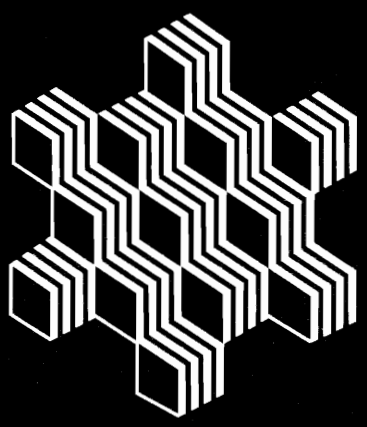
Secondary School Curriculum



CHEMISTRY 534

THE DISCOVERY OF MATTER AND ENERGY

Québec

Secondary School Curriculum

CHEMISTRY 534

THE DISCOVERY OF MATTER AND ENERGY

Direction générale des programmes
Direction de la formation générale des jeunes

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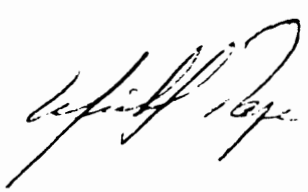

Michel Pagé
Minister of Education

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TABLE OF CONTENTS

FOREWORD

This document is the program-guide for Chemistry 534. Chemistry 534 is intended for Secondary V students who have sucessfully completed Physical Sciences 436 (the enriched path) and who plan to continue their studies at the CEGEP level in the Natural Sciences concentration, science-related vocational education programs or certain other CEGEP programs. Secondary IV students who have passed Physical Sciences 436 and who simply want to continue developing their skills, attitudes and knowledge relating to the study of the chemical properties of matter may also take this course.

This program-guide was developed by the Direction de la formation générale des programmes and is intended for Chemistry teachers; it outlines the compulsory and optional enrichment content of the program. Directors of educational services, teaching coordinators and education consultants in the field of natural sciences should refer to this document when preparing and conducting information sessions and in-service training activities related to this program.

School boards are responsible for providing the pedagogical support and the material that will enable students to attain the objectives in a manner consistent with the guidelines for implementing this program (See Chapter 8).

Teachers, with the assistance of the education consultants, are responsible for determining specific enrichment activities for students who can, and who want to, cover more than the compulsory content. Teachers may use the optional objectives (indicated by **) in each module, or develop their own activities.

The program-guide defines the skills, attitudes and knowledge to be developed by the students. For each intermediate objective, it proposes learning activities, teaching strategies and other information that can help teachers prepare their courses and carry out formative evaluation of student learning.

1. INTRODUCTION

1.1 Background

A comprehensive survey of the educational community conducted by the ministère de l'Éducation in 1977 revealed that the curriculum no longer met the needs of students or of society in general. Thus, in 1978, the Ministère began to revise all elementary- and secondary-school programs.

A *Plan of Action*[1], published in 1979, redefined the objectives of Québec education and suggested ways of dealing with certain problems identified by the educational community and society in general. The *Plan of Action* also outlined compulsory and optional programs for each year of elementary and secondary school.

First published in 1981 and revised in 1986 and again in 1990, the *Basic School Regulations*[2] now make it compulsory for Secondary IV students to pass a six-credit science course covering the basic principles of physics and chemistry in order to obtain a Secondary School Diploma. Students can choose either the regular path (Physical Sciences 416) or the enriched path (Physical Sciences 436) of this course. Those who pass Physical Sciences 436 can take Secondary V Physics (Physics 534) and Secondary V Chemistry (Chemistry 534).

1.2 Analysis of the Situation

In 1986, the Direction des programmes held wide-ranging consultations with science educators because it felt that physics and chemistry programs had undergone substantial change. A major part of this consultation process was a formal needs analysis whose purpose was to determine the orientations and content of the new programs, to establish

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[1] Québec, ministère de l'Éducation, *The Schools of Québec: Policy Statement and Plan of Action*, Code 49-1070A (Québec: ministère de l'Éducation, 1979).

[2] Québec, ministère de l'Éducation, Direction générale du développement pédagogique, *Basic school regulations (régime pédagogique) for secondary school education*, 1990.

priorities, and to ensure that secondary-level courses were compatible with CEGEP programs.

This needs analysis led to the publication of the document *New Physical Sciences Programs: Key Issues and Rationale*[3], which describes the current situation regarding physics and chemistry programs and specifies the measures and the orientations needed to improve the situation. This document served as a basis for further consultation with the various educators and officials involved in this matter.

