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CHEMISTRY PROGRAM

SECONDARY V

JULY 1999

Québec

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Direction de la formation générale des adultes
Service de l'évaluation des apprentissages

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INTRODUCTION

1. Background

The Secondary V *Chemistry* program is intended for secondary-level adult education students in Québec. It comprises three 50-hour courses, equivalent to the *Chemistry 534* program offered in the youth sector.

According to the basic school regulation, this program is optional in the second cycle of secondary school and, as such, credits awarded for the three courses may be applied toward a *Secondary School Diploma* (SSD). Also, the three courses are equivalent to the *Chemistry 534* program, which is a prerequisite for admission to certain general and technical education programs at the college level.

1.1 Context in which the program was developed

In 1991, following the review of adult education science programs, the Direction générale de l'éducation des adultes set up an advisory committee whose mandate was to analyze the content of the new Secondary V chemistry and physics programs in the youth sector with a view to implementing them in the adult sector.

The committee determined that, although the content of the youth-sector programs was entirely relevant, these programs could not be implemented without changes because of certain organizational and andragogical constraints in adult education. It therefore recommended that the programs be rewritten in order to adapt the objectives and approach to the adult sector. In order to harmonize the programs in the two sectors, it was agreed that the content of the youth-sector program would be retained and that particular attention would be paid to the development of skills related to the experimental method.

In the winter of 1994, work on the new adult-sector chemistry program began. A first version was submitted to the school boards for consultation in April 1996. Teachers and non-teaching professionals from more than forty school boards participated in the project. This version of the program reflects their comments.

1.2 Relationship to other programs

1.2.1 Youth-sector programs

The related content of the Secondary V *Chemistry* program has been harmonized with that of the *Chemistry 534* program in the youth sector. The content of the youth-sector program has been divided into three courses: *Gases*; *Chemical Reactions 1: Energy and Chemical Dynamics*; and *Chemical Reactions 2: Equilibrium and Oxidation-Reduction*. Furthermore, elements of the youth-sector program*, The Tools and Methods of Science* (TMS 532), have been integrated into each course of this program.

1.2.2 Adult-sector programs

This program replaces the previous program, in particular the *Chemistry 252* and *253* courses and the module of the *Chemistry 241* course covering gases.

1.2.3 Prerequisites

The three courses in the adult education Secondary IV *Physical Sciences* program or *Physical Sciences 436* in the youth sector or their equivalent are prerequisites to the Secondary V *Chemistry* program.

In addition, since this is a Secondary V program, students must have successfully completed the Secondary IV language of instruction and general mathematics courses.

1.3 Development of skills related to the experimental method

The need to emphasize experimentation as a means of assimilating knowledge and as an integral part of the curriculum leading to postsecondary education in the sciences led to the development of a Secondary V chemistry program that focuses largely on the experimental method and the development of related skills. These skills should be evaluated in the same way as related content at the end of the courses.

Because of the particular nature of adult education and its organizational constraints, students are introduced to the experimental method in the Secondary V science courses. Such an introduction, however, requires more time than is available in the 50-hour duration of one course. This is why the skills required to perform the experimental method are introduced step by step as the student moves through the three courses. While terminal objectives have been set for each course, the level of competency targeted by the program can be attained only after all three courses have been successfully completed.

The first course familiarizes students with the elements of an experimental procedure, with laboratory work and with the presentation and analysis of experimental data.

The second course builds on this knowledge. Students will be called upon to write up an experimental procedure, follow an experimental procedure and write different parts of a laboratory report.

The third course focuses on integration. At the end of this course, the students should be able to write an experimental procedure, carry out the related experiments and write a laboratory report.

While strictly adhering to the learning objectives related to the experimental method, the authors have attempted to be realistic with respect to the means available to adult education centres and to the specific nature of individualized learning. Although the development of skills related to the experimental method is absolutely essential, such development can be arrived at through relatively simple methods and in a manner accessible to the greatest number of centres possible.

1.4 The HTS (history-technology-society) perspective

As a follow-up to the Secondary IV *Physical Sciences* program, this chemistry program is designed to help students establish relationships between the theoretical concepts presented and the context in which these concepts were discovered, the influence that science and technology have had on each other throughout the years and the consequences that scientific discoveries and technological applications have had for society and the environment. This is what the authors have called the HTS perspective.

In the Secondary IV *Physical Sciences* program, this orientation was adopted for the formulation of objectives and as the approach for learning science. In this chemistry program, the objectives related to the HTS perspective complement the other objectives, reflecting the fact that science does not operate in a vacuum and, while it contributes to the development of society, its progress is affected by the political, social and technological realities of the time.

Each of the three courses has a terminal objective for each section: history, technology, and society and the environment.

2. Structure of the program and learning content

2.1 Relationship between the Courses

The program comprises three courses, which must be studied consecutively. This sequence is necessary both because of the logical relationships between the elements of content and because of the progressive acquisition of skills related to the experimental method.

2.1.1 Course 1: Gases

In this course, by learning about the scientific method, students will gain a better understanding of the behaviour of gases, as well as be able to establish links with related technical phenomena, social changes and environmental consequences.

This course covers:

- the properties of the states of matter and the general behaviour of substances undergoing phase changes;
- the presence of gases in nature and their use by humans;
- the laws governing the behaviour of gases;
- the ideal gas law and Dalton's law of partial pressures;
- the energy balance of a chemical reaction occurring in a gaseous state.

