PROGRAM OF STUDY

CHEMISTRY

Subject Area: Mathematics, Science and Technology

Adult General Education

DBE
Diversified Basic Education

Québec

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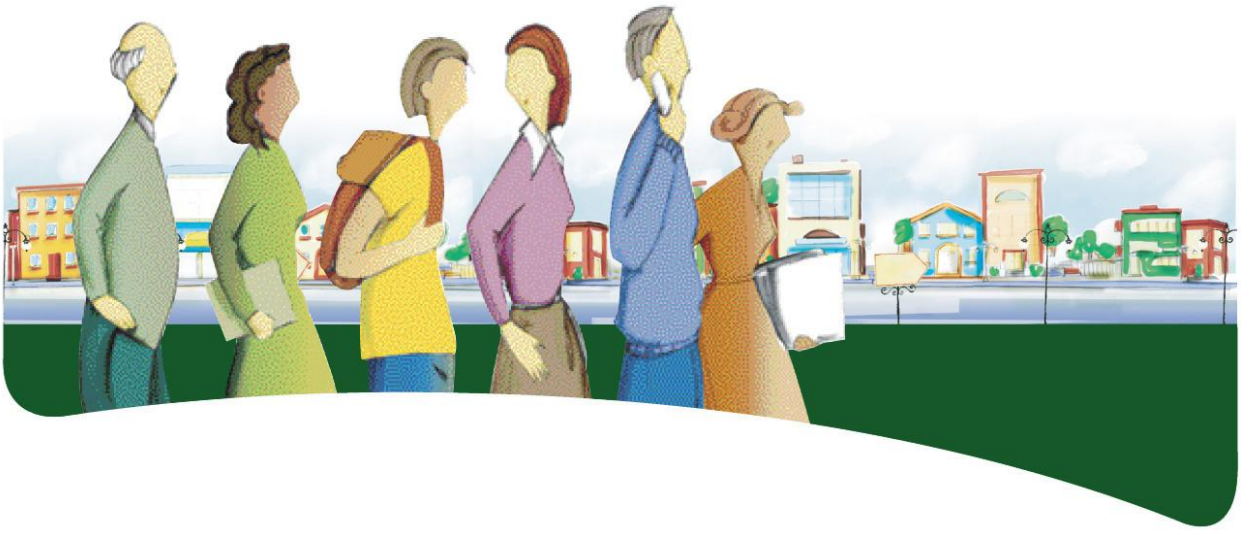


Introduction

1.1 Contribution of the Subject to the Education of Adult Learners

As an integral part of the societies it helped to shape, science represents both an important aspect of their cultural heritage and a key factor in their development. The rapid emergence of large amounts of complex scientific knowledge and the proliferation of its applications presume that people should possess a fund of specific knowledge as well as strategies for freeing themselves of the constraints inherent in change. This requires that they see the achievements of science in perspective, understand the scope and limitations of this knowledge, and be able to evaluate their impact. For this reason, science is not the preserve of a small group of experts.

As one of the sciences, chemistry serves to broaden the general knowledge of adult learners and heighten their awareness of the role this knowledge can play in their ability to take informed decisions. The study of chemistry stimulates curiosity, imagination, the desire to explore and the pleasure of experimentation and discovery of new knowledge. It also responds to the learners' need to understand, explain and create their environment. Chemistry is omnipresent in our daily lives, in the areas of health, nutrition, the environment, materials and energy. A considerable number of applications and innovations are based on chemistry.

The Chemistry program extends the training provided by the science and technology programs in Secondary III and IV. It is intended to consolidate and enrich adult learners' scientific training, and is a prerequisite for several pre-university and technical programs. Its compulsory concepts are organized around general concepts related to gases, chemical dynamics and energies involved in chemical reactions, and chemical equilibrium.

1.2 Approach to the Subject

Science is a means of analyzing the world around us. Its aim is to describe and explain certain aspects of our universe. Made up of a set of theories, knowledge, observations and methods, it is characterized by its attempt to develop simple, intelligible models to explain our complex world. When subsequently combined with other models, these models become increasingly encompassing, eventually becoming theories. As we construct new knowledge, these theories and models are constantly being tested, modified and reorganized.

Chemistry deals with the composition, reactions and properties of matter. It overlaps with several other scientific disciplines, such as physics, biology and materials science. It provides the opportunity to create new substances with specific properties that it characterizes and studies. Chemistry has its own vocabulary and symbols and uses mathematical language.

1.3 Connections Between the Subject and the Other Elements of the Diversified Basic Education Program

The Chemistry program is connected to the other components of the Diversified Basic Education Program such as the broad areas of learning, the cross-curricular competencies and the other subject areas.

1.3.1 Connections With the Broad Areas of Learning

The broad areas of learning are divided into five areas of life: *Health and Well-Being*, *Environmental Awareness and Consumer Rights and Responsibilities*, *Media Literacy*, *Career Planning and Entrepreneurship*, and *Citizenship and Community Life*. The Chemistry program uses learning situations pertaining to these broad areas to make learning meaningful. In this way, adults are able to see that their learning is related to their various everyday activities.

Health and Well-Being

The knowledge that students acquire in studying chemistry can provide answers to many questions related to how the body works, as well as to health, safety and comfort. The learning situations related to this broad area of learning can pique interest and incite adult learners to ask themselves how the chemical reactions caused by certain molecules will affect the body, thus encouraging them to adopt healthier lifestyle habits to improve their health and well-being.

Environmental Awareness and Consumer Rights and Responsibilities

Many advances in chemistry have changed consumer habits and have led to various consequences for the environment. For example, concerns about chemical pollutants in the water led numerous consumers to purchase bottled water, and that gave rise to the problem of dealing with the empty bottles. The proliferation of plastic packaging makes recycling and disposal more complicated. The learning acquired in chemistry encourages adult learners to adopt more responsible behaviours towards the use of resources.

Media Literacy

Adults use the various media to learn, obtain information and communicate. It is important that they develop a critical view of the information they receive and pass on. Movies, newspapers, television and various other electronic media address topics related to chemistry. A strong grounding in science is useful for assessing the reliability of information. In addition, electronic communication devices and their use can elicit adult learners' interest, encourage them to become more engaged in their learning, and boost their motivation.

Career Planning and Entrepreneurship

Many employment sectors require a grounding in scientific knowledge. For this reason, the tasks that the adults will carry out in this program offer opportunities for them to better understand the work of people employed in sectors that involve chemistry. In this way, they will become acquainted with scientific work, develop their interests, measure their aptitudes for such trades and occupations, and consider a career in this field.

Citizenship and Community Life

The competencies developed and the knowledge acquired in studying chemistry lead to a new perspective on social issues. Various problems such as those associated with the disposal of chemical products, for example, can provide opportunities to learn about responsible citizenship. Adults can thus improve the quality of their participation in society in general.

1.3.2 Connections With the Cross-Curricular Competencies

The development of scientific literacy involves the acquisition and then development of three subject-specific competencies which, in turn, contribute to the acquisition of the more general cross-curricular competencies. These are grouped in several categories, reflecting different facets of the ability to act.

Intellectual Competencies

The learning situations in this program require that adult learners *use information* judiciously and question the reliability of their sources. The search for answers or solutions enables them to acquire problem-solving skills that they can then apply in other situations. They *use creativity* and *exercise critical judgment* when analyzing scientific texts or presentations or when evaluating the consequences of chemistry.

Methodological Competencies

The attention to precision associated with the methods used in chemistry requires that adult learners *adopt effective work methods*. They *use information and communications technologies*, which provide them with access to a wider variety of information sources and means of action.

Personal and Social Competencies

Adult learners who move from the abstract to the concrete or from decision to action, and who agree to take risks *achieve their potential*. In chemistry, the development of knowledge is based on the sharing of ideas or points of view, and peer or expert validation. In these contexts, adult learners are encouraged to *cooperate with others*.

Communication-Related Competency

The assimilation of new concepts and their representations through mathematical, scientific and technical language increases the adult learners' capacity to *communicate appropriately*. They must not only become familiar with the vocabulary, codes and conventions of chemistry, but must also learn to use them adequately.

1.3.3 Connections With the Other Subject Areas

Each subject has its own view of the world. From an interdisciplinary perspective, it is important to connect the learning achieved in chemistry with that acquired in other subjects. In this way, other subjects can shed light on chemistry just as chemistry can, in turn, help us gain a better understanding of other subjects.

Mathematics, Science and Technology

The programs of study in Mathematics, Science and Technology, which include chemistry, all belong to the same subject area. They target the development of similar subject-specific competencies in terms of problem-solving, reasoning and communication. In the Diversified Basic Education Program, this subject area includes the Computer Science program.

Mathematics is closely related to the science programs. The vocabulary, graphics, notation and symbols used in mathematics constitute a language of rigorous precision, of which chemistry takes advantage. Mathematics is frequently used in developing or constructing models and in problem solving, both practical and theoretical.

Conversely, chemistry helps adult learners concretely understand certain mathematical concepts, such as variables, proportional relationships and various functions. It provides meaningful contexts for the study of measurement or statistics.

The computer boom has accelerated the development of knowledge in chemistry. It is, in fact, thanks to computer science that chemistry has higher-performance tools for finding information, processing data, and presenting and sharing results. For its part, chemistry provides contexts for the application of computer science principles, thereby stimulating the creation and development of new products.

Languages

The Languages subject area provides essential tools for developing scientific competencies. In chemistry, an adult learner who interprets information or who describes or explains a phenomenon makes use of competencies developed in the subject area of languages. Chemistry presents the student with an opportunity to use precise vocabulary and to understand the importance of rigorously accurate language.

Since English is used worldwide in scientific communication, the adult learner who possesses a command of English, as well as of a second or third language, has access to more numerous and diverse sources of information.

Social Sciences

The advances made by science occur in a social and historical setting. The historical perspective places scientific progress in context, enabling adults to appreciate the importance of progress and measure its implications. Similarly, wealth (and its method of distribution) influences both the development of societies and the advancement of chemistry.

Since societies are dependent on the tools and means at their disposal, the study of chemistry enables students to see their history and development in a different light.

Arts Education

The subjects in Arts Education contribute substantially to the development of creativity. The Chemistry program draws on this creativity for solving problems. In turn, chemistry contributes to the arts. For example, a good understanding of the composition and properties of materials enables visual artists to improve their techniques and sometimes even start new artistic trends. Chemistry is also behind the fabrics created for costumes and the lighter and more flexible materials used to produce scenery.

