depending on the chemical environment in which it is found. The ion $H_2PO_4^{-1}{}_{(aq)}$ is such a species. Write an equation which shows its acid dissociation. What is the formula of its conjugate base? What is the formula of its conjugate acid when it acts as a base?

Oxidation and Reduction

Unit Overview

The study of oxidation and reduction can be treated as an illustration of equilibrium. Students should be able to define oxidation and reduction in terms of electron transfer, and express oxidation-reduction processes in terms of half reactions. Tables of standard reduction (or oxidation) potentials should be used to determine E° values. Students should also use tables and experimental results to assess the spontaneity of reactions.

The corrosion of metals and metallic deposition are applications which should be given consideration in this unit. Other practical applications of electrochemistry should be explored. These topics would be ideal for case studies, independent research activities, or laboratory investigations.

Connections between this and the **Acid-Base** unit can be made, by considering the corrosive effects of acids. Qualitatively, students could investigate the effect of pH on the corrosion of metals. An interesting laboratory research investigation would be to assess the corrosive damage to metals due to acid precipitation.

Factors of scientific literacy which should be emphasized

A3 holistic
A4 replicable
A5 empirical
A9 human/culture related

B1 change
B3 orderliness
B8 quantification
B9 reproducibility of results
B11 predictability
B12 conservation
B28 equilibrium
B33 entropy

C1 classifying
C3 observing and describing
C4 working cooperatively
C5 measuring
C6 questioning
C7 using numbers
C11 controlling variables
C14 problem solving
C16 designing experiments
C17 using mathematics
C19 consensus making

D1 science and technology
D4 science, technology, and the environment
D5 public understanding gap
D9 social influence on science and technology
D10 technology controlled by society

E3 using equipment safely
E4 using audiovisual aids
E5 computer interaction
E7 manipulative ability
E11 measuring mass
E12 using electronic instruments

F2 questioning
F4 valuing natural environments
F6 consideration of consequence

G5 avocation
G7 vocation

Foundational Objectives for Chemistry and the Common Essential Learnings

Explore the tendency of elements to participate in electron transfer.

- Define oxidation and reduction in terms of transfer of electrons.
- Develop a reduction potential series based on experimental results.
- Write half reactions and net ionic equations involving oxidation-reduction processes.
- Use a table to compare reduction potentials of half-reactions.
- Describe the processes of corrosion and metallic deposition, using the terms oxidizing agent, reducing agent, oxidized species, and reduced species.
- Identify and investigate means of protecting metals against corrosion.
- Describe the conditions under which automobiles corrode most quickly.

Observe, measure and consider the applications of electron transfer through external circuits.

- Determine the direction of electron flow in an electrochemical cell.
- Measure the voltage in several electrochemical cells.
- Calculate the potential difference in volts of electrochemical cells, using a standard reduction potential table.
- Explain the difference between a standard potential and an observed potential.
- Compare electrochemical and electrolytic cells.
- Examine applications of electrochemistry.

Strengthen students' knowledge and understanding of how to compute, measure, estimate and interpret mathematical data, when to apply these skills and techniques, and why these processses apply within redox chemistry. (NUM)

- Recognize whether a computed answer is sensible.
- Make appropriate use of calculators and computers.
- Verify answers by referring to the problem requirements, by checking the validity of each step in the method of solution, by looking for errors in reasoning or information and wherever appropriate, using an alternative method of solution.
- Distinguish btween quantitative situations where precision is required and those where approximations are acceptable.
- Understand the meaning of precision and determine the most appropriate degree of precision for a needed measurement.

Understand and use the vocabulary, structure and forms of expression which characterize the study of oxidation-reduction reactions. (COM)

- Incorporate the vocabulary of redox chemistry into the writing and talking they do about the topic.
- Use reduction potentials tables to predict spontaneity of reaction and potential difference of reaction.
- Recognize the structure of a reduction potential table and its relationship to experimental eveidence.
- Recognize and correctly use symbols such as E°, $mol \cdot L^{-1}$, v, $M^{2+}_{(aq)}$.
- Read diagrams, tables and expository (information-giving) text to enhance understanding of redox chemistry, and explain that understanding both orally and in writing by using analogies, charts, diagrams and descriptive statements.