2.1.2 Course 2: Chemical Reactions 1: Energy and Chemical Dynamics

In this course, by learning about the scientific method, students will gain a better understanding of chemical dynamics and energy transfers involved in chemical reactions, as well as be able to establish links with related technical phenomena, social changes and environmental consequences.

This course covers:

- energy transfers related to phase changes, mixtures of substances at different temperatures, solutions or chemical reactions;
- the rate of chemical reactions and the factors on which it depends;
- the collision theory and the relationship between energy, the rate of a chemical reaction and the factors on which such a rate depends.

2.1.3 Course 3: Chemical Reactions 2: Equilibrium and Oxidation-Reduction

In this course, by learning about the scientific method, students will gain a better understanding of chemical equilibrium and oxidation-reduction, as well as be able to establish links with related technical phenomena, social changes and environmental consequences.

This course covers:

- qualitative and quantitative analysis of chemical equilibrium;
- oxidation-reduction and the operation of electrochemical cells.

2.2 Learning objectives

Each course is described by a general objective and a series of terminal and intermediate objectives. A table at the beginning of each course sets out the general and terminal objectives for the course.

2.2.1 General objectives

The general objective is a statement of the intention of the course. It specifies the relationships to be established among the three categories of terminal objectives.

2.2.2 Terminal objectives

The terminal objectives have been divided into three categories: related content, the experimental method and the HTS (history-technology-society) perspective. The order in which these objectives are presented in no way indicates their relative importance or a fixed learning sequence.

All of the terminal objectives are prescriptive. They are formulated as learning objectives.

The terminal objectives indicate the significance to be given to learning and the target to be attained through the intermediate objectives, which describe more precisely the scope of the terminal objectives.

As a reminder of the continuity between the terminal objectives related to the experimental method, the objectives are numbered as follows: A1, A2, A3, A4 in the first course, B1, B2, B3, B4, B5 in the second course and C1, C2, C3, C4 in the third course. Objectives with the same number, for example, A1, B1 and C1, generally deal with the same aspect of the experimental method.

2.2.3 Intermediate objectives

All of the terminal objectives associated with related content are accompanied by a list of intermediate objectives. Some of these intermediate objectives are also related to a terminal objective associated with the experimental method or the HTS perspective. In such cases the letters EX (experimental method), H (history), T (technology) or S (society) appear to the left of the objective.

In addition to being related to certain intermediate objectives associated with related content (identified by the letters EX), the terminal objectives associated with the experimental method are accompanied by their own intermediate objectives. The relationships between these two categories of intermediate objectives and the terminal objectives associated with the experimental method are presented at the end of each course after the description of each terminal objective associated with related content.

None of the terminal objectives associated with the HTS perspective are accompanied by their own intermediate objectives. They are all described by intermediate objectives associated with related content. They are identified by the letter H, T or S to the left of the objective. A complete list of these objectives can be found at the end of each course.

All the intermediate objectives are prescriptive.

2.2.4 Additional information

Additional information is provided for most of the intermediate objectives associated with related content. This information is not prescriptive, limiting, or exhaustive. It is intended to help the eventual users of the program and includes details on content, limits, possible paths of exploration, and so on.

3. Evaluation of learning

The evaluation of learning aims, on the one hand, at helping students learn and, on the other, at providing the data necessary for the certification of studies. In general, information on the evaluation of learning and the certification of studies can be found in other official documents, such as the definition of the domain and the *Administrative Manual for the Certification of Studies in General Education for Adults and in Vocational Education*. Refer to these documents for further information on evaluation and certification.

Formative evaluation is a part of teaching and learning. Its purpose is to support and guide decisions concerning the choice of learning situations, instructional material and the type of pedagogical intervention. It is the responsibility of teachers and is governed by policies established by the school boards. If necessary, the Ministère may suggest conceptual frameworks or examples of formative evaluation instruments.

For purposes of summative evaluation, the Ministère provides a *Definition of the Domain* for each course in a program and, if applicable, uniform or complementary examinations. Following summative evaluation, a judgment is made on the student's attainment of the learning objectives of a course, after which learning may be certified.

CONTENT OF THE PROGRAM — COURSE BY COURSE

Course 1

GASES

By learning about the scientific method, students will gain a better understanding of the behaviour of gases, as well as be able to establish links with related technical phenomena, social changes and environmental consequences.

GENERAL OBJECTIVE

By learning about the scientific method, students will gain a better understanding of the behaviour of gases, as well as be able to establish links with related technical phenomena, social changes and environmental consequences.

TERMINAL OBJECTIVES

Related Content

1. To explain the properties of the three main states of matter and the general behaviour of substances undergoing phase changes.
2. To describe the presence of gases in nature and their use by humans.
3. To explain the relationship between the volume of a gas and the pressure it exerts (Boyle's law).
4. To explain the relationship between the volume of a gas and its temperature (Charles's law).
5. To explain the relationship between the number of moles of a gas and its volume.
6. To apply the ideal gas law and Dalton's law of partial pressures.
7. To explain the energy balance of a chemical reaction occurring in a gaseous state.

EX Experimental Method

A1 To become familiar with the scientific method.

A2 To become familiar with writing an experimental procedure.

A3 To become familiar with carrying out an experiment.

A4 To become familiar with the scientific analysis of experimental data.

HTS Perspective

H To illustrate the relationships between the study of gases and the evolution of chemistry, using examples from history.

T To illustrate the role of gases in technical applications, using examples.

S To illustrate environmental consequences and social changes related to the production and use of gases, using examples.