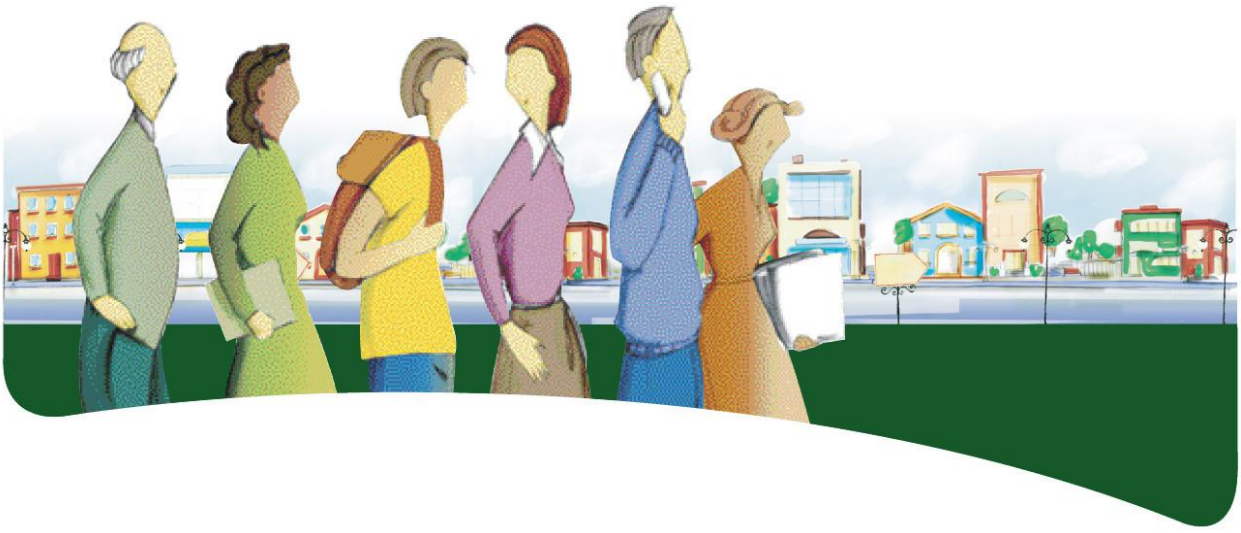
Personal Development

The Chemistry program takes into account reflections related to personal development when it encounters questions of an ethical nature, such as the implications of research and the marketing of new molecules. It also contributes to personal development by equipping adult learners with knowledge about how substances react with each other. This leads to a better understanding of the effects of certain molecules on the human body, which can then lead to the adoption of more responsible behaviours.

Career Development

The fields of application for chemistry touch on numerous sectors of activity and can be associated with the occupations in these sectors. The learning situations proposed in the chemistry courses give adult learners ideal opportunities to explore different work activities and their related occupations. In return, the activities associated with the Career Development program can help adult learners discover an interest in scientific questions in the field of chemistry.

Chapter 2



Pedagogical Context

2.1 Learning Situations

Learning situations help adult learners construct and mobilize knowledge and develop subject-specific and cross-curricular competencies. Related to a specific context, they present a problem to be solved or an issue to be examined. They involve one or more tasks leading to the production of a specific piece of work.

Through their context, learning situations help achieve the educational aim of the broad area of learning to which they are related. *Meaningful*, *open-ended* and *complex* learning situations confer more meaning on the knowledge acquired, and foster the integration of subject-specific content and key features of the competencies. A learning situation is *meaningful* when it focuses on adult learners' interests as they relate to current events, major social issues, or scientific or technological achievements that affect everyday life. It is *open-ended* when it enables adult learners to choose a method and explore several possible solutions. It is *complex* when it requires adult learners to mobilize a greater number of resources and provides them with the opportunity to apply more than one competency.

Although the use of learning situations is compulsory, none of the examples given in the courses is prescribed. The same applies to examples of tasks. Teachers create or choose those that they deem appropriate.

2.2 Families of Learning Situations

Learning situations that share a resemblance because of the types of tasks they include constitute a family. Whatever their level of complexity, situations in the same family foster the transfer of learning. The Chemistry program consists of two families of learning situations: *Research* and *Expertise*.

Research

Learning situations in the *Research* family consist of tasks aimed at solving a problem in chemistry. Such situations require creativity. Adult learners establish their action plan, select the tools they need and use them to solve the problem. They present the results of their work and, if applicable, propose new hypotheses or solutions. Learning situations in the *Research* family involve the use of laboratory equipment and techniques specific to chemistry.

Expertise

Learning situations in the *Expertise* family involve tasks in which adult learners study a chemical phenomenon or a chemistry-related technological application. They are then required to identify the scientific concepts at play, determine how they work together and explain them. To do so, the adult learners must make use of all available information and draw upon concepts, laws, theories or models from the field of chemistry. This type of analysis sometimes leads to the use of measurement and observation materials and techniques common in chemistry, while the study of the application can sometimes lead to using tools and techniques of graphic representation or dismantling procedures assisted by technology. In this way, adults can formulate a clear explanation of the phenomenon or the elements of chemistry involved in the application.

The learning situations in the *Research* and *Expertise* families allow for the construction of knowledge, the mobilization of resources, the implementation of investigative processes and the development of the competencies in the Secondary V Chemistry program.

The families of learning situations are compulsory. Every course must include situations drawn from the two families indicated above.

2.3 Educational Resources

In developing their competencies, adults draw on different resources that can be classified as personal, conceptual, informational, material, institutional or human.

Personal resources include knowledge, skills, strategies, attitudes and techniques that adult learners have already acquired. Conceptual resources comprise knowledge acquired in different academic subjects, while informational resources include textbooks, reference documents and any other materials used in searching for information. Material resources can include many types of instruments and objects. Institutional resources refer to public or parapublic organizations, industries or local businesses, and any other community resource. Teachers and classmates are the most immediately accessible human resources. Laboratory technicians are good resources, especially where laboratory safety is concerned. As needed, adult learners can also consult teachers in other subjects or different experts.

Chapter 3

Subject-Specific Competencies

3.1 How the Subject-Specific Competencies Work Together

In the Diversified Basic Education Program, a competency is defined as the **ability to act effectively by mobilizing a range of resources**. It is demonstrated in contexts of a certain complexity, and the degree to which it is mastered may increase throughout a person's education and even lifetime. The Chemistry program targets the development of three subject-specific competencies. These competencies are associated with three complementary dimensions of science: practice and methodology, theory, and communication.

The first competency, *Seeks answers or solutions to problems involving chemistry,* emphasizes the methodology used to solve problems in science. It focuses on the mobilization of concepts and techniques associated with chemistry, primarily within the context of an investigative process that most often takes place in a laboratory.

The second competency, *Makes the most of his/her knowledge of chemistry,* stresses the ability to conceptualize and to transfer learning, especially when analyzing phenomena or applications. It involves the assimilation of concepts related to chemistry that enable us to understand and explain these phenomena and applications.

The third competency, *Communicates ideas relating to questions involving chemistry, using the languages associated with science and technology*, is demonstrated by the knowledge and use of specialized terminology and symbols. It draws on the various languages used in chemistry that are essential to sharing information and to interpreting and producing messages of a scientific nature.

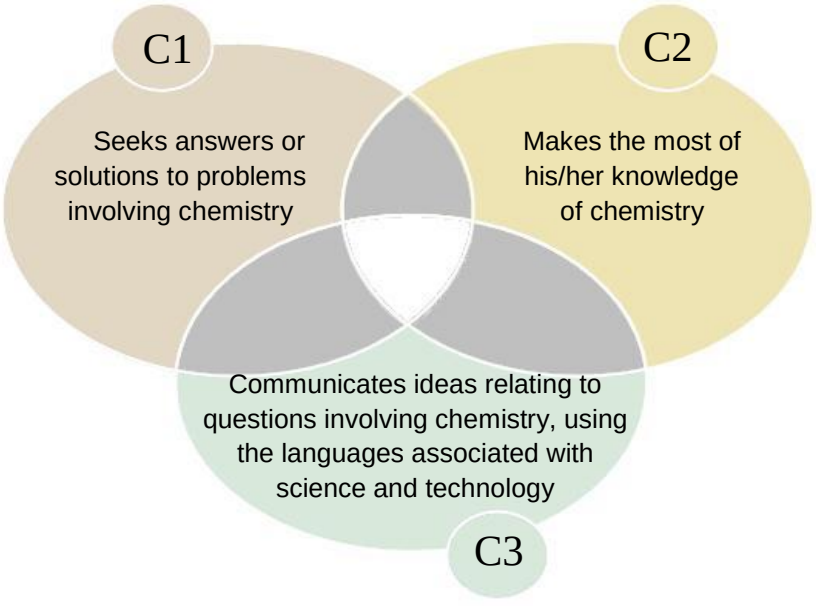


Diagram 1 - How the Subject-Specific Competencies Work Together

The three competencies are interrelated in various ways and are developed in synergy. For example, adult learners cannot seek answers to problems involving chemistry without learning and applying specific knowledge and mastering communication strategies. Likewise, to make the most of chemistry knowledge requires using a language shared by the members of the scientific community. This knowledge is applied repeatedly in solving problems.

The Three Aspects of Demonstrating a Competency

A competency is demonstrated through action and is expressed in the satisfactory execution of tasks in a given context. There are three aspects to its demonstration: contextualization, mobilization of resources and reflection.

First of all, applying a competency requires a thoughtful reading of the characteristics of the context, in other words, contextualization. Second, adult learners must take into account any constraints inherent in the context, make a plan and mobilize a set of resources. Lastly, they must be able to explain how they went about mobilizing an appropriate set of resources to act in a given situation. The concept of competency therefore involves the ability to think about the steps taken to carry out tasks and solve problems. This reflection process allows adult learners to better adjust their actions and the teachers to adjust their interventions.

Interactions Between the Aspects of Demonstrating a Competency

The three aspects of demonstrating a competency are not a simple juxtaposition of concepts. They interact in a dynamic way:

- The interaction between contextualization and the mobilization of resources involves re-using and recombining the same knowledge in a number of ways, depending on the contexts.
- The interaction between reflection and contextualization enables the adults to perceive more clearly the characteristics of the situation and to better understand its constraints.
- The interaction between reflection and the mobilization of resources primarily involves the reorganization of knowledge. It is also related to any type of analysis that enables adult learners to identify the strengths and weaknesses of the course of action taken.

Each of these interactions contributes to the transfer of learning. The following diagram illustrates how the different aspects of demonstrating a competency work together.