The findings in the *Information Document* are also based on a variety of studies concerning science education. Included among these are the Rapport Evalensci, the analysis of the ASOPE, the Projet de l'orientation de l'éducation scientifique prepared by the Direction générale du développement pédagogique, the reports submitted by the Association des professeurs de sciences du Québec, various studies on science education and scientific knowledge such as those prepared by Jacques Désautels, Pierre-Léon Trempe and their associates, the advisory documents published by the Conseil supérieur de l'éducation, the report by the Science Council of Canada and the report on science education in French Canada. The development of this program-guide is based on this work and on comparative studies concerning science education in Québec and elsewhere.

1.2.1 CURRENT SITUATION

During the 1960s and 1970s, Secondary V chemistry programs were greatly influenced by the CHEM STUDY method developed in the United States. In the 1960s, this method was used with secondary school students who planned to study science at the post-secondary level. After CEGEPs were created, this method was used with gifted Secondary IV and V science students. Descriptive teaching methods for chemistry gave way to methods that focused on the explanation of phenomena. The subject matter, however, did not always reflect the students' level of intellectual development.

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[3] Québec, ministère de l'Éducation, Direction de la formation générale, *New Physical Sciences Programs: Key Issues and Rationale*, Code 72-0004 (Québec: ministère de l'Éducation, 1987). Hereafter referred to as the *Information Document*.

The teaching time allotted to this discipline gradually decreased without a corresponding reduction in the amount of subject matter that students were expected to cover. Teaching styles were influenced by the fact that ministry- and locally-prepared evaluation instruments mainly assessed the student's knowledge, with little concern for the development of skills and attitudes. This situation made it difficult for teachers to adopt teaching strategies based on the experimental method. The subject matter was presented as a set of absolute objective truths, and students became passive consumers of knowledge rather than active architects of their own scientific education. As a result, little time was devoted to the development of scientific skills and attitudes.

In addition, it seems that students start out with positive attitudes towards science. However, these attitudes gradually change so that by the end of secondary school, students have lost interest in science as it is currently taught. They view science as an incomprehensible set of formal procedures, as an arid examination of things that is based on spurious assumptions and divorced from the human aspects of modern life. Therefore, it should come as no surprise that Québec universities do not produce the number of scientists required in a modern society.

1.2.2 DESIRED SITUATION

The Secondary V chemistry program should provide young Quebecers with the background they need to continue studying sciences at the post-secondary level, and prepare them to meet the challenges of everyday life that are strongly influenced by scientific and technological discoveries. By studying chemistry, young people will be better equipped to participate in decision-making processes that will affect the future of humanity.

In order to breathe new life into chemistry courses and to make them appealing to students, educators must design programs that are in tune with the basic realities of modern society. A knowledge of science, complemented by a strong sense of ethics, is one of the key elements in a person's development and one of the major components of fundamental education. Furthermore, the cultural identity of a society can only be expressed in conjunction with some form of scientific and technological autonomy.

Consequently, when conducting scientific activities, it is important to refer to the history of science as well as current social and environmental issues. This approach is now regarded as an effective way of encouraging young people to work for change. Although secondary-level chemistry studies should prepare students for a career, they should above all motivate them to become responsible citizens of the world.

In addition, the initial training of current science teachers, social values and prejudices and methods of evaluation are some of the many powerful influences that make it difficult to alter our approach to teaching chemistry. However, such change is essential. It is important to bear in mind that this goal can be achieved only if society as a whole learns to value scientific and technological education.

1.3 Relationship with Other Programs

Chemistry 534 is the continuation of Physical Sciences 436; both programs are based on the same foundations and orientations. Students will be able to use and reinforce what they have learned since elementary school (i.e. skills and attitudes associated with the scientific method, sense of ethics, concern for the environment, knowledge of natural phenomena and technology related to chemistry). They will also apply some of the principles and concepts studied in earlier biology and mathematics programs. Finally, this program familiarizes young people with work methods, thought processes and related content, thereby preparing them for chemistry and certain vocational programs offered at the post-secondary level.

2. VALUES, FOUNDATIONS, AND ORIENTATIONS

2.1 Values

This program promotes values that reflect a constructivist view of science. Secondary V students will be able to develop various facets of their scientific education by investigating natural and chemistry-related phenomena. This experience will surely prepare them to meet the challenges of the future.

- Intellectual Values
  - methodical and rigorous work habits
  - an interest in research
  - a constant search for the truth

- Social and Cultural Values
  - recognition that scientific and technological research is a cultural activity
  - concern for providing young men and women with equal opportunities in the field of science and technology
  - international solidarity in dealing with today's major problems
  - an understanding of nature
  - team spirit
  - a concern for correct language

- Moral Values
  - respect for life and the environment
  - a sense of responsibility
  - a concern for health and safety
  - individual effort and self-discipline

The knowledge, skills and attitudes that students will acquire in this program are indissociable and reflect the values listed above.