TERMINAL OBJECTIVE 1

To explain the properties of the three main states of matter and the general behaviour of substances undergoing phase changes.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
1.1	EX	To compare the observable properties of the solid, liquid and gaseous states of matter.	Compressibility, fluidity, expandability, shape
1.2		To explain the properties of the three main states of matter, using a model.	Order, disorder, agitation, independence of molecules, cohesive force
1.3		To describe molecular motion in the three states of matter.	Translation, rotation, vibration
1.4		To explain the phenomena of diffusion and Brownian motion, using a model.	
1.5		To compare the rate of diffusion of a substance in a liquid and in a gas, as well as in two different gases.	
1.6		To describe phase changes, using examples and a model describing the three states of matter.	Triangle of phase changes
1.7		To define "melting point" and "boiling point."	Melting and boiling curves (temperature vs. time), Celsius scale
1.8		To compare the melting and boiling points of various substances in relation to their states and to a given temperature.	
1.9	T	To describe a technical process that relies on a phase change, using examples.	Refrigerator, air conditioner, heat pump, etc.
1.10		To give an example of a state of matter other than solid, liquid or gas.	Plasma, liquid crystal, amorphous solid

TERMINAL OBJECTIVE 2

To describe the presence of gases in nature and their use by humans.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
2.1		To describe the origin of gases present in nature, using examples.	Components of air, petroleum gas, volcanic gases, etc.
2.2		To describe the role of gases in the ecosystem.	Atmosphere; respiration; organic decomposition; volcanoes; photosynthesis; protection from the sun; oxygen, water, carbon and nitrogen cycles; etc.
2.3	T	To give examples of technical applications based on the use of air or other gaseous substances.	Dirigible balloon (also known as blimp or airship), hot air balloon, test balloon, sailboat, heating, electric bulb, preservation (food, works of art, etc.), anaesthesia, respiratory therapy, engines, etc.
2.4	S	To describe the consequences of the emission of gaseous pollutants on the environment, using examples.	Nitrogen, sulphur and carbon oxides; ozone, etc.
2.5	S	To describe some of the health effects of absorbing toxic gases, using examples.	Chlorine, carbon monoxide, sulphur oxides, solvent vapours, ammonia, etc.

TERMINAL OBJECTIVE 3

To explain the relationship between the volume of a gas and the pressure it exerts (Boyle's law).

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
3.1		To describe the consequences of a change in pressure on the volume of a gas kept at a constant temperature, using the model of gases.	Qualitative relationship
3.2		To associate the definition of pressure with its units of measurement.	Units of measurement: Pa, N/m^2, atm, lb/sq. in., bar
3.3		To state the cause of atmospheric pressure.	Weight of an atmospheric column
3.4		To explain the pressure exerted by a gas on the walls of its container, using the model of gases.	Molecular collisions, kinetic energy
3.5		To compare the behaviour of a gas in a container with flexible walls with that of a gas in a container with rigid walls.	Flexible walls (variable volume): equilibrium of pressure Rigid walls (constant volume): gas under pressure, vacuum pumping (balloon, piston, tire, pressurized tank, etc.)
3.6		To describe the consequences of a change in volume on the pressure exerted by a gas kept at a constant temperature, using the model of gases.	Qualitative relationship
3.7	EX	To deduce Boyle's law from a graphic analysis of experimental data.	PV = constant where T and n do not vary
3.8	T	To describe the use of a difference in pressure in a technical application.	Aerosol cans, draft beer, the use of meteorological phenomena (wind, ascending and descending currents), jet engines, rockets, dynamite, etc.
3.9	T	To describe the operation and use of a barometer and a manometer.	
3.10		To solve problems related to pressure and Boyle's law.	$P_1V_1 = P_2V_2$ Atmospheric pressure, deep-sea diving, tire pressure, blood pressure, etc.

TERMINAL OBJECTIVE 4

To explain the relationship between the volume of a gas and its temperature (Charles's law).

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
4.1	EX	To determine, through experimentation, the relationship between the volume and temperature of a gas kept at a constant pressure.	
4.2		To define "absolute zero."	Extrapolation to $V = 0$ (volume nil) of the curve of V as a function of T
4.3		To state Charles's law.	$\frac{V}{T(K)} = \text{constant}$ where P and n do not vary
4.4		To define temperature as a measure of the kinetic energy of molecules.	
4.5		To describe the consequences of a change in temperature on the pressure or volume of a gas, using the model of gases.	Variable volume and constant volume
4.6		To compare the Kelvin, Celsius and Fahrenheit scales.	
4.7	H	To state historical facts related to the development and use of the different temperature scales.	The work of Fahrenheit, Celsius and Kelvin; Canada's adoption of the International System of Units (SI)
4.8		To solve problems related to Charles's law.	$\frac{V_1}{T_1} = \frac{V_2}{T_2}$ conversions (°C ↔ K)

TERMINAL OBJECTIVE 5

To explain the relationship between the number of moles of a gas and its volume.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
5.1	EX	To deduce the relationship between the number of moles of a gas and the volume it occupies, on the basis of a graphic analysis of experimental data.	Graphic analysis, deduction of V/n = constant
5.2		To describe the consequences of a change in the number of moles on the volume of a gas, using the model of gases.	
5.3	EX	To determine, through experimentation, the nature of the gases produced by electrolysis, as well as the ratio between the volumes of gases obtained.	
5.4		To explain a chemical reaction in light of Avogadro's principle.	Atomic theory, molecules, rearrangement of atoms (reaction)
5.5		To define the molar volume and the density of a gas.	
5.6	T	To describe technical applications based on differences in density between two points in the air or between two different gaseous media, using examples.	Hot air balloon, dirigible balloon (also known as blimp or airship), CO_2 fire extinguisher, ozone, etc.
5.7	H	To illustrate the progress made in chemistry thanks to the work of Avogadro, using examples.	Historical perspective
5.8		To solve problems related to the relationship between the number of moles of a gas and its volume.	$\frac{V_1}{n_1} = \frac{V_2}{n_2}$ Molar volume, density, Avogadro's number, stoichiometric calculations, balanced equations, etc.