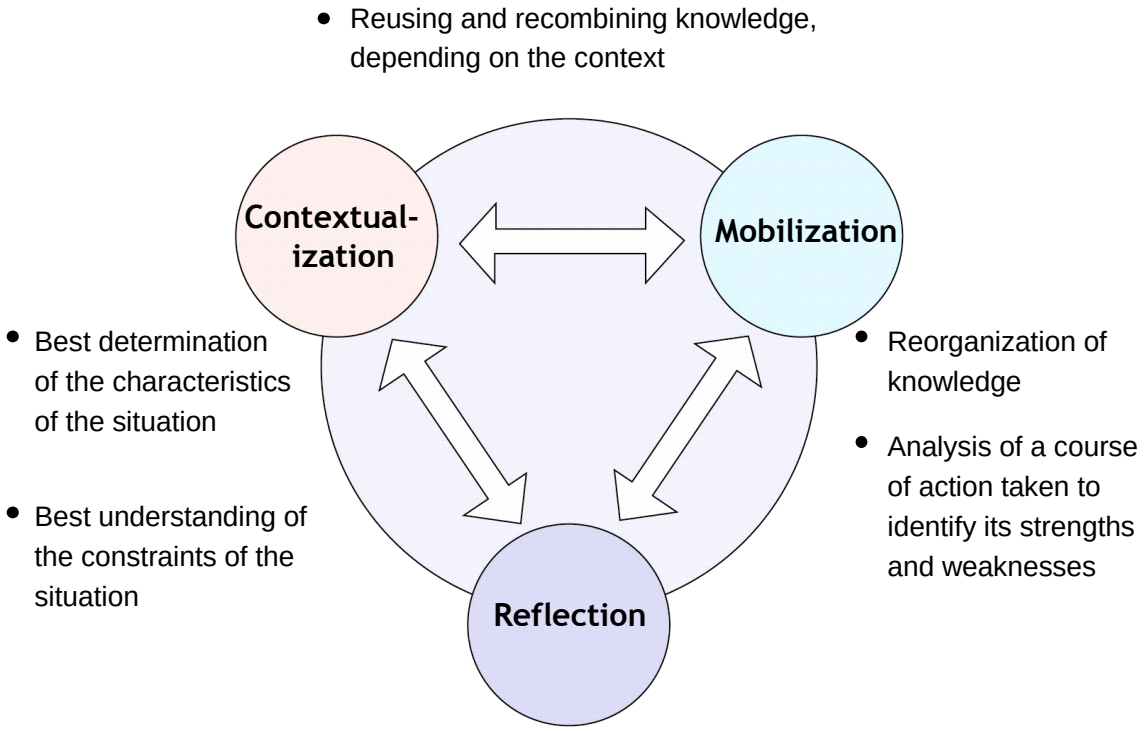


Diagram 2 - Interactions Between the Aspects of Demonstrating a Competency

3.2 Competency 1: Seeks answers or solutions to problems involving chemistry

3.2.1 Focus of the Competency

Like other science subjects, chemistry is characterized by a rigorous approach to the search for answers or solutions to the problems belonging to its field. Its type of reasoning is based on investigative processes that require the mobilization of strategies, techniques and concepts that are grounded in science. The structuring of these resources implies that the adult learner is capable of selecting and adapting them to a particular situation. It is by exploring various avenues, testing hypotheses, receiving feedback and reformulating a problem that the adult learner will finally be able to construct a satisfying solution. In the majority of cases, this competency involves carrying out experiments and requires the use of specialized materials.

The first aspect of this competency becomes evident when the adult learner develops a way of representing a problem based on meaningful indicators and relevant elements. This initial

representation of the problem may require several adjustments and be used to explore various problem-solving scenarios.

After selecting one of these scenarios, adult learners develop a plan of action that takes into account applicable material constraints and limitations, as well as the resources available to them to solve the problem.

The adult learners carry out their plan of action, taking care to record all observations that may be useful to them at a later point. They may even, in certain cases, carry out trials. New data may then require them to adapt their initial plan or search for more appropriate solutions.

The data collected must then be analyzed. The adult learners identify tendencies and significant relationships, provide relevant explanations and draw conclusions. If applicable, they make a judgment of the accuracy of their results according to the discrepancy they observe in comparison with an acceptable conventional value. These comparisons enable them to validate or invalidate their hypothesis and judge the relevance of their answer. In their report, the adult learners take care to use the significant figures, together with the margin of error.

3.2.2 Key Features and Manifestations of the Competency

- **Defines a problem**
  - Determines the elements that seem relevant
  - Determines the relationships between the different elements
  - Reformulates the problem in terms of chemistry concepts
  - Formulates realistic hypotheses or possible solutions

- **Develops a plan of action**
  - Chooses a hypothesis or a solution
  - Determines the necessary resources
  - Plans the steps involved in implementing the plan of action

- **Carries out the plan of action**
  - Handles equipment and substances and carries out planned operations
  - Gathers potentially useful data or observations
  - Adjusts the plan of action or its implementation, if necessary

- **Analyzes his/her results**
  - Processes the data gathered or his/her observations
  - Looks for significant patterns or relationships

- Makes connections between his/her results and chemistry concepts
- Judges the appropriateness of the answer or solution found
- Formulates new hypotheses or solutions, if applicable

3.2.3 Development of the Competency

In order to foster development of the competency *Seeks answers or solutions to problems involving chemistry*, teachers propose learning situations that are based on an investigative process and that encourage the students' involvement in problem solving.

Chemistry is the search for answers to questions about phenomena that are governed by laws. It makes use of an investigative process that generates models or theories that serve as the basis for understanding these phenomena.

In order to carry out the plan of action, it is necessary, in most cases, to perform a certain number of tasks in the laboratory. Review activities focus on the procedures chosen and favour a better use of the steps of these procedures and their related techniques and strategies, as well as their adaptation to different contexts.

3.3 Competency 2: Makes the most of his/her knowledge of chemistry

3.3.1 Focus of the Competency

Chemistry is indispensable for understanding many of the issues in the world today. People who are able to take advantage of their knowledge in this field are better equipped to participate in society and understand their role in it more clearly. To acquire this knowledge, adult learners must use methods of reasoning and investigative processes that they have studied in their chemistry courses.

The first manifestation of this competency appears when the adult learners examine the context of the phenomenon or application under study. They consider the elements that seem pertinent, identify the chemistry principles involved and form a representation of the phenomenon or application by referring to concepts.

The adult learners who engage in this analysis demonstrate their understanding of the principles involved by describing them qualitatively or quantitatively. They establish the relationships between them using the concepts, laws, theories and models that underlie them. They may find it useful to perform a certain number of tasks in the laboratory.

In order to explain a phenomenon or application in terms of chemistry, competent adult learners refer to the relevant concepts, laws, theories or models. They make use of scientific and

mathematical formalism to justify their explanations, as needed. Presenting their results provides them with the opportunity to explain their course of action and how they mobilized their resources. They take care to make proper use of significant figures, not forgetting the degree of uncertainty associated with them. Since the same principles are valid for several phenomena or applications, they may be called upon to transfer or adapt their explanation to other contexts.

3.3.2 Key Features and Manifestations of the Competency

- **Identifies the principles of chemistry underlying a phenomenon or application**
  - Considers the elements of the context
  - Identifies the principles of chemistry
  - Creates a representation of the phenomenon or application, based on chemistry concepts

- **Analyzes the principles of chemistry underlying a phenomenon or application**
  - Describes the principles of chemistry underlying a phenomenon or application qualitatively or quantitatively
  - Uses concepts, laws, theories or models to establish the relationships between chemistry principles underlying a phenomenon or application

- **Explains a phenomenon or an application from the standpoint of chemistry**
  - Develops an explanation based on concepts, laws and models of chemistry
  - Justifies his/her explanation using scientific and, if necessary, mathematical formalism
  - Adapts the proposed explanation to other contexts, if applicable

3.3.3 Development of the Competency

To enable adult learners to develop the competency *Makes the most of his/her knowledge of chemistry*, teachers propose learning situations involving an application or phenomenon related to one or more principles of chemistry.

To satisfy the need for understanding a phenomenon or application, it is necessary to construct new knowledge and to relate this to the knowledge already constructed. All this knowledge is used to explain the use of the principles of chemistry in the manufacture or operation of the application or, again, to describe and explain the phenomenon.

Review activities involve assimilating knowledge, using resources and adapting them to the requirements of different contexts.

3.4 Competency 3: Communicates ideas relating to questions involving chemistry, using the languages associated with science and technology

3.4.1 Focus of the Competency

Communication plays an essential role in the acquisition of scientific knowledge. This knowledge is constructed based on a set of common meanings, the exchange of ideas and the negotiation of points of view. This competency cannot be developed in isolation from the other two competencies in the program, to whose development it contributes.

In this program, adult learners interpret and produce messages on chemistry-related questions. In addition to tables, graphs, diagrams, models and equations, these messages involve chemistry-specific vocabulary and symbols. In fact, there are standards and conventions governing the writing of protocols and reports. Adult learners take these into account when they prepare for a task, search for information, establish a plan of action, write a report or provide an explanation. They also verify the reliability of the sources they consult and respect the intellectual property rights of persons whose ideas they borrow or whose results they make use of.

3.4.2 Key Features and Manifestations of the Competency

- **Interprets scientific or technological messages**
  - Places the message in context
  - Makes sure the sources are reliable
  - Selects the elements needed to interpret the message
  - Grasps the precise meaning of words or statements
  - Establishes connections between concepts and their graphic or symbolic representations

- **Produces scientific or technological messages**
  - Structures his/her message
  - Uses scientific and technological vocabulary
  - Uses the symbolic and graphical languages associated with science and technology
  - Adheres to the established standards and conventions for the different languages
  - Demonstrates rigour and coherence
  - Respects intellectual property rights

3.4.3 Development of the Competency

To enable adult learners to develop the competency *Communicates ideas relating to questions involving chemistry, using the languages associated with science and technology*, teachers propose learning situations involving various forms of presentation and the use of precise scientific and technological vocabulary. This helps them to make connections between various representations of concepts.

The learning situations related to the first and second competencies generally offer the adult learner an opportunity to develop this third competency. In fact, this competency is needed to read or present a project, write and analyze a report, develop or carry out a protocol, and study or create a model. Situations in which adult learners share their findings or seek answers to questions foster the development of their ability to communicate in a language adapted to science and technology.

Review activities focus on the resources and techniques that form the basis of communication, on their use and on their adaptation to the requirements of the context.

3.5 Processes

To solve a chemistry problem or study a phenomenon or an application, adult learners use an investigative process. The following diagram illustrates recognized scientific investigative processes.