Suggested activities and ideas for research projects

- Prepare five 5-8 cm long uncoated steel nails by rubbing them with emery cloth or fine sandpaper to remove any surface protection. Make an agar gel by heating 300 mL of water to a boil. Stop heating and stir into the water 2 g of powdered agar. While the gel is still hot, prepare two petri dishes. Place a straight nail and a bent nail in one petri dish.

  Into a test tube, pour some hot gel - about 150 mL – and add 10 mL of 0.1 M KSCN (potassium thiocyanate) solution. Pour this over the iron nails.

  Into a second petri dish, place three iron nails: one with copper wire wound around it, a second with magnesium ribbon wound around it, and a third clean iron nail. Wind the magnesium and the copper tightly so that there is contact between the nail and the metal. Make up another gel solution containing KSCN and pour this into the petri dish.

  Look at these samples on the overhead projector over a period of two or three days.

  A variation of this activity is to add 1 mL of 0.1 M $K_3Fe(CN)_6$ (potassium ferricyanide) and ten drops of phenolphthalein indicator to the agar, and then pour the mixture over the nails in the petri dishes. After a day or two, the agar gel will turn pink near the regions on the nails where the corrosion is most active. (Note: The ferricyanide compound has low toxicity and is relatively safe. Upon decomposition, however, the fumes are extremely hazardous. Make sure that your stock supply of potassium ferricyanide is stored securely. Ordinary gelatin might work just as well as agar in these activities, since it is just being used as a holding phase. The source of protein in the gel is not important. Agar powder is more expensive than plain gelatin.) **(This activity was adapted from *CHEM13 NEWS*, #81, November 1976, page 22, based on an activity designed by L. Sibley, St. Catharines, ON.)**

- (Catalytic oxidation of NH_3. Try this first!) Place 30 mL of concentrated ammonium hydroxide in a 250 mL Erlenmeyer flask. Make a coil of copper gauze or copper wire and support it from the glass rod so that it doesn't touch the liquid when inserted in the flask. Heat the copper, and, when it is red-hot, hang it in the flask. The wire will soon get so hot that it melts and sputters dramatically.

  Methanol instead of ammonium hydroxide in the flask will oxidize to produce methanal (formaldehyde). Use a fume hood. **(This activity was adapted from *CHEM13 NEWS*, #81, November 1976, page 22, based on an activity designed by L. Sibley, St. Catharines, ON.)**

- Prepare small metal strips of copper, zinc, magnesium, and iron. Clean each metal surface with sandpaper, and place each sample side by side into a petri dish. Prepare five other petri dishes in the same way.

  Into the first dish, pour copper (II) nitrate, $Cu(NO_3)_2$, solution, until each piece of metal is covered. In the second dish, use zinc nitrate, $Zn(NO_3)_2$, solution. Repeat in the other petri dishes, using magnesium nitrate, $Mg(NO_3)_2$, silver nitrate, $AgNO_3$, hydrochloric acid, HCl, and iron (II) ammonium sulphate, $Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O$.

  Allow the samples to stand for several days. Observe the results. Rank the metals according to how well they acted as reducing agents. Rank the metal ions in solution according to how well they acted as oxidizing agents. Write net ionic equations for all reactions that occurred. Develop a reduction potential series based on the experimental results.

- Tarnished silver is oxidized silver, usually in the form of Ag_2S. Reduce the silver to its metallic state using a reaction between metallic aluminum and the tarnished silver in a medium of hot baking soda ($NaHCO_3$) solution. Find a pan large enough to place an aluminum foil pie plate or a large piece of aluminum foil on the bottom. Heat, to about 80°C, enough baking soda solution (about 25 g/L) to cover the largest item to be cleaned. Immerse the tarnished silver in the solution and hold it so that it is in contact with the aluminum. Remove, rinse, and dry the silver once it is clean. (Questions for investigation: Why is the solution of baking soda used, rather than just hot water? Why is the solution hot, rather than cold? Will a metal other than aluminum work? Could rust be removed from iron with this method?)