TERMINAL OBJECTIVE 6

To apply the ideal gas law and Dalton's law of partial pressures.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
6.1		To determine the equation of the ideal gas law.	$PV = nRT$
6.2		To demonstrate that the ideal gas law includes Boyle's law and Charles's law.	
6.3		To define standard temperature and pressure conditions (STP).	0 ^{o}C and 101.3 kPa
6.4		To distinguish an ideal gas from a real gas.	Limits of application of the ideal gas law
6.5	EX	To determine the partial pressure exerted by each component of a gas mixture, on the basis of experimental results.	
6.6		To state Dalton's law of partial pressures.	$P_{total} = P_1 + P_2 + P_3 \ldots$
6.7	H	To associate discoveries resulting from the study of gases to progress made in pure or applied chemistry.	Ideal gas law Work of Dalton, Charles, Gay-Lussac, Boyle, etc.
6.8	S	To associate social changes and environmental consequences with the technological use of gases.	Transportation, food, medicine, etc.
6.9		To solve problems related to the ideal gas law and the law of partial pressures.	$PV = nRT$, $P_{total} = P_1 + P_2 + P_3 \ldots$ stoichiometry, etc.

TERMINAL OBJECTIVE 7

To explain the energy balance of a chemical reaction occurring in a gaseous state.

	INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
7.1	To distinguish monatomic, diatomic and polyatomic gases.	
7.2	To explain the formation of chemical bonds from the point of view of energy stability.	Stability of noble gases, electronic structure, types of bonds
7.3	To describe the formation of molecules of diatomic and polyatomic gases.	Pure covalent and polar bonds; two-dimensional representation of molecules (H_2, Cl_2, CO_2, CH_4, NH_3, etc.)
7.4	To associate the stability of a bond with bond and dissociation energy.	Table of bond energies (kJ/mole)
7.5	To determine the energy balance of a chemical reaction occurring in a gaseous state.	Heat of formation, heat of reaction
7.6	To solve problems related to the formation of molecules or the heat of reaction.	Reactions in the gaseous state

EXPERIMENTAL METHOD

TERMINAL OBJECTIVES

INTERMEDIATE OBJECTIVES

A1 To become familiar with the scientific method.

A1.1 To learn about the experimental method by observing phenomena.

A1.2 To use experimentation to establish a simple relationship between two parameters.

A2 To become familiar with writing an experimental procedure.

A2.1 To distinguish between the object of the experiment and the parameters measured.

A2.2 To understand the need to explore one relationship at a time.

A2.3 To identify the constant parameters, the independent variable and the dependent variable.

A3 To become familiar with carrying out an experiment.

A3.1 To follow a simple experimental procedure.

A3.2 To observe a phenomenon in an experiment.

A3.3 To handle equipment in a simple experiment.

A3.4 To become familiar with measurement and experimental uncertainty.

A3.5 To apply the appropriate safety rules.

A4 To become familiar with the scientific analysis of experimental data.

A4.1 To present experimental data in a double-entry table or in a graph.

A4.2 To process experimental data.

A4.3 To become familiar with the use of significant figures.

A4.4 To distinguish between experimental error and uncertainty.

A4.5 To interpret a graph.

A4.6 To deduce a mathematical relationship from experimental data.

RELATIONSHIPS BETWEEN THE OBJECTIVES ASSOCIATED WITH RELATED CONTENT AND WITH THE EXPERIMENTAL METHOD

RELATED CONTENT		EXPERIMENTAL METHOD			
1.1	To compare the observable properties of the solid, liquid and gaseous states of matter.	A1		A3	A4
3.7	To deduce Boyle's law from a graphic analysis of experimental data.	A1	A2		A4
4.1	To determine, through experimentation, the relationship between the volume and temperature of a gas kept at a constant pressure.	A1	A2	A3	A4
5.1	To deduce the relationship between the number of moles of a gas and the volume it occupies, on the basis of a graphic analysis of experimental data.	A1	A2		A4
5.3	To determine, through experimintation, the nature of the gases produced by electrolysis, as well as the ratio between the volumes of gases obtained.	A1	A2	A3	A4
6.5	To determine the partial pressure exerted by each component of a gas mixture, on the basis of experimental results.	A1	A2		A4

HISTORY-TECHNOLOGY-SOCIETY PERSPECTIVE

TERMINAL OBJECTIVES

INTERMEDIATE OBJECTIVES

H To illustrate the relationships between the study of gases and the evolution of chemistry, using examples from history.

4.7 To state historical facts related to the development and use of the different temperature scales.

5.7 To illustrate the progress made in chemistry thanks to the work of Avogadro, using examples.

6.7 To associate discoveries resulting from the study of gases to progress made in pure or applied chemistry.

T To illustrate the role of gases in technical applications, using examples.

1.9 To describe a technical process that relies on a phase change, using examples.

2.3 To give examples of technical applications based on the use of air or other gaseous substances.

3.8 To describe the use of a difference in pressure in a technical application.

3.9 To describe the operation and use of a barometer and a manometer.

5.6 To describe technical applications based on differences in density between two points in the air or between two different gaseous media, using examples.