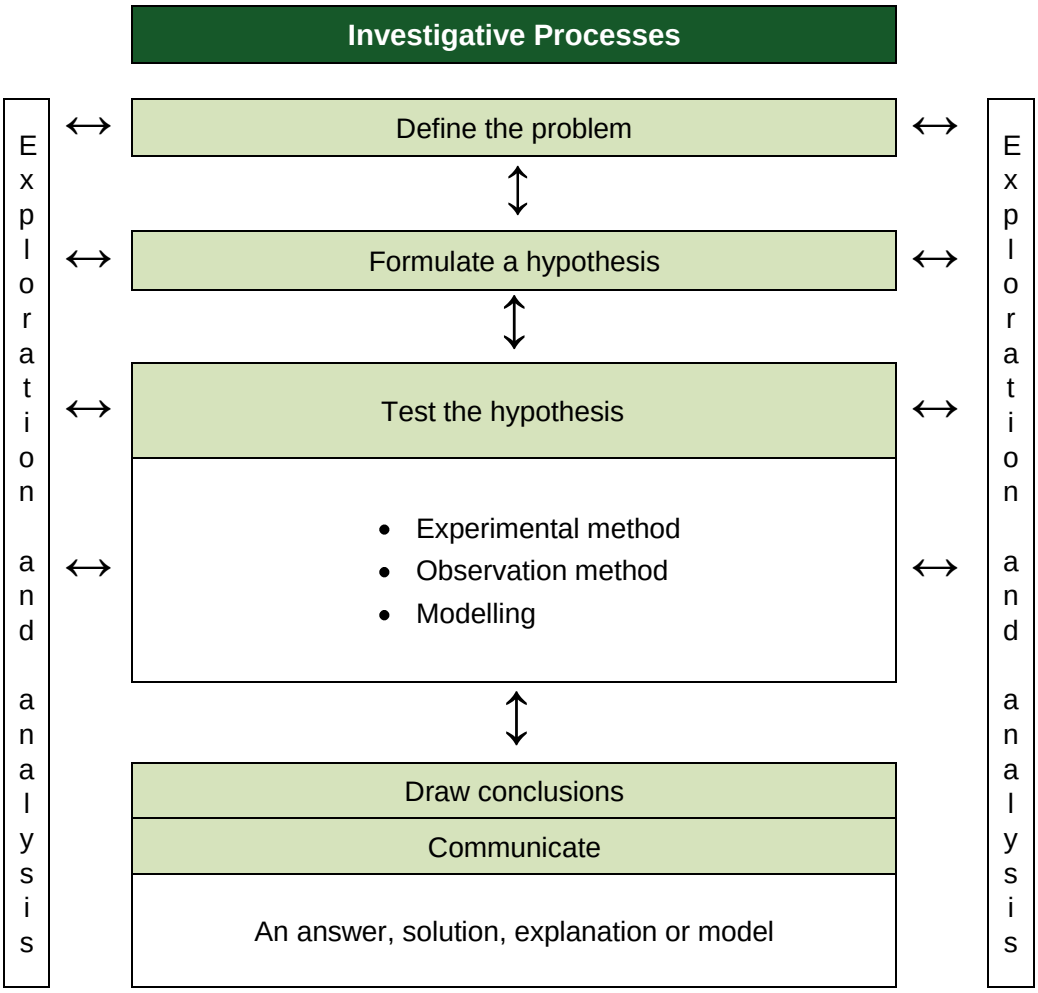


Diagram 3 - Investigative Processes

As suggested by the vertical double-headed arrows, investigative processes are rarely linear. Before adult learners are able to draw conclusions and communicate their solution, they may return several times to a previous step. The horizontal double-headed arrows refer to the exploration and analysis strategies used to proceed more effectively towards a conclusion. Examples of each of the strategies and each of the steps are given in Appendixes 1 and 2.

The *investigative processes* encompass the different methods mentioned in the Secondary Cycle Two program: the experimental method, modelling and the observation method. As illustrated in the previous diagram, these processes diverge only at the hypothesis testing stage; that is why, in this program, they are grouped together under the general heading “Investigative Processes.” The tables in Appendix 3 present in detail each of the methods used to test hypotheses.

The Chemistry program gives adult learners the opportunity to use all these methods, although the experimental method is the one most in evidence. It is called upon explicitly in the development of Competency 1. This emphasis on the experimental method helps to illustrate, on the one hand, the difficulties involved in scientific research, and on the other hand, the work accomplished by scientists who have been able to develop different chemistry laws and theories in spite of the occasional lack of precision in the measuring instruments they used.

Chapter 4

Subject-Specific Content

4.1 Knowledge

The Chemistry program aims to consolidate and enrich scientific and technical knowledge that is based on the development of competencies, the construction of knowledge and the mobilization of resources in connection with the compulsory concepts, processes, techniques and cultural references. In addition, it aims to train users of chemistry who are aware of its implications and to prepare some adult learners for careers in the fields of science and technology.

4.1.1 Compulsory Concepts

The compulsory concepts in the Chemistry program are connected to *The Material World* and relate to gases, chemical dynamics and energy transfers involved in chemical reactions, and chemical equilibrium. A list can be found in Chapter 5 in the course table. These are repeated in Chapter 6 under the Subject-Specific Content heading for each course, along with the orientations and a list of knowledge to be acquired.

4.1.2 Techniques

Techniques involve methodical procedures that provide guidelines for the proper application of theoretical knowledge. They fall into two categories: techniques related to laboratory work and measurement techniques.

Many of these techniques require the use of instruments or chemicals. Safety and the use of safety equipment must be a constant concern for all those using such techniques.

Summary of Techniques
Techniques related to laboratory work
- Safely using laboratory materials and equipment - Preparing solutions - Collecting samples
Measurement techniques
- Checking the reliability, accuracy and sensitivity of measuring instruments - Interpreting measurement results (significant figures, measurement errors)

Table 1 - Summary of Techniques

4.2 Cultural References

Cultural references are particularly meaningful when it comes to scientific literacy. They contribute to the enrichment of learning situations by rooting them in social and cultural reality. They may include technical objects, technological systems, technological procedures, products, scientists of both sexes, community resources, human activities and events related to the learning content of the courses. A list of cultural references is given for each course in Chapter 6.

The knowledge related to cultural references forms part of the subject-specific content to be mobilized in this program of study. While the use of references is compulsory, the list of examples is provided for illustration purposes only. The established list is not exhaustive.

Chapter 5

Organization of the Courses in the Program

5.1 Introduction to the Courses

The Two Chemistry Courses

The Chemistry program is composed of two courses, CHE-5061-2 and CHE-5062-2, which must be taken in that order because of the logical links between the elements of the content and the progression of expectations in the context of an investigative process that includes experimentation.

Course CHE-5061-2, *Chemistry: Gases and Energy*, deals with the chemical and physical properties of matter in a gaseous state, as well as energy transfers involved in chemical reactions, regardless of the state—solid, liquid or gaseous—of the substances involved. Laboratory work consolidates the learning related to experimentation that was acquired in Secondary III and IV.

Course CHE-5062-2, *Chemistry: Kinetics and Equilibrium*, deals with reaction rates in chemical changes and the state of equilibrium of reversible changes. Laboratory activities provide for the autonomous application of skills related to experimentation.

The following table presents the content of the courses in the Chemistry program.

Courses		
Title	**Hours/ Credits**	**Compulsory Concepts**
CHE-5061-2 ***Chemistry: Gases and Energy***	50 hours 2 credits	• Chemical properties of gases - Reactivity • Physical properties of gases - Kinetic theory of gases - General gas law - Ideal gas law - Dalton's law - Avogadro's hypothesis - Molar volume of a gas • Energy transfers that occur in reactions - Endothermic and exothermic reactions - Energy diagram - Activation energy - Enthalpy change - Molar heat of reaction - Relationship between thermal energy, specific heat capacity, mass and temperature variation
CHE-5062-2 ***Chemistry: Kinetics and Equilibrium***	50 hours 2 credits	• Reaction rate - Factors that influence the reaction rate - Rate law • Chemical equilibrium - Factors that influence the state of equilibrium - Le Châtelier's principle - Equilibrium constant - Relationship between the pH and the molar concentration of hydronium and hydroxide ions

Table 2 - Program Courses

Chapter 6

Courses

6.1 Organization of Course Information

This chapter contains a detailed description of each of the courses in the Chemistry program, presented under the following headings:

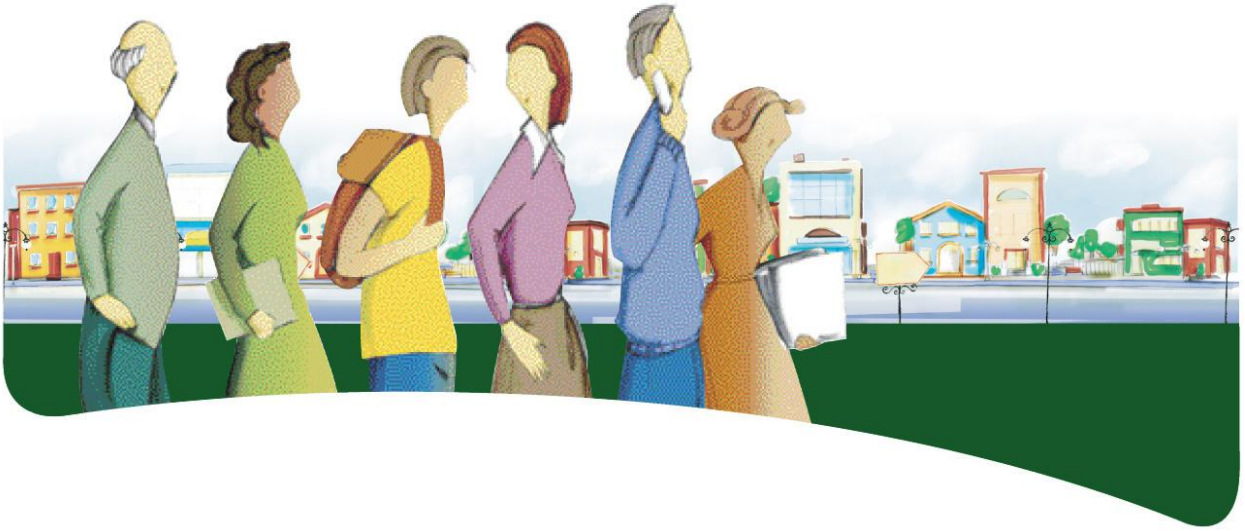
Headings
Introduction
Subject-Specific Competencies
Processes
Cross-Curricular Competencies
Subject-Specific Content
Families of Learning Situations
Broad Areas of Learning
Example of a Learning Situation
End-of-Course Outcomes
Evaluation Criteria for the Competencies Targeted by the Course

Course

CHE-5061-2

Chemistry: Gases and Energy

Chemistry



INTRODUCTION

The course entitled *Chemistry: Gases and Energy* is aimed at enabling adult learners to function effectively in situations from the *Research* and *Expertise* families that involve the behaviour of gases or the energy transfers involved in chemical reactions.

Adult learners enrolled in this course study phenomena or technological applications related to the properties of gases or the energy transfers involved in chemical reactions, and look for answers or solutions to problems involving them. They thus acquire knowledge about the chemical and physical properties of gases, as well as about the energy transfers involved in chemical reactions. This knowledge helps them explain the factors associated with certain phenomena, for example, volcanic eruptions, the ozone layer or photosynthesis, and enables them to understand the operation of a technological application such as a manometer, internal combustion engine or heat pump. Furthermore, since experimentation and modelling occupy a central place in the development of competencies and the construction of knowledge related to the concepts in the course, the adult learners carry out several laboratory activities that help them consolidate their learning from Secondary III and IV about techniques and methods.