- Electroplating is an interesting, practical application of electrochemistry. One activity is to copper plate a key. An electroplating bath of 200 mL of 1 M copper (II) sulphate, 5 mL of concentrated sulphuric acid, and 10 mL of ethanol per group is required.

Rub the key being electroplated with steel wool or sandpaper to remove any debris. Attach a thin copper wire to the key. Dip it into a dilute sodium hydroxide solution and then into a dilute nitric acid solution. It is important to avoid touching the key once it has undergone this cleaning process. Oily residue affects the ability of the plating metal to adhere to the surface.

Hang the key and a copper electrode in the solution so that there is no contact between them. Connect the copper electrode and the copper wire which is suspending the key to a 6 volt battery or a power supply.

After a few minutes the deposition of copper should be evident on the key. Allow the electrolytic cell to operate for about fifteen minutes. Disconnect the battery or power supply and remove the key. Rinse it thoroughly. Buffing with a mild abrasive, such as chalk dust, may produce a better lustre.

As a follow up, students could investigate other applications, such as the galvanization of steel with zinc, or chrome-plating car bumpers. Once they understand the chemistry involved in those processes, other electroplating experiments could be designed. Involving students in independent research and the design of experiments may help to give them a much better understanding of chemistry.

- The 'standard' hydrogen half-cell can be produced by connecting two porous carbon electrodes placed on opposite sides of a one litre beaker containing about 600 mL of 6.0 M HCl to a 6 volt power source. If this system runs for several minutes, enough hydrogen gas and chlorine gas will be produced and adsorbed at their respective electrodes to produce a pair of gas electrodes. If the electrodes are connected to a voltmeter when the power source is disconnected, the system will be observed to be functioning as an electrochemical cell. The observed voltage can then be compared with the predicted voltage for a hydrogen-chlorine cell.

- Purchase some 3% hydrogen peroxide solution from a drug store. (If a stronger solution is purchased for dilution, observe strict precautions against its deterioration. Store in a refrigerator, and only for 6 months or less.) Measure from 1 to 3 mL into a 250 mL Erlenmeyer flask, acidify with 10 drops of concentrated sulphuric acid, and add enough water to start a titration. Titrate using 0.01 M potassium permanganate. The end-point will be the faint pink colour of dilute MnO_4^-.

$$2MnO_4^- + 6H^+ + 5H_2O_2 \rightarrow 2Mn^{2+} + 5O_2 + 8H_2O$$

Calculate the percentage of H_2O_2 in the original sample.

- Construct carbon electrodes for electrolysis experiments from a 30-40 cm length of NMD7 14-2 electric cable. (This is ordinary house wiring material with two 14 gauge insulated conductors and a ground wire.) Use a pair of pliers to pull the uninsulated ground wire out, leaving the two insulated conductors. Cut from 6 to 8 cm of the outer plastic sheathing from one end of the piece of cable and strip about 1 cm of the insulation from the ends of the exposed conductors. Salvage some carbon rods from some old dry cells and drill a 2mm hole down the centre of the carbon rod to a depth slightly greater than length of the stripped ends of the conductors. Insert the wires in the holes of the rods until the plastic insulation touches the carbon rod. Seal the connection of the conductor to the rod with some silicone. Finally, expose about 1 cm of conductor at the other end of the apparatus to serve as a connection to the power source, and bend the apparatus to give you a configuration appropriate to the container you are using.

  Ordinary pencils can be used as electrodes by sharpening them at both ends, and then carefully using an utility knife to remove the tapered section. This leaves about 2 cm exposed to act as electrical connector and, at the other end, as active electrode. Use these electrodes to decompose various solutions by electrolysis. Several variables such as the concentration of the solutions, the temperature of the solution, the voltage of the power source, and others can be examined.