S To illustrate environmental consequences and social changes related to the production and use of gases, using examples.

2.4 To describe the consequences of the emission of gaseous pollutants on the environment, using examples.

2.5 To describe some of the health effects of absorbing toxic gases, using examples.

6.8 To associate social changes and environmental consequences with the technological use of gases.

Course 2

CHEMICAL REACTIONS 1: ENERGY AND CHEMICAL DYNAMICS

By learning about the scientific method, students will gain a better understanding of chemical dynamics and energy transfers involved in chemical reactions, as well as be able to establish links with related technical phenomena, social changes and environmental consequences.

GENERAL OBJECTIVE

By learning about the scientific method, students will gain a better understanding of chemical dynamics and energy transfers involved in chemical reactions, as well as be able to establish links with related technical phenomena, social changes and environmental consequences.

TERMINAL OBJECTIVES

Related Content

1. To analyze the energy transfers that occur in phase changes and mixtures of substances at different temperatures.
2. To analyze the energy transfers that occur during dissolutions.
3. To explain the energy transfers that occur in chemical reactions.
4. To analyze the rate of a chemical reaction and the factors on which it depends.
5. To explain the relationship between energy, reaction rate and the factors on which such a rate depends, using the collision theory.

EX Experimental Method

- B1 To apply the experimental method in simple cases.
- B2 To write up a simple experimental procedure.
- B3 To carry out a simple experiment.
- B4 To analyze experimental data.
- B5 To become familiar with the writing of a laboratory report.

HTS Perspective

- H To illustrate the relationships between the study of energy transfers and chemical dynamics, and the evolution of chemistry, using examples from history.
- T To illustrate the use of energy transfers and chemical dynamics in technical applications, using examples.
- S To illustrate environmental consequences and social changes related to the energy produced by chemical reactions, using examples.

TERMINAL OBJECTIVE 1

To analyze the energy transfers that occur in phase changes and mixtures of substances at different temperatures.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
1.1		To recognize the different forms of energy acting in the phenomena observed in their environment.	Heat, light, chemical energy, kinetic energy, potential energy, nuclear energy, etc.
1.2		To associate a macroscopic phenomenon with corresponding changes occurring at the atomic or molecular level.	Concept of a model, chemical reactions, physical changes, heat transfer
1.3		To describe a heat transfer in terms of kinetic energy and the variation in temperature.	Heat, temperature, principle of conservation of energy
1.4	EX	To classify physical and chemical phenomena according to whether they represent endothermic or exothermic reactions, on the basis of observations.	Solutions, dissociations, chemical reactions, phase changes
1.5	EX	To determine, through experimentation, the factors that influence the final temperature of a mixture.	Quantity of substances, initial temperature, nature of substances, etc.
1.6		To establish relationships between the definition of specific heat capacity and its units of measurement.	$Q = mc\Delta T$ Units: J/g°C, cal/g°C
1.7		To describe the energy transfers produced during phase changes of a pure substance.	Temperature curve as a function of time (supply of constant energy)
1.8	H	To describe briefly how Joule established a relationship between heat and mechanical energy.	
1.9	T	To give examples of energy conversions involving heat.	Steam engine, combustion engine, thermal generating station, production of fire by rubbing stones, matches, role of lubricants, etc.
1.10		To solve problems related to energy transfers that occur during phase changes and mixtures of substances at different temperatures.	$m_1c_1\Delta T_1 = m_2c_2\Delta T_2$ Phase changes, principle of conservation of energy, etc.

TERMINAL OBJECTIVE 2

To analyze the energy transfers that occur during dissolutions.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
2.1		To describe the phenomenon of the dissolution of a solute in a solvent.	Broken bonds, dispersion, electrolytes and non-electrolytes
2.2		To compare endothermic and exothermic dissolutions.	Energy transfer, variation in observed temperature
2.3		To explain the energy balance of a dissolution.	Solute-solute, solvent-solvent and solute-solvent interactions
2.4		To interpret chemical equations for dissolutions which include the *energy* term.	
2.5		To establish relationships between molar heat of solution and its units of measurement.	Unit: kJ/mol Conventional signs
2.6	EX	To determine, through experimentation, the molar heat of solution of a substance.	
2.7		To describe applications of solutions in everyday activities.	Cleaning products, paint, solvents, glue, instant coffee, sugar in coffee, etc.
2.8		To solve problems related to the molar heat of solution.	Meaning of the variation in temperature, conventional signs, etc.

TERMINAL OBJECTIVE 3

To explain the energy transfers that occur in chemical reactions.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
3.1		To determine the energy balance of a chemical reaction.	Bond energy, two-dimensional geometric model, balances
3.2		To associate the heat of a reaction with a variation in enthalpy.	Enthalpy, change in enthalpy (ΔH)
3.3		To compare enthalpy diagrams of endothermic and exothermic reactions.	Energy absorbed, energy released, ΔH
3.4		To recognize oxidation reactions in their environment.	Synthesis: breathing, corrosion, energy exchanges in cells, etc. Combustion: burning of propane and wood, fireworks, etc.
3.5		To write the combustion equation for several hydrocarbons.	Reactants, products, ΔH
3.6	EX	To inductively discover Hess's law through an experiment.	Additivity of reaction energies
3.7	H	To associate discoveries resulting from the study of energy transfers to progress made in pure or applied chemistry.	
3.8	T	To describe a technical application of fossil fuels to produce heat.	Heating systems, industrial boilers, etc.
3.9	S	To illustrate the consequences of the use of fossil fuels on quality of life and the environment, using examples.	Comfort, development of cities, industrial production, pollution, anti-pollution measures, etc.
3.10	S	To describe the consequences of the incomplete combustion of hydrocarbons.	By-products (carbon monoxide, soot, etc.), efficiency
3.11		To solve problems related to energy transfers that occur in chemical reactions.	Heat of reaction, energy diagrams, Hess's law