By the end of this course, in *Research* and *Expertise* situations, adult learners will be able to:

- ✓ carry out an investigative process that includes experimentation to solve a problem related to gases or the energy transfers involved in chemical reactions
- ✓ analyze a phenomenon or technological application related to the behaviour of gases or the energy involved in chemical reactions
- ✓ predict, qualitatively and quantitatively, the behaviour of gaseous substances and the spontaneity of a chemical reaction
- ✓ prepare an experimental protocol, according to guidelines, to answer a question related to the chemical and physical properties of gases, or dealing with the energy transfers involved in a chemical reaction
- ✓ write a laboratory report, using an outline, on the chemical and physical properties of gases or the energy transfers involved in a chemical reaction

SUBJECT-SPECIFIC COMPETENCIES

The following table lists, for each competency, the key features studied in the course. The manifestations of the key features are presented in Appendix 4.

Competency 1 Seeks answers or solutions to problems involving chemistry	Competency 2 Makes the most of his/her knowledge of chemistry	Competency 3 Communicates ideas relating to questions involving chemistry, using the languages associated with science and technology
▪ Defines a problem ▪ Develops a plan of action ▪ Carries out the plan of action ▪ Analyzes his/her results	▪ Identifies the principles of chemistry underlying a phenomenon or application ▪ Analyzes the principles of chemistry underlying a phenomenon or application ▪ Explains a phenomenon or an application from the standpoint of chemistry	▪ Interprets scientific or technological messages ▪ Produces scientific or technological messages

PROCESSES

The investigative processes enable adult learners to solve problems involving the principles of chemistry and to study an application or a phenomenon related to the behaviour of gases or the energy transfers involved in chemical reactions. The following are the steps in an investigative process:

- Define the problem
- Formulate a hypothesis
- Test the hypothesis
- Draw conclusions and communicate

The most appropriate investigative processes for this course are the observation method, the experimental method and modelling. It is during hypothesis verification that these methods become distinguishable. Section 3.5 and Appendixes 1 to 3 present these investigative processes, with their respective characteristics.

In this course, laboratory experiments require adult learners to carry out specific tasks in accordance with the following limitations and instructions.

Experimental Method	
Steps	**Tasks**
1. Plans an experiment	With guidance, the adult learner: - writes up an experimental protocol for chemistry - selects the materials required to do an experiment - identifies the applicable safety rules, the constant parameters and the parameters to be investigated (independent variable, dependent variable)
2. Conducts the experiment	The adult learner: - follows the experimental protocol - collects data, keeping in mind the factor of experimental error - applies the appropriate safety rules
3. Interprets the results	In writing up a report, using an outline, the adult learner: - takes significant figures into account when processing the data - analyzes the results - identifies the sources of error - discusses the results - writes the conclusion, making connections with the problem in question

CROSS-CURRICULAR COMPETENCIES

The cross-curricular competencies supplement the subject-specific competencies. The development of one contributes to the development of the others. Course CHE-5061-2 allows for putting all the cross-curricular competencies into practice. Some of them, indicated in grey shading in the table below, are especially targeted in the sample learning situation that will be presented in the last part of the course.

Cross-Curricular Competencies			
Intellectual	**Communication-Related**	**Personal and Social**	**Methodological**
Uses information	Communicates appropriately	Achieves his/her potential	Adopts effective work methods
Solves problems		Cooperates with others	Uses information and communications technologies
Exercises critical judgment			
Uses creativity			

SUBJECT-SPECIFIC CONTENT

A) KNOWLEDGE

The compulsory concepts and techniques are presented in the tables in the following two sections.

1. Concepts

The knowledge written in italics has been acquired in the science and technology programs and must be mobilized again in this course.

The Material World	
General concept: Chemical properties of gases The extensive use of gases in many different areas of human activity makes it important to study the reactivity of various gaseous substances. This provides information, for example, on their possible uses and on ways of handling them safely.	
COMPULSORY CONCEPTS	**KNOWLEDGE TO BE ACQUIRED**
Reactivity	• Associates the use of certain gases in various applications with their chemical reactivity (e.g. argon in light bulbs, nitrogen in bags of chips, acetylene in welding torches)
General concept: Physical properties of gases The similarities observed in the behaviour of various gases (e.g. compressibility, expansion, diffusion, undefined shape and volume) have led to the definition of kinetic molecular theory. At the beginning of Cycle Two, the study of gases focused on the relationship between pressure and volume. In this program, students continue to examine this topic by looking at the general gas law and the ideal gas law. Dalton's law, also called the "law of partial pressures," is useful in the study of gaseous mixtures. The application of these laws requires mastery of the mathematical operations connected with the conversion of units of measurement and multi-variable algebraic expressions. Avogadro's hypothesis explains volumetric combinations associated with chemical reactions involving gases. As a corollary of this hypothesis, molar volume is used to simplify calculations concerning the quantity of gases consumed or produced. The molar volumes used are those established at standard temperature and pressure (0°C and 101.3 kPa), and at room temperature and standard pressure (25°C and 101.3 kPa).	
COMPULSORY CONCEPTS	**PREVIOUSLY ACQUIRED KNOWLEDGE**
Compressible and incompressible fluids	• *Distinguishes between compressible and incompressible fluids*
Pressure	• *Defines pressure as the force exerted by particles when they collide with a constricting surface* • *Describes qualitatively the main factors that affect the pressure exerted by a fluid*
Avogadro's number	• *Expresses a quantity of particles using Avogadro's number*
Concept of the mole	• *Defines the mole as the unit of measurement of the amount of a substance* • *Expresses an amount of a substance in moles*

Physical properties of gases (cont.)	
COMPULSORY CONCEPTS	**KNOWLEDGE TO BE ACQUIRED**
Kinetic theory of gases	• Explains the macroscopic behaviour of a gas (e.g. compressibility, expansion, diffusion) using kinetic theory
General gas law	• Determines the relationship between the pressure of a gas and its volume when the temperature and number of moles of gas are kept constant • Determines the relationship between the pressure of a gas and its temperature when the number of moles of gas and the volume are kept constant • Determines the relationship between the volume of a gas and its temperature when the pressure and the number of moles of gas are kept constant • Determines the relationship between the pressure of a gas and the number of moles of that gas when the volume and temperature are kept constant • Determines the relationship between the volume of a gas and the number of moles of that gas when the temperature and pressure are kept constant • Applies the mathematical relationship between the pressure, volume, number of moles and temperature of a gas ($P_1V_1/n_1T_1 = P_2V_2/n_2T_2$)
Ideal gas law	• Explains qualitatively the relationship between the factors affecting the behaviour of gases (pressure, volume, number of moles, temperature) in a given situation (e.g. a balloon exposed to cold, the operation of a bicycle pump) • Applies the mathematical relationship between the pressure, volume and number of moles of a gas, the ideal gas constant and the temperature of a gas ($pV = nRT$)
Dalton's law	• Explains qualitatively the law of partial pressures • Applies the mathematical relationship between the total pressure of a gas mixture and the partial pressures of the individual component of the gas mixture ($P_{total} = Pp_A + Pp_B + Pp_C + \ldots$)
Avogadro's hypothesis	• Uses Avogadro's hypothesis to predict the number of molecules in equal volumes of gases subjected to the same temperature and pressure
Molar volume of a gas	• Calculates the molar volume of a gas at standard temperature and pressure • Calculates the molar volume of a gas at room temperature and standard pressure • Determines the number of moles of a gas at a given temperature and pressure

General concept: Energy transfers that occur in reactions

The energy balance of a reaction may be described using an energy diagram. The drawing and interpretation of an energy diagram show the enthalpy change (energy stored as kinetic and potential energy) of the substances involved and of certain aspects of chemical dynamics, such as activation energy.

The additivity of reaction heats (Hess's law) or bond enthalpies are among the methods used to evaluate the molar heat of reaction. Calorimetry is a way to experimentally determine the quantity of heat involved in certain chemical or physical changes.

COMPULSORY CONCEPTS	PREVIOUSLY ACQUIRED KNOWLEDGE
Forms of energy	• *Defines "joule" as the unit of measurement for energy*
Distinction between heat and temperature	• *Describes heat as a manifestation of energy* • *Describes the relationship between heat and temperature*
Decomposition and synthesis	• *Represents a decomposition or synthesis reaction using the particle model* • *Associates known chemical reactions with decomposition or synthesis reactions (e.g. respiration, photosynthesis, combustion, digestion)*
Oxidation	• *Represents an oxidation reaction using the particle model* • *Associates known chemical reactions with oxidation reactions (e.g. combustion, corrosion)* • *Associates a chemical equation in which oxygen is one of the reactants with one of the possible cases of an oxidation reaction*
Precipitation	• *Describes the visible manifestation of precipitation (formation of a solid deposit after two aqueous solutions are mixed)* • *Represents a precipitation reaction using the particle model*
Combustion	• *Describes the perceivable manifestations of rapid combustion (e.g. heat liberation, light emission)* • *Explains a combustion reaction using the fire triangle*
Acid-base neutralization reaction	• *Gives examples of acid-base neutralization reactions (e.g. adding lime to neutralize the acidity of a lake)* • *Names the products formed during acid-base neutralization (salt and water)* • *Recognizes an acid-base neutralization from its equation*

COMPULSORY CONCEPTS	KNOWLEDGE TO BE ACQUIRED
Endothermic and exothermic reactions	• Distinguishes an endothermic reaction from an exothermic reaction according to perceptible signs (e.g. temperature variations, emission of light) • Distinguishes an endothermic reaction from an exothermic reaction according to the position of the energy term in the chemical equation
Energy diagram	• Interprets the energy diagram of a chemical reaction • Produces an energy diagram representing the energy balance for a chemical reaction
Activation energy	• Determines the activation energy for a reaction using its energy diagram

Energy transfers that occur in reactions (cont.)	
COMPULSORY CONCEPTS	**KNOWLEDGE TO BE ACQUIRED**
Enthalpy change	• Explains qualitatively the enthalpy change of substances during a chemical reaction • Determines the enthalpy change of a chemical reaction, using its energy diagram
Molar heat of reaction	• Determines the molar heat of a reaction using a calorimeter • Determines the molar heat of a reaction using Hess's Law or bond energies
Relationship between thermal energy, specific heat capacity, mass and temperature variation	• Describes qualitatively the relationship between the change in thermal energy (quantity of heat) of a substance, its mass, its specific heat capacity and the variations in temperature to which it is exposed • Applies the mathematical relationship between thermal energy, specific heat capacity, mass, and temperature variation ($\Delta E = Q = mc\Delta T$)

2. Techniques

The techniques presented here are grouped in two categories. Many of these techniques require the use of instruments or chemicals. Safety and the use of safety equipment must be a constant concern for all those using such techniques.