- Use dialysis tubing (a semipermeable membrane) borrowed from your biology supplies as a substitute for porous cups or salt bridges in producing electrochemical cells. A portable battery can be designed by using an Erlenmeyer flask, a length of soaked dialysis tubing tied off to form a bag about 6 cm long, and whatever combination of metal ion solution/thin metal strips that you have. Some possibilities are aluminum nitrate and aluminum foil, copper nitrate and copper foil or silver nitrate and silver foil. Foil is preferred since the stopper may then be inserted into the flask easily and still allow the electrodes to pass out of the flask.

- Place a folded, moistened filter paper in a funnel. Half fill the paper with degreased iron filings. Pour some 0.1 M copper sulphate solution into the filter and observe the filtrate. Write an equation for the reaction which occurs. (Questions: What metals could be substituted for iron? Which metal ion solutions could be substituted for the copper sulphate?)

- Research and prepare a report to the class on the chemistry of one of the methods of protection of metals from corrosion. Include an explanation of the problems caused by corrosion, and the conditions under which the corrosion is fastest.

- What reactions are involved in the discharging of a lead storage battery (car battery) and in its subsequent recharging?

- Examine a piece of galvanized iron. Describe the pattern on the surface of the metal. Why is iron galvanized? What substances are used in the galvanizing process? What causes the pattern on the surface of the metal?

- Fertilizer storage bins may be either galvanized or epoxy-coated. Why must iron fertilizer bins be protected with some coating? What are the advantages and disadvantages of each method?

- Pipelines, bridges, the steel framework of large building and other structures may be safeguarded from corrosion by the use of cathodic protection. Why is cathodic protection necessary for such structures? How does it work? Design a demonstration to show a piece of metal which is protected in this manner.

- Some brands of paint claim that they can not only prevent rust but can treat rusted surfaces so that they will stop rusting and rust no more. How do these products work?

- Cut a 1 cm by 3 cm strip of copper foil in half to produce two 0.5 cm wide strips. Cut a 0.5 cm length from the end of one strip to serve as an unreacted sample for comparison.

  Place one of the long strips in 5 - 10 mL of dilute HCl(aq) for five minutes. Describe any reaction. Then remove the foil and rinse it. Examine it for evidence of a reaction.

  Wrap the other strip tightly around a 1 cm square of thin zinc sheet, so that there is contact between the two metals. Place it in 5 - 10 mL of dilute $HCl_{(aq)}$ for five minutes. Describe any reaction. Then remove the foil and rinse it. Examine it for evidence of a reaction.

  Compare the two strips and the 0.5 cm square.

- Carefully dissect several different brands of 1.5 volt 'D' dry cell batteries. Dissect as well a 9 volt dry cell. Use caution and protective clothing since the contents are corrosive and toxic. Compare the similarities and differences of construction and structure. What chemical reactions produce the electricity in these cells?

- Research the "cold fusion" controversy. Is this an example of fusion or of electrochemistry?

Sample ideas for evaluation and for encouraging thinking

- Why is it important to prevent sparking near a car battery when it is being boosted with jumper cables?

- Identify the substance which is oxidized and the substance which is reduced in the following reactions.
  - magnesium metal reacts with steam to form magnesium oxide and hydrogen gas
  - solid carbon reacts with steam to form carbon monoxide gas and hydrogen gas
  - copper(II) sulfide reacts with ammonia to produce copper metal, nitrogen gas and hydrogen sulphide gas.

- Why is an oxidizing agent always reduced during a redox reaction?

- Explain how you can use a standard reduction potentials chart to determine the direction electrons will flow in an electrochemical cell.

- Suppose you wished to plate your house key with chromium. To which terminal of the battery would the key be connected? What would the other electrode be made of? What solution would you use? Sketch a diagram showing a completed setup for this project.

- Suppose you wanted to select the metal which reacts with the greatest number of solutions containing metal ions. Use a standard reduction potential chart to pick this metal. Explain how the chart provided the information necessary for you to make your choice.

- A salt bridge or a porous cup is needed to complete the circuit in an electrochemical cell. Explain how these act to complete the circuit. Why won't an electrochemical cell run without them?