TERMINAL OBJECTIVE 4

To analyze the rate of a chemical reaction and the factors on which it depends.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
4.1		To define "reaction rate."	Disappearance of reactants, appearance of products
4.2		To interpret graphs illustrating a chemical reaction over time.	Concentration of reactants and products as a function of time, rate as a function of time
4.3	EX	To determine, through experimentation, the influence of the surface area, the nature of the reactants and their concentration on the rate of a reaction.	Nature of reactants, concentration, surface area
4.4		To describe the influence of the nature of the reactants on the rate of a reaction.	Number of broken bonds
4.5		To describe the influence of concentration on the rate of a reaction.	
4.6		To describe the influence of pressure on the rate of a reaction.	Gaseous state
4.7		To compare the rates of different reactions.	Nature and concentration of reactants
4.8		To describe the influence of the surface area on the rate of a reaction.	Combustion of wood, wood shavings and dust; corrosion; treatment of surfaces; etc.
4.9		To describe the influence of temperature on the rate of a reaction.	Freezing of food, etc.
4.10		To describe the effect of a catalyst on the rate of a chemical reaction.	Catalysis, catalyst, acceleration of reactions
4.11	T	To give examples of the use of catalysts and the related advantages.	Enzymes, catalyst container, etc.
4.12		To solve problems related to the rate of a reaction and the factors on which it depends.	

TERMINAL OBJECTIVE 5

To explain the relationship between energy, reaction rate and the factors on which such a rate depends, using collision theory.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
5.1		To explain the rate of a reaction using the collision theory.	Effective and ineffective collisions, proper orientation, etc.
5.2		To interpret the energy diagram of a reaction.	Activation energy, activated complex, ΔH
5.3		To interpret the distribution curve of the kinetic energy of molecules.	Activation energy, temperature
5.4		To illustrate the effect of the factors that influence the rate of a reaction, using the collision theory and energy diagrams.	Concentration, pressure, nature of reactants, surface area, temperature, catalyst
5.5		To compare the energy diagrams of various reactions.	Spontaneous, slow, fast, reversible reactions
5.6		To associate the relative abundance of natural substances with their ability to react spontaneously.	Composition of air, etc.
5.7		To describe the influence of the reaction mechanism on the rate of a reaction, using the collision theory and energy diagrams.	Steps, intermediate forms, rate-determining step, action of a catalyst
5.8	H	To associate discoveries resulting from the study of chemical dynamics with progress made in pure or applied chemistry.	
5.9	T	To describe technical applications of chemical dynamics, using examples.	
5.10	S	To illustrate the consequences of the introduction of a chemical into the environment, using examples.	Stable and unstable pollutants, plastics, nitrogen oxides (NO_x), acid precipitation, etc.
5.11		To solve problems related to the collision theory and the relationship between energy, reaction rate and the factors on which such a rate depends.	

EXPERIMENTAL METHOD

TERMINAL OBJECTIVES

INTERMEDIATE OBJECTIVES

B1 To apply the experimental method in simple cases.

B1.1 To use experimentation as a means of exploration.

B1.2 To use experimentation to discover a law by inductive reasoning.

B2 To write up a simple experimental procedure.

B2.1 To establish the steps in a procedure.

B2.2 To determine the independent variable, the dependent variable and the constant parameters.

B2.3 To become familiar with the writing of procedures.

B3 To carry out a simple experiment.

B3.1 To develop skill in handling experimental equipment.

B3.2 To gather experimental data taking into account experimental uncertainty in writing the numerical data.

B3.3 To apply the appropriate safety rules.

B4 To analyze experimental data.

B4.1 To identify the causes of experimental errors.

B4.2 To take signficant figures into account when processing data.

B4.3 To interpret experimental data with precision.

B5 To become familiar with the writing of a laboratory report.

B5.1 To be familiar with the role of a laboratory report.

B5.2 To be familiar with the parts of a laboratory report.

B5.3 To discuss an experiment and write a conclusion.

RELATIONSHIPS BETWEEN THE OBJECTIVES ASSOCIATED WITH RELATED CONTENT AND WITH THE EXPERIMENTAL METHOD

RELATED CONTENT		EXPERIMENTAL METHOD				
1.4	To classify physical and chemical phenomena according to whether they represent endothermic or exothermic reactions, on the basis of observations.	B1		B3		
1.5	To determine, through experimentation, the factors that influence the final temperature of a mixture.	B1	B2	B3	B4	
2.6	To determine, through experimentation, the molar heat of solution of a substance.	B1		B3	B4	B5
3.6	To deduce Hess's law by means of an experiment.	B1	B2	B3	B4	B5
4.3	To determine, through experimentation, the influence of the surface area, the nature of the reactants and their concentration on the rate of a reaction.	B1	B2	B3	B4	B5

HISTORY-TECHNOLOGY-SOCIETY PERSPECTIVE

TERMINAL OBJECTIVES

INTERMEDIATE OBJECTIVES

H To illustrate the relationships between the study of energy transfers and chemical dynamics, and the evolution of chemistry, using examples from history.