In the Laboratory	
TECHNIQUES	**KNOWLEDGE TO BE ACQUIRED**
Laboratory work	
- Safely using laboratory materials and equipment	• Uses laboratory materials and equipment safely (e.g. allows a hotplate to cool before touching it, uses beaker tongs) • Handles chemicals safely (e.g. uses a spatula and a pipette filler)
- Collecting samples	• Collects samples in an appropriate fashion (e.g. sterilizes the container, uses a spatula, refrigerates the sample)
- Preparing solutions	• Prepares an aqueous solution of a specific concentration given a solid solute • Prepares an aqueous solution of a specific concentration given a concentrated aqueous solution
Measurement	
- Checking the reliability, accuracy and sensitivity of measuring instruments	• Takes the same measurement several times to check the reliability of the instrument used • Carries out the required operations to ensure the accuracy of a measuring instrument (e.g. cleans and calibrates a balance, dries out a graduated cylinder, calibrates a manometer) • Takes the sensitivity of a measuring instrument into account (e.g. uses a 25-mL graduated cylinder rather than a 100-mL one to measure 18 mL of water)

TECHNIQUES (cont.)	KNOWLEDGE TO BE ACQUIRED
- Interpreting measurement results (significant figures, measurement errors)	• Determines the margin of error attributable to a measuring instrument (e.g. the uncertainty of a measurement made using a graduated cylinder is provided by the manufacturer or corresponds to half of the smallest division on the scale) • Identifies the measurement errors associated with the user and the environment • Expresses a result with a number of significant figures that takes into account the errors related to the measure (e.g. a measurement between 10.3 and 10.4 cm, taken with a ruler graduated in millimetres, should be expressed as 10.35 cm or 103.5 mm). • Expresses the value of a measurement with its absolute or relative uncertainty (e.g. 24.1 ± 0.1 mL, or 24.1 mL ± 0.4%)

B) CULTURAL REFERENCES

Cultural references make learning situations more meaningful. The following table presents some of the references related to this course. Learning situations may also draw on other cultural references.

Cultural References	
Technical objects, technological systems, processes and products	**Gases** – Measuring and control instruments associated with gas (manometer, sphygmomanometer, barometer) – Ozone layer – Volcanic eruptions – Filters and gas masks – Gas handling, use and storage – Hot air balloons, dirigibles and weather balloons – Internal combustion engines – Refrigeration – Deep-sea diving – Air pumps – Food-related uses of gas (e.g. preservation, ripening, gasification) – Medical uses of gases (anesthetics, resuscitation) **Energy** – Cooling and heating packs – Energy efficiency of fuels – Food choices – Regulation of heat in the geosphere – Solar panels – Fossil fuels – Biofuels

Cultural References (cont.)				
Area	**Scientists**	**Community Resources**	**Applications**	**Events**
The Material World	Amadeo Avogadro Edme Mariotte Robert Boyle Jacques Charles John Dalton Louis Joseph Gay-Lussac William Thomson Benjamin Franklin Nicolas Léonard Sadi Carnot James Prescott Joule Jean Rey John Mayow Karl William Scheele Joseph Priestley Germain Henri Hess Svante August Arrhenius	Association francophone pour le savoir (ACFAS) Conseil du développement du loisir scientifique (CDLS) National Research Council of Canada (NRC) Chemical Institute of Canada (CIC) International Union of Pure and Applied Chemistry (IUPAC)		Science fairs Nobel Prize in Chemistry Launch of the space shuttle

FAMILIES OF LEARNING SITUATIONS

The learning situations in this course, derived from the *Research* and *Expertise* families, involve gases or energy changes in chemical reactions. These situations focus on a problem linked to different concepts. The paragraphs below give examples of tasks that can be assigned to adult learners in learning situations that draw on various concepts.

One learning situation involving Avogadro's hypothesis and the molar volume of a gas at room temperature can be used to predict the value of this volume under laboratory conditions and to verify it using an experiment. The adult learner can thus design an experiment, write a procedure and implement it.

Furthermore, a situation involving activation energy and the molar heat of a reaction can be used to predict the value of the molar heat of dissolution of an acid, using Hess's law. The adult learner thus decides to carry out a series of activities in the laboratory, prepares the procedure and carries out the experiment.

A situation involving the kinetic theory of gases and the energy transfers involved in chemical reactions may lead adult learners to construct a model to explain the phenomenon of the decomposition of water by electrolysis. Furthermore, adult learners could, in an experiment, measure the volume of gas released during a chemical reaction and then identify the gas. In

addition, they could measure the energy required for this reaction in order to produce an energy diagram of this decomposition.

In the learning situation described below, the main tasks help adult learners develop the second and third competencies. This situation therefore belongs to the *Expertise* family.

BROAD AREAS OF LEARNING

Learning situations are more meaningful for adult learners when their context is connected to the broad areas of learning. The broad areas of learning most readily applicable to the learning situations for the course CHE-5061-2 are *Health and Well-Being*, *Career Planning and Entrepreneurship*, *Environmental Awareness and Consumer Rights and Responsibilities*, and *Media Literacy*. The following example reflects the educational aim of the broad areas of learning *Health and Well-Being*, and *Environmental Awareness and Consumer Rights and Responsibilities.*

Broad Areas of Learning
Health and Well-Being
Career Planning and Entrepreneurship
Environmental Awareness and Consumer Rights and Responsibilities
Media Literacy
Citizenship and Community Life

EXAMPLE OF A LEARNING SITUATION

KEEPING WARM

A friend is currently heating his house using electricity and wants to switch to a fuel-burning central heating system. He is wondering, however, which fuel would be the most appropriate for his needs: wood, natural gas, oil or propane. He is most interested in a system that is energy-efficient, affordable, clean and safe. To advise your friend on this subject, you must determine the energy efficiency of each of the fuels mentioned. Considering the chemical equations for combustion reactions and referring to a list of intermediate reactions and their enthalpy change, you can use Hess's law to calculate the overall energy balance for each type of fuel. The products of the reaction, particularly the gases released, will also allow you to determine the type and extent of the pollution created and its impact on the environment. Lastly, research on the price of each of these resources will enable you to estimate the cost associated with using these heating systems. With this information, you will be able to recommend the system that is most suited to your friend's needs.

To determine the pollution levels created, you must identify the products generated by the combustion fuels, research their impact on the environment and classify them.

An annotated research document on the installation and usage standards is required to ensure the safety of the system.

The file must include:

- the balanced chemical equation for each combustion reaction
- the intermediate reactions for each combustion reaction and the overall energy balance
- the approximate cost for each fuel and the literature consulted on the subject
- a list of products generated by each combustion system and their impact on the environment
- a recommendation with respect to the heating system, including the appropriate scientific justifications

END-OF-COURSE OUTCOMES

Learning situations are administered on the premise that the adult learner will become familiar with an investigative process involving the experimental method, the observation method or modelling. They also enable adult learners to apply their problem-solving skills, use their acquired knowledge and produce messages.

Adult learners who solve a problem related to gases or to the energy changes in chemical reactions form a representation of the problem based on their reading and interpretation of scientific and technological messages. They develop a plan of action for one of their hypotheses, thus using their knowledge of the chemical and physical properties of gases and of the energy changes in chemical reactions. To achieve these results, adult learners are guided in preparing an experiment protocol and determining the constant parameters, the independent variable and the dependent variable, and in writing the instructions with respect to the laboratory activities. They implement a plan of action by carrying out activities in the laboratory; they gather data taking into account the experimental uncertainty involved in recording numerical data; and they apply the appropriate safety rules. Using an outline, they process data, analyze results and write up discussions about the experiment and its conclusion. If applicable, their report mentions the sources of errors that may explain the discrepancy between their results and those predicted by the theory.

Adult learners who study a phenomenon or technological application related to gases or to the energy changes in chemical reactions formulate questions on the contextual aspects and point out the principles of chemistry involved. Using concepts, laws, theories or models, they explain the specific use or manipulation of certain gases in relation to their properties and the energy exchanges between molecules during a chemical reaction. In this way, they determine the quantity of gas present or the quantity of energy associated with such reactions, and illustrate the behaviours of the gases or reaction process in chemical reactions. Lastly, adult learners demonstrate their understanding of the principles of chemistry by describing the effect of the variation of certain initial

parameters and by applying their explanations to other phenomena or applications governed by the same principles.

EVALUATION CRITERIA FOR THE COMPETENCIES TARGETED BY THE COURSE

Evaluation Criteria for Competency 1	Evaluation Criteria for Competency 2	Evaluation Criteria for Competency 3
▪ Appropriate representation of the situation ▪ Development of a suitable plan of action ▪ Appropriate implementation of the plan of action ▪ Development of relevant explanations, solutions or conclusions	▪ Formulation of appropriate questions ▪ Appropriate use of knowledge of chemistry ▪ Suitable production of explanations	▪ Accurate interpretation of scientific or technological messages ▪ Appropriate production or transmission of scientific or technological messages

Course

CHE-5062-2

Chemistry: Kinetics and Equilibrium

Chemistry

INTRODUCTION

The course entitled *Chemistry: Kinetics and Equilibrium* is aimed at enabling adult learners to function effectively in situations from the *Research* and *Expertise* families that involve elements of kinetics and chemical equilibrium.

Adult learners enrolled in this course study phenomena or technological applications related to the reaction rate of a chemical reaction or to chemical equilibrium, and look for answers or solutions to problems involving them. They thus acquire knowledge about rate law, equilibrium constants, factors that influence the reaction rate and the state of equilibrium, Le Châtelier's principle and the relationship between the pH and the molar concentration of hydronium and hydroxide ions. This knowledge helps them to explain the factors associated with certain phenomena, for example, control of blood pH or enzyme reactions, and enables them to understand how a technological application, such as swimming pool maintenance products and biodegradable plastics, works. In addition, as the experimental method and modelling occupy a central place in the development of competencies and the construction of knowledge related to the concepts in the course, adult learners carry out several laboratory activities designed to help them autonomously exercise the specific skills related to techniques and methods.

By the end of this course, in *Research* and *Expertise* situations, adult learners will be able to:

- ✓ carry out an investigative process that includes experimentation to solve a problem related to chemical kinetics or chemical equilibrium
- ✓ analyze a phenomenon or technological application involving the factors that influence the reaction rate or the state of equilibrium
- ✓ predict the effect of modifying a parameter on the rate of a chemical reaction or on the state of equilibrium of a chemical system
- ✓ follow an experimental protocol that they have prepared; one which involves chemical kinetics or the state of equilibrium of a chemical system
- ✓ write a laboratory report on chemical kinetics or the state of equilibrium of a chemical system

SUBJECT-SPECIFIC COMPETENCIES

The following table lists, for each competency, the key features studied in the course. The manifestations of the key features are presented in Appendix 4.

Competency 1 Seeks answers or solutions to problems involving chemistry	Competency 2 Makes the most of his/her knowledge of chemistry	Competency 3 Communicates ideas relating to questions involving chemistry, using the languages associated with science and technology
▪ Defines a problem ▪ Develops a plan of action ▪ Carries out the plan of action ▪ Analyzes his/her results	▪ Identifies the principles of chemistry underlying a phenomenon or application ▪ Analyzes the principles of chemistry underlying a phenomenon or application ▪ Explains a phenomenon or an application from the standpoint of chemistry	▪ Interprets scientific or technological messages ▪ Produces scientific or technological messages

PROCESSES

The investigative processes enable adult learners to solve problems involving the principles of chemistry, and to study an application or a phenomenon involving kinetics and chemical equilibrium. The following are the steps in an investigative process:

- Define the problem
- Formulate a hypothesis
- Test the hypothesis
- Draw conclusions and communicate

The most appropriate investigative processes for this course are: the observation method, the experimental method and modelling. It is during the step of verifying a hypothesis that these methods become distinguishable. Section 3.5 and Appendixes 1 to 3 present these investigative processes, with their respective characteristics.