- What would be the result if one tried to electroplate a steel spoon using AC power instead of DC power?

- Suppose a steel spoon was plated with gold. What are some of the advantages of plating the spoon with gold rather than leaving it as pure steel? What are some of the advantages of a steel spoon plated with gold over a spoon of pure gold?

- How can phenolphthalein be used to indicate the polarity of a wire carrying DC current?

Appendix

MICROSCALE CHEMISTRY EXPERIMENTATION FOR HIGH SCHOOLS PART II: HOME-MADE EQUIPMENT

Reprinted, with permission, from *CHEM 13 NEWS*, #200 (January 1991), pages 4-7.

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(Part 1 in this two part series appeared in our December issue, pages 8-10. We welcome good microscale experiments and suggestions for home-made microscale equipment — see page 6 [page 165 of this Guide], for example — from our readers.)

In Part 1 of this series, we looked at microscale equipment that was commercially available. Almost all of the items were polymer-based rather than glass. For those of us whose memories of glassblowing were of frustration and despair, the arrival of plasticware enables us to create new items of equipment with nothing more than a sharp knife, an electric drill, and a sturdy glue. To illustrate, we will describe here three useful items that can be constructed easily.

A Gas Collection Apparatus

The concept of this apparatus originated (we believe) with Robert Becker of Greenwich High School, CT. However, we have taken the original glass design and made a simpler and more robust apparatus from polyallomer. The basic requirements are a 1.5 mL microtube (1) and a graduated 1 mL micropipet (2). Drive a 7/64" hole through the centre of the cap of the microtube. Cut the micropipet as shown below and save sections (a), (b) and (c). Insert section (a) through the bottom of the microtube cap until the wider part of the stem rests against the underside of the cap.

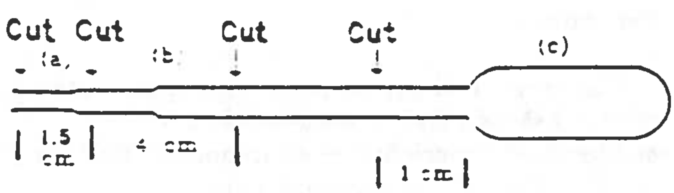

Fig. 1

To prepare hydrogen, fill the bulb (c) about three-fourths full with water (3). Place some zinc granules and hydrochloric acid in the microtube, cap the microtube and lower the open end of the bulb over the stem as in Fig. 2. Squirting the collected gas at a flame gives a loud sound.

For carbon dioxide, use a completely water-filled bulb. Place marble chips and hydrochloric acid in the microtube, cap the microtube and collect the carbon dioxide in the bulb. To test the gas, half-fill a microtube with lime water (*CHEM 13 NEWS*, March 1990, page 4). Insert the stem section (b) 'backwards' into the bulb section (c) as an extension and place the end beneath the level of the lime water. Squeezing the bulb should result in a cloudiness in the lime water.

A Simple Electrochemical Cell

A simple electrochemical cell can be constructed by drilling a hole in the side of two 1.5 mL microtubes and linking the two by means of a length of plastic tube (4). We use a length of about 1.6 cm so that the resulting cell will fit into a microtube rack (5). To seal the joints, we use the general purpose glue 'Goop' (6). The call can be used to measure potentials between different metals by filling the apparatus with sodium sulfate solution and inserting narrow strips of dissimilar metals. To connect the strips to a voltmeter, we use the mini-alligator clips (7) joined to the wires with low-temperature solder (8). To minimise the possibility of an air bubble trapped in the cross-arm, we add a small quantity of detergent to the solution.

An Electrochemical Cell with Divider

The same type of cell can be created with a partition to enable standard cell potentials to be determined (Fig. 3). For the divider, we use the microtube filter inserts (9). The rim is cut off to leave a length of about 1.6 cm. Holes are drilled in the sides of two microtubes and the fitter insert sealed in place with "Goop'. A copper(II) sulfate solution can be placed in one arm and a zinc sulfate solution in the other.

Fig. 2

Fig. 3