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.

<table>
<tr><th colspan="2">The Material World</th></tr>
<tr><td colspan="2">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.</td></tr>
<tr><th>COMPULSORY CONCEPTS</th><th>KNOWLEDGE TO BE ACQUIRED</th></tr>
<tr><td>Reactivity</td><td>• 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)</td></tr>
<tr><td colspan="2">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).</td></tr>
<tr><th>COMPULSORY CONCEPTS</th><th>PREVIOUSLY ACQUIRED KNOWLEDGE</th></tr>
<tr><td>Compressible and incompressible fluids</td><td>• Distinguishes between compressible and incompressible fluids</td></tr>
<tr><td>Pressure</td><td>• 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</td></tr>
<tr><td>Avogadro's number</td><td>• Expresses a quantity of particles using Avogadro's number</td></tr>
<tr><td>Concept of the mole</td><td>• Defines the mole as the unit of measurement of the amount of a substance
• Expresses an amount of a substance in moles</td></tr>
</table>

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