In this course, laboratory experiments require adult learners to carry out specific tasks in accordance with the following limitations and instructions.

Experimental Method	
Steps	**Tasks**
1. Plans an experiment	The adult learner: - writes up an experimental protocol for chemistry - selects the materials required to do an experiment - identifies the applicable safety rules, the constant parameters and the parameters to be investigated (independent variable, dependent variable)
2. Conducts the experiment	The adult learner: - follows the experimental protocol and adjusts it as required - takes measurements, keeping in mind the factor of experimental error - applies the appropriate safety rules
3. Interprets the results	In writing up a report, the adult learner: - takes significant figures into account when processing the data - analyzes the results - estimates the maximum allowable error due to the user and the environment - discusses the results - writes the conclusion, making connections with the problem in question

CROSS-CURRICULAR COMPETENCIES

The cross-curricular competencies supplement the subject-specific competencies. The development of one contributes to the development of the others. Course CHE-5062-2 allows for putting all the cross-curricular competencies into practice. Some of them, indicated in grey shading in the table below, are especially targeted in the sample learning situation presented for the requirements of the course.

Cross-Curricular Competencies			
Intellectual	**Communication-Related**	**Personal and Social**	**Methodological**
Uses information	Communicates appropriately	Achieves his/her potential	Adopts effective work methods
Solves problems		Cooperates with others	Uses information and communications technologies
Exercises critical judgment			
Uses creativity			

SUBJECT-SPECIFIC CONTENT

A) KNOWLEDGE

The compulsory concepts and techniques are presented in the tables in the following two sections.

1. Concepts

The knowledge written in italics has been acquired in the science and technology programs and must be mobilized again in this course.

The Material World	
General concept: Reaction rate The rate at which reactants are transformed into products depends on several factors (nature of the reactants, concentration, surface area, temperature, catalysts). There are therefore many different ways to speed up or slow down changes in matter. The rate law uses algebraic expressions to compare the rates of various chemical reactions and, in some cases, to calculate their numerical value. The rate law provides a better understanding of the dynamic nature of equilibrium and can be used to express equilibrium constants mathematically.	
COMPULSORY CONCEPTS	**PREVIOUSLY ACQUIRED KNOWLEDGE**
Concentration	• *Describes the effect of variations in the quantity of solute or solvent on a solution's concentration* • *Determines the concentration of an aqueous solution (g/L, percentage, ppm, mol/L)*
Stoichiometry	• *Determines the quantities of reactants or products using stoichiometric calculations*
COMPULSORY CONCEPTS	**KNOWLEDGE TO BE ACQUIRED**
Factors that influence the reaction rate:	• Determines experimentally the factors that influence the reaction rate
- nature of the reactants	• Explains the effect of the nature of the reactants on the reaction rate
- concentration	• Explains the effect of the concentration of the reactants on the reaction rate
- surface area	• Explains the effect of the surface area of the reactants on the reaction rate
- temperature	• Explains the effect of the temperature of the reactants on the reaction rate
- catalysts	• Explains the effect of a catalyst on the reaction rate
Rate law	• Describes the relationship between the concentration of the reactants and the reaction rate using algebraic expressions • Determines the effect of a variation in the concentration of a reactant on the reaction rate, using the related algebraic expression

General concept: Chemical equilibrium

Dynamic equilibrium is a state found in many different chemical, physical and biological systems. The qualitative study of the state of equilibrium and the factors that influence it are required to understand many phenomena or applications. Le Châtelier's principle is used, among other things, to predict changes in systems after their conditions have been modified.

Whatever system is being considered, the interpretation and calculation of the equilibrium constant expression (water ionization constant, acidity and alkalinity constants, solubility product constant) can be used to deal with both the qualitative and quantitative aspects of chemical equilibrium. The use of first- and second-degree equations may be necessary.

The water ionization constant is used to understand the interdependency of the molar concentrations of hydronium and hydroxide ions. The pH of aqueous solutions can be calculated by determining either of these molar concentrations and using logarithmic functions. Scientific notation must be mastered.

COMPULSORY CONCEPTS	PREVIOUSLY ACQUIRED KNOWLEDGE
Types of bonds (ionic)	• *Defines an ionic bond as a bond resulting from the gain or loss of electrons* • *Draws a schematic representation of an ionic bond* • *Identifies molecules that have an ionic bond (e.g. NaCl, NH_4OH)* • *Associates an ionic bond with an electrolytic substance*
Strength of electrolytes	• *Qualitatively associates the strength of an electrolyte with its degree of dissociation*
Electrical conductivity	• *Describes the mechanism that allows aqueous solutions to conduct electricity (electrolytic dissolution of a solute, formation of mobile ions)*
Acid-base neutralization reaction	• *Gives examples of acid-base neutralization reactions (e.g. adding lime to neutralize the acidity of a lake)* • *Names the products formed during acid-base neutralization (salt and water)* • *Recognizes an acid-base neutralization from its equation*
Salts	• *Determines the molecular formula of the salt produced by the neutralization of a given acid and a given base*
pH scale	• *Describes the pH scale (acidity, alkalinity, neutrality, increasing and decreasing values)*
COMPULSORY CONCEPTS	**KNOWLEDGE TO BE ACQUIRED**
Factors that influence the state of equilibrium:	• Explains qualitatively the state of dynamic equilibrium
- concentration	• Explains the effect of a change in the concentration of a reactant or a product on a system's state of equilibrium
- temperature	• Explains the effect of a temperature change on a system's state of equilibrium
- pressure	• Explains the effect of a pressure change on a system's state of equilibrium
Le Châtelier's principle	• Predicts the direction of the shift in equilibrium of a system following a change in concentration, temperature or pressure • Predicts the effects of the shift in equilibrium of a system on the concentrations of reactants and products

Chemical equilibrium (cont.)	
COMPULSORY CONCEPTS	**KNOWLEDGE TO BE ACQUIRED**
Equilibrium constant:	
- water ionization constant	• Writes the water ionization constant as an algebraic expression • Calculates the molar concentration of hydronium and hydroxide ions, using the water ionization constant at 25°C
- acidity and alkalinity constants	• Writes as an algebraic expression the equilibrium constant for the dissociation of an acid or a base • Experimentally determines the acidity or alkalinity constant of a system • Associates the strength of acids and bases with the value of their acidity or alkalinity constant
- solubility product constant	• Writes as an algebraic expression the equilibrium constant for the dissociation of various substances in water • Calculates the solubility product constant of a substance • Explains the use of various substances using their solubility product constant (e.g. rapidly dissolving salts have a high constant)
Relationship between the pH and the molar concentration of hydronium and hydroxide ions	• Describes the relationship between the pH and the molar concentration of hydronium and hydroxide ions • Applies the relationship between the pH and the molar concentration of hydronium ions ($pH = -\log_{10} [H^+]$)

2. Techniques

The techniques presented here are grouped in two categories. Many of these techniques require the use of instruments or chemicals. Safety and the use of safety equipment must be a constant concern for all those using such techniques.

In the Laboratory	
TECHNIQUES	**KNOWLEDGE TO BE ACQUIRED**
Laboratory work	
- Safely using laboratory materials and equipment	• Uses laboratory materials and equipment safely (e.g. allows a hotplate to cool before touching it, uses beaker tongs) • Handles chemicals safely (e.g. uses a spatula and a pipette filler)
- Preparing solutions	• Prepares an aqueous solution of a specific concentration given a solid solute • Prepares an aqueous solution of a specific concentration given a concentrated aqueous solution
- Collecting samples	• Collects samples appropriately (e.g. sterilizes the container, uses a spatula, refrigerates the sample)
Measurement	
- Checking the reliability, accuracy and sensitivity of measuring instruments	• Takes the same measurement several times to check the reliability of the instrument used • Carries out the required operations to ensure the accuracy of a measuring instrument (e.g. cleans and calibrates a balance, dries a graduated cylinder) • Takes the sensitivity of a measuring instrument into account (e.g. uses a 25-mL graduated cylinder rather than a 100-mL one to measure 18 mL of water)
- Interpreting measurement results (significant figures, measurement errors)	• Determines the margin of error attributable to a measuring instrument (e.g. the error in a measurement made using a graduated cylinder is provided by the manufacturer or corresponds to half of the smallest division on the scale) • Estimates measurement errors associated with the user and the environment • Expresses a result with a number of significant figures that takes into account the errors related to the measure (e.g. a measurement between 10.3 and 10.4 cm, taken with a ruler graduated in millimetres, should be expressed as 10.35 cm or 103.5 mm) • Expresses the value of a measurement with its absolute or relative uncertainty (e.g. 24.1 ± 0.1 mL or 24.1 mL ± 0.4%)

B) CULTURAL REFERENCES

Cultural references make learning situations more meaningful. The following table presents some of the references related to this course. Learning situations may also draw on other cultural references.

<table>
<tr><th colspan="5">Cultural References</th></tr>
<tr><td>Technical objects, technological systems, processes and products</td><td colspan="4">Kinetics
– Combustion rate
– Fire protection methods
– Catalytic converters
– Catalysts and inhibitors
– Food additives
– Enzyme reactions
– Pharmacokinetics (action and elimination of medication)
– Biodegradable plastics
– Fertilizer dissolution rate
– Anti-corrosion surface treatments

Chemical equilibrium
– Household cleaning products
– Swimming pool maintenance products
– Haber process
– Fishkeeping
– Control of blood pH
– Control of gastric acidity
– Impact of human activities on biogeochemical cycles
– Biocides (e.g. pesticides, insecticides)
– Stratospheric ozone
– Physicochemical soil decontamination
– Water cycle
– Carbon cycle</td></tr>
<tr><th>Area</th><th>Scientists</th><th>Community Resources</th><th>Applications</th><th>Events</th></tr>
<tr><td>The Material World</td><td>James Clerk Maxwell
James Prescott Joule
Ludwig Boltzmann
Svante August Arrhenius
J.H. Van’t Hoff
Henry-Louis Le Châtelier
Fritz Haber
Wilhelm Ostwald
Alfred Nobel
Nicolas Leblanc
Ernest Solvay</td><td>Association francophone pour le savoir (ACFAS)
Conseil de développement du loisir scientifique (CDLS)
National Research Council of Canada (NRC)
Chemical Institute of Canada (CIC)
International Union of Pure and Applied Chemistry (IUPAC)</td><td></td><td>Science fairs
Nobel Prize in Chemistry</td></tr>
</table>

FAMILIES OF LEARNING SITUATIONS

The learning situations in this course, derived from the *Research* and *Expertise* families, involve kinetics and chemical equilibrium for gases in a closed system as well as aqueous and acid-base solutions. The paragraphs below give examples of tasks that can be assigned to adult learners in such learning situations.