1.8 To describe briefly how Joule established a relationship between heat and mechanical energy.

3.7 To associate discoveries resulting from the study of energy transfers to progress made in pure or applied chemistry.

5.8 To associate discoveries resulting from the study of chemical dynamics with progress made in pure or applied chemistry.

T To illustrate the use of energy transfers and chemical dynamics in technical applications, using examples.

1.9 To give examples of energy conversions involving heat.

3.8 To describe a technical application of fossil fuels to produce heat.

4.11 To give examples of the use of catalysts and the related advantages.

5.9 To describe technical applications of chemical dynamics, using examples.

S To illustrate environmental consequences and social changes related to the energy produced by chemical reactions, using examples.

3.9 To illustrate the consequences of the use of fossil fuels on quality of life and the environment, using examples.

3.10 To describe the consequences of the incomplete combustion of hydrocarbons.

5.10 To illustrate the consequences of the introduction of a chemical into the environment, using examples.

Course 3

CHEMICAL REACTIONS 2: EQUILIBRIUM AND OXIDATION-REDUCTION

By learning about the scientific method, students will gain a better understanding of chemical equilibrium and oxidation-reduction, as well as be able to establish links with related technical phenomena, social changes and environmental consequences.

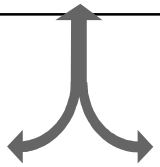
GENERAL OBJECTIVE

By learning about the scientific method, students will gain a better understanding of chemical equilibrium and oxidation-reduction, as well as be able to establish links with related technical phenomena, social changes and environmental consequences.

TERMINAL OBJECTIVES

Related Content

1. To analyze qualitatively the state of equilibrium of a system.
2. To analyze quantitatively the dynamic aspect of chemical equilibrium.
3. To explain the operation of electrochemical cells.



EX Experimental Method

C1 To apply the experimental method.

C2 To write up an experimental procedure.

C3 To carry out an experiment.

C4 To write a laboratory report.

HTS Perspective

H To illustrate the relationships between the study of chemical equilibrium and oxidation-reduction, and the evolution of chemistry, using examples from history.

T To illustrate the use of chemical equilibrium and electrochemistry in technical applications, using examples.

S To illustrate environmental consequences and social changes related to the use of chemical equilibrium and oxidation-reduction, using examples.

TERMINAL OBJECTIVE 1

To analyze qualitatively the state of equilibrium of a system.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
1.1		To state the three conditions that characterize a system in a state of equilibrium.	Constant macroscopic properties, coexistence of products and reactants, closed system
1.2		To describe a vapour-liquid equilibrium and an equilibrium involving solutions.	
1.3	EX	To verify, through experimentation, whether or not a system is in equilibrium.	
1.4		To associate equilibrium with the reversibility of reactions.	Forward and reverse reactions, symbol of equilibrium
1.5		To interpret curves illustrating forward and reverse reactions over time.	Equal rates in a state of equilibrium
1.6	EX	To determine, through experimentation, how increasing the concentration of a reactant affects a system in equilibrium.	Disturbance, restoration of equilibrium
1.7		To describe the influence of concentration, pressure and temperature on a system in equilibrium, using examples.	Disturbance, restoration of equilibrium
1.8		To describe the effect of adding a catalyst on the equilibrium of a reaction.	Overall effect nil
1.9		To predict the consequences of disturbing the state of equilibrium of a system, using Le Châtelier's principle.	Reaction favoured, restoration of equilibrium
1.10	S	To describe social changes and environmental consequences related to a disturbance of the equilibrium of a natural cycle, using examples.	Pollution, natural catastrophes, etc.
1.11		To solve qualitative problems related to the state of equilibrium of a system.	

TERMINAL OBJECTIVE 2

To analyze quantitatively the dynamic aspect of chemical equilibrium.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
2.1		To compare the dissociation of a strong acid with that of a weak acid.	Complete ionization versus equilibrium
2.2		To use the mathematical definition of pH.	$pH = - \log [H_3O^+]$
2.3	EX	To establish, through experimentation, a mathematical relation to characterize the equilibrium of the ionization of an acid.	Ionization constant (K_a)
2.4	EX	To determine, through experimentation, the relative strength of two or more acids.	HCl, CH_3COOH, etc.
2.5		To write the ionization equations for polyacids.	H_3PO_4, H_2SO_4, etc.
2.6		To write the expression of the equilibrium constant (K_c) and of the constants K_a, K_b and K_{sp} to characterize different chemical systems.	Generalization of the expression K_a
2.7		To apply Le Châtelier's principle in relation to the equilibrium constant of different systems.	Disturbance, restoration of equilibrium
2.8		To describe the influence of temperature on the equilibrium constant.	Favoured reaction
2.9		To analyze the equilibrium of the ionization of water.	Ionization constant, Le Châtelier's principle
2.10	EX	To determine the pH of a solution using measurements obtained by titration.	Acid-base neutralization
2.11	T	To illustrate the use of acids and bases in everyday life, using examples.	Cleaning products, bleach, chlorine in swimming pools, batteries, etc.
2.12	S	To give an example of the importance of pH in certain specific environments.	Biological fluids, soil, lakes, etc.
2.13	H	To associate discoveries resulting from the study of chemical equilibrium with progress made in pure or applied chemistry.	

TERMINAL OBJECTIVE 2 (cont.)

To analyze quantitatively the dynamic aspect of chemical equilibrium.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
2.14	T	To describe the use of chemical equilibrium in an industrial application, using examples.	
2.15	S	To associate social changes and environmental consequences with the industrial use of chemical equilibrium.	
2.16		To solve problems related to the dynamic aspect of chemical equilibrium.	Stoichiometry, equilibrium concentrations, equilibrium constant, Le Châtelier's principle, etc.