One learning situation involving reaction rates may require that adult learners explain the role of enzymes in digestion. They can then carry out different experiments to validate their explanation.

In a learning situation addressing the factors that could influence the state of equilibrium of a system, adult learners can prepare a procedure for an experiment with the objective of discovering the effect of these factors on the direction of a reaction, carry out the experiment and write a complete report.

In another situation, the adult learner is required to study, understand and explain the factors to be considered in introducing a new species of fish in a balanced aquarium that is already home to a specimen. The adult learner can describe the characteristics of the environment, suggest actions to be taken that take chemical kinetics into consideration, and present the links that connect the external factors and their effects on the state of equilibrium, making sure to provide scientific justification in each case.

In the learning situation described on the following page, the main tasks help adult learners develop the first and third competencies. This situation therefore belongs to the *Research* family.

BROAD AREAS OF LEARNING

Learning situations are more meaningful for adult learners when their context is connected to the broad areas of learning. The broad areas of learning most readily applicable to the learning situations for the course CHE-5062-2 are *Health and Well-Being*, *Career Planning and Entrepreneurship, Environmental Awareness and Consumer Rights and Responsibilities*, and *Citizenship and Community Life*. The following example reflects the educational aim of the broad area of learning *Environmental Awareness and Consumer Rights and Responsibilities.*

Broad Areas of Learning
Health and Well-Being
Career Planning and Entrepreneurship
Environmental Awareness and Consumer Rights and Responsibilities
Media Literacy
Citizenship and Community Life

EXAMPLE OF A LEARNING SITUATION

MANUFACTURING AMMONIA? THAT'S EASY!

Your uncle works for a company that makes ammonia using the Haber process. Knowing that you are taking a chemistry course, he challenges you to explain the process for making ammonia, in terms of temperature and pressure. The only information he gives you is that hydrogen and nitrogen are the reactants. Taking into consideration the means available at your centre, he would also like you to produce a reaction with similar properties to illustrate your explanation.

To meet your uncle's challenge, you first have to determine the chemical equation for manufacturing ammonia on a large scale using the Haber process. You then need to develop an experimental procedure that will allow you to test the effects of temperature, pressure or the concentration of products or reactants on the state of equilibrium of a similar chemical reaction. Finally, you will explain the Haber process, presenting the temperature and pressure conditions, as well as the possibility of using a catalyst that promotes the creation of ammonia. You must choose and use a similar reaction to illustrate the effect of these factors.

The file must include:

- a summary research document on the Haber process where the chemical equation is stated correctly
- an experimental procedure and a laboratory report
- an explanation of the Haber process
- the presentation of a similar reversible reaction in which the influence of at least two of the following factors are illustrated: temperature, pressure, catalyst, concentration of products or reactants

END-OF-COURSE OUTCOMES

Learning situations are administered on the premise that the adult learner will become familiar with an investigative process involving the experimental method, the observation method or modelling. In chemistry, these learning situations foster the implementation of problem-solving skills, the use of knowledge and the production of messages.

Adult learners solving a problem related to the kinetics or state of equilibrium of a chemical system form a representation of the problem based on their reading and interpretation of scientific and technological messages. They develop a plan of action for one of their hypotheses, thus using their knowledge of reaction rates and the equilibrium constants, notably the factors that influence reaction rates and the state of equilibrium, Le Châtelier's principle and the relationship between the pH and molar concentration of hydronium and hydroxide ions. To do so, adult learners must write up an experiment protocol in which they select the required material, set down instructions with respect to the activities and determine the applicable safety rules. They implement a plan of action by carrying

out their planned laboratory activities. During these activities, they handle the materials and equipment properly, apply the appropriate safety rules and take measurements, taking into account the uncertainty associated with the instruments used and the experimental conditions. In a laboratory report, they present a rigorous analysis of the results and discuss them. Lastly, they write up the conclusions of the experiment, making connections with the initial problem. Their report mentions the sources of errors and their estimated values.

Adult learners who study a phenomenon or technological application involving chemical kinetics or chemical equilibrium formulate questions on the contextual aspects and point out the principles of chemistry involved. Using concepts, laws, theories or models, they explain the relationship between the pH and the molar concentration of hydronium and hydroxide ions, or how the modification of certain factors influences the reaction rate or the state of equilibrium. In this way, they illustrate the influence of certain factors on the kinetics of chemical reactions or on the state of equilibrium of a chemical system, graphically determine the reaction rate, or calculate the equilibrium constant, the molar concentration of substances or the pH of a solution. Lastly, adult learners demonstrate their understanding of the principles of chemistry by describing the effect of the variation of certain initial parameters and by applying their explanations to other phenomena or applications governed by the same principles.

EVALUATION CRITERIA FOR THE COMPETENCIES TARGETED BY THE COURSE

Evaluation Criteria for Competency 1	Evaluation Criteria for Competency 2	Evaluation Criteria for Competency 3
▪ Appropriate representation of the situation ▪ Development of a suitable plan of action ▪ Appropriate implementation of the plan of action ▪ Development of relevant explanations, solutions or conclusions	▪ Formulation of appropriate questions ▪ Appropriate use of knowledge in chemistry ▪ Suitable production of explanations	▪ Accurate interpretation of scientific or technological messages ▪ Appropriate production or transmission of scientific or technological messages

Appendixes

Appendix 1

Exploration and analytical strategies enable the adult learner to progress more effectively towards an answer or solution when using an investigative process.

Exploration Strategies
• Collecting as much scientific, technological and contextual information as possible to define a problem or predict patterns • Referring to similar problems that have already been solved • Anticipating the results of a process • Developing various scenarios • Exploring various possible solutions • Considering various points of view on scientific issues

Analytical Strategies
• Determining the constraints and important elements involved in solving a problem • Dividing a complex problem into simpler subproblems • Using different types of reasoning (e.g. inference, inductive and deductive reasoning, comparison, classification, prioritization) in order to process information • Reasoning by analogy in order to process information and adapt scientific and technological knowledge • Generalizing from particular cases that are structurally similar • Selecting relevant criteria that help determine where one stands on a scientific issue

Appendix 2

Investigative Processes	
Steps	**Examples**
Define the problem	Identify the relevant information. Find the related concepts. Use personal theoretical knowledge, theoretical knowledge drawn from documents, previous experiments, past experience or logic.
Formulate a hypothesis	Develop questions based on different facts. Make analogies or try to predict results. Establish causal relationships. Propose a model.
Test the hypothesis	Prepare and make observations, conduct an experiment or build a model to prove or disprove the initial hypothesis.
Draw conclusions	Express understanding of the facts. Develop an explanation or a new model or theory.
Communicate	Formulate an answer, solution, explanation, model or opinion.

Appendix 3

Scientific methods for testing a hypothesis

Modelling	
Modelling consists in constructing a concrete representation of an abstract situation that is difficult to observe or impossible to see. A model must help people understand a given reality, explain certain properties of what it attempts to represent, and help people predict new phenomena. The model can take different forms: a text, a drawing, a mathematical or chemical formula or equation, a software program or a scale model.	
Steps	**Examples**
1. Develop a model	- Identify the components and the relationships between them - Choose the method of representation
2. Build the model	- Make a scale model or a diagram - Develop a formula
3. Validate the model	- Identify possible contradictions and inconsistencies - Verify the validity of the elements - Make changes or go back to the preceding steps, if necessary

Observation Method	
The scientific observation method helps observers to interpret facts on the basis of predetermined criteria and generally accepted elements within a given field. In light of the information collected, observers gain a new understanding of the facts, which is inextricably linked to the context in which the observations were made. Based on the way they interpret and organize information, the observers reinterpret the world, taking into consideration their prior knowledge and the conceptual schemes that they apply to the facts observed.	
Steps	**Examples**
1. Plan the observation	- Determine the observation criteria - Prepare an observation checklist
2. Gather information	- Gather information, referring to the observation criteria
3. Interpret the information	- Organize the information in order to explain the phenomenon or the application - Make connections between the items of information gathered

Experimental Method	
The experimental method involves the development of an experimental procedure that includes the identification of a certain number of variables. The aim of the procedure is to identify and compare observable or quantifiable elements and check them against the initial hypotheses. Moving back and forth between the different stages of the experimental method allows adult learners to ask bold questions, to formulate new hypotheses, to adjust the experimental procedure and to take the limitations of the experiment into account.	
Steps	**Examples**
1. Plan an experiment	- Determine the possible variables - Determine the variable to be measured - Break the experiment down into steps
2. Conduct the experiment	- Prepare an apparatus for the experiment - Perform a set of tasks - Make observations or take measurements
3. Interpret the results	- Process the data collected - Establish relationships - Discuss possible errors

Appendix 4

Competency 1 Seeks answers or solutions to problems involving chemistry	Competency 2 Makes the most of his/her knowledge of chemistry	Competency 3 Communicates ideas relating to questions involving chemistry, using the languages associated with science and technology
Defines a problem • Determines the elements that seem relevant • Determines the relationships between the different elements • Reformulates the problem in terms of chemistry concepts • Formulates realistic hypotheses or possible solutions **Develops a plan of action** • Chooses a hypothesis or a solution • Determines the necessary resources • Plans the steps involved in implementing the plan of action **Carries out the plan of action** • Handles equipment and substances and carries out the planned activities • Gathers potentially useful data or observations • Adjusts the plan of action or its implementation, if necessary **Analyzes his/her results** • Processes the data gathered or his/her observations • Looks for significant patterns or relationships • Makes connections between his/her results and chemistry concepts • Judges the appropriateness of the answer or solution found • Formulates new hypotheses or solutions, if applicable	**Identifies the principles of chemistry underlying a phenomenon or application** • Considers the elements of the context • Identifies the principles of chemistry • Creates a representation of the phenomenon or application, based on chemistry concepts **Analyzes the principles of chemistry underlying a phenomenon or application** • Describes the principles of chemistry underlying a phenomenon or application qualitatively or quantitatively • Uses concepts, laws, theories or models to establish the relationships between chemistry principles underlying a phenomenon or application **Explains a phenomenon or an application from the standpoint of chemistry** • Develops an explanation based on concepts, laws and models of chemistry • Justifies his/her explanation using scientific and, if necessary, mathematical formalism • Adapts the proposed explanation to other contexts, if applicable	**Interprets scientific or technological messages** • Places the message in context • Makes sure the sources are reliable • Selects the elements needed to interpret the message • Grasps the precise meaning of words or statements • Establishes connections between concepts and their graphic or symbolic representations **Produces scientific or technological messages** • Structures his/her message • Uses scientific and technological vocabulary • Uses the symbolic and graphical languages associated with science and technology • Adheres to the established standards and conventions for the different languages • Demonstrates rigour and coherence • Respects intellectual property rights

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