TERMINAL OBJECTIVE 3

To explain the operation of electrochemical cells.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
3.1	EX	To observe an oxidation-reduction reaction.	Pairs of metals
3.2		To describe an oxidation-reduction reaction.	Oxidation, reduction, oxidizing agent, reducing agent
3.3		To write the net reaction equation and the equations for the half-reactions of an oxidation-reduction reaction.	Loss and gain of electrons, conservation of charge
3.4	EX	To list ions in order of their reducing power, on the basis of observations made during an experiment.	
3.5		To predict whether a reaction will be spontaneous or not, using a list of ions in order of their reducing power.	
3.6	EX	To measure the potential difference produced by different pairs of metals.	
3.7		To define "standard reduction potential" and "standard oxidation potential."	
3.8		To determine the potential difference that a pair of metals can generate, on the basis of standard reduction potentials.	
3.9	T	To describe the operation of an electrochemical cell, using a diagram.	Cell, half-cell, salt bridge, reaction process
3.10	EX	To construct an electrochemical cell.	
3.11		To explain the eventual weakening of an electrochemical cell, using Le Châtelier's principle.	Concentration, equilibrium, decrease in potential difference, "death" of the cell
3.12	T	To describe the operation of an electrolytic cell.	
3.13		To balance oxidation-reduction reactions using oxidation numbers.	

TERMINAL OBJECTIVE 3 (cont.)

To explain the operation of electrochemical cells.

		INTERMEDIATE OBJECTIVES	ADDITIONAL INFORMATION
3.14	H	To associate discoveries in electrochemistry with progress made in pure or applied chemistry.	Voltaic cell, use of electrolysis, development of modern cells, etc.
3.15	T	To illustrate technical applications of electrochemistry, using examples.	Electrochemical cell, electrolysis (plating, extraction of metals), etc.
3.16	S	To associate social changes and environmental consequences with the development of electrochemistry.	
3.17		To solve problems related to oxidation-reduction and electrochemical cells.	

EXPERIMENTAL METHOD

TERMINAL OBJECTIVES

INTERMEDIATE OBJECTIVES

C1 To apply the experimental method.

C1.1 To use experimentation as a means of verification.

C1.2 To use experimentation for research purposes.

C2 To write up an experimental procedure.

C2.1 To choose the equipment necessary for an experiment.

C2.2 To write up the procedure clearly.

C2.3 To determine the applicable safety measures.

C3 To carry out an experiment.

C3.1 To follow their own written experimental procedure.

C3.2 To handle the equipment correctly.

C3.3 To take the measurements correctly, taking experimental uncertainty into account.

C3.4 To apply the appropriate safety measures.

C4 To write a laboratory report.

C4.1 To be familiar with the structure of a laboratory report.

C4.2 To describe the experiment performed: goals, equipment, steps, diagram.

C4.3 To present the results of the experiment.

C4.4 To present a rigorous analysis of the results.

C4.5 To discuss the results.

C4.6 To write the conclusions of the experiment clearly, relating them to the problem stated.

C4.7 To clearly and logically present all the parts of a report.

RELATIONSHIPS BETWEEN THE OBJECTIVES ASSOCIATED WITH RELATED CONTENT AND WITH THE EXPERIMENTAL METHOD

RELATED CONTENT		EXPERIMENTAL METHOD			
1.3	To verify, through experimentation, whether or not a system is in equilibrium.	C1		C3	C4
1.6	To determine, through experimentation, how increasing the concentration of a reactant affects a system in equilibrium.	C1		C3	C4
2.3	To establish, through experimentation, a mathematical relation to characterize the equilibrium of the ionization of an acid.	C1		C3	
2.4	To determine, through experimentation, the relative strength of two or more acids.	C1	C2	C3	C4
2.10	To determine the pH of a solution using measurements obtained by titration.	C1			C4
3.1	To observe an oxidation-reduction reaction.	C1		C3	
3.4	To list ions in order of their reducing power, on the basis of observations made during an experiment.	C1	C2	C3	C4
3.6	To measure the potential difference produced by different pairs of metals.	C1		C3	
3.10	To construct an electrochemical cell.	C1	C2	C3	C4

HISTORY-TECHNOLOGY-SOCIETY PERSPECTIVE

TERMINAL OBJECTIVES

INTERMEDIATE OBJECTIVES

H To illustrate the relationships between the study of chemical equilibrium and oxidation-reduction, and the evolution of chemistry, using examples from history.

2.13 To associate discoveries resulting from the study of chemical equilibrium with progress made in pure or applied chemistry.

3.14 To associate discoveries in electrochemistry with progress made in pure or applied chemistry.

T To illustrate the use of chemical equilibrium and electrochemistry in technical applications, using examples.

2.11 To illustrate the use of acids and bases in everyday life, using examples.

2.14 To describe the use of chemical equilibrium in an industrial application, using examples.

3.9 To describe the operation of an electrochemical cell, using a diagram.

3.12 To describe the operation of an electrolytic cell.

3.15 To illustrate technical applications of electrochemistry, using examples.

S To illustrate environmental consequences and social changes related to the use of chemical equilibrium and oxidation-reduction, using examples.

1.10 To describe social changes and environmental consequences related to a disturbance of the equilibrium of a natural cycle, using examples.

2.12 To give an example of the importance of pH in certain specific environments.

2.15 To associate social changes and environmental consequences with the industrial use of chemical equilibrium.

3.16 To associate social changes and environmental consequences with the development of electrochemistry.

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