2.2 Foundations

The content of this program-guide reflects recent findings in the fields of educational theory and epistemology, even though these elements were difficult to incorporate into a program that is structured around learning objectives. The program is based on the following sociological, pedagogical and epistemological foundations.

2.2.1 SOCIOLOGICAL FOUNDATIONS

The principles of chemistry are applied in a variety of fields. Some of these applications are taken for granted (e.g. preserving foods, photography) whereas others are less known (e.g. superconductors, rocket fuels). Nevertheless they all, in some way, affect our lives, society as a whole and the environment. Each year, more than 200 000 compounds are added to the 10 000 000 classified chemicals.

There is no doubt that chemistry and its related technologies are omnipresent in many aspects of our lives. Each spawns new activities which in turn lead to new research and technology. It is important to help students understand natural and chemistry-related technological phenomena, to formulate equations and so on, but it is equally important to make them aware that chemistry is very much concerned with the quality of our lives. Students would certainly benefit from this knowledge. Young people are interested in learning about the many theoretical aspects and practical applications of chemistry.

By learning how chemists have contributed to our knowledge of the behaviour of matter and by conducting their own individual or group research and experiments, students will develop analytical, decision-making and communication skills and thereby become informed citizens.

2.2.2 PEDAGOGICAL FOUNDATIONS

It is generally agreed that people can master anything if they are given the opportunity to practise the theory. Over the last few decades, a great deal of research in the fields of science education and psychology has shown that students learn best when they are

actively involved in the learning process. Thus it is important for teachers to ensure that students participate physically and intellectually by adopting teaching methods that focus not only on the learning content, but on the students, their intellectual abilities and interests.

It is often mistakenly assumed that students will automatically learn what has been presented to them, remember what has been shown, apply the methods that have been demonstrated and adopt the values that have been promoted. Pedagogical research has shown that this is not the case. The teaching approach advocated by this program involves organizing learning situations that will enable the students to discover the structure of science in their own way and guiding them through their learning process. For the students, learning means actively participating in the learning process rather than passively absorbing copious amounts of information. Such an approach usually leads them to change their attitudes toward the sciences.

Some students who will be taking this course have not reached the formal operational stage of their development. Some may have basic cognitive difficulties or may not have developed their deductive reasoning abilities sufficiently. For this reason, an inductive approach should be adopted.

Students often indicate their interest in a subject by asking questions. If they are not sufficiently motivated to ask questions, it will be difficult to teach them anything meaningful. To spark the students' interest, the teacher should try to explain abstract concepts in terms of concrete situations relating to the students' environment, taking into account the knowledge, skills and attitudes they have already acquired.

The teacher should then help them construct the learning content by having them carry out concrete experiments that take into account their initial explanations or representations of a concept or phenomenon. If necessary, the teacher should provide demonstrations, simulations, pre-established procedures or employ other appropriate techniques to illustrate certain points. Finally, the teacher should conduct discussions so as to help students review the learning content and provide feedback.

To facilitate learning, teachers should choose their instructional approach carefully. When examining a problem with students, it is important to avoid shifting too quickly from a qualitative study to the quantitative or mathematical approach normally used by chemists.

2.2.3 EPISTEMOLOGICAL FOUNDATIONS

Scientific knowledge is a product of human intellectual activity and its development is characterized by a series of mistakes, successes, dead ends, repetitions, gaps, setbacks and productive collaborations. Although it has evolved to deal with current problems, this knowledge is basically rooted in the past. It must be borne in mind that scientific knowledge is constructed by human beings, and is not necessarily an absolute reflection of reality.

Thus, the teacher should encourage students to develop their own hypotheses, procedures, models and conclusions and allow them to reject, retain or refine them on the basis of their observations of the natural environment, discussions with their classmates, and generally accepted scientific principles. In this way, they will gradually become familiar with the strengths and limitations of the experimental approach and the relative merits of the different theories, and will learn to appreciate the work involved in looking for truths. Students should be given the opportunity to work like scientists.

According to this "constructivist" philosophy, scientific knowledge is constructed from human beings' intellectual efforts to acquire knowledge and understanding of natural and technological phenomena on the basis of what is already known. The teacher should help the students apply what they already know to construct knowledge and to construct their own development.

2.3 Learning Content and Integrating Themes

This chemistry program is centred on the following integrating themes:

- "scientific" work methods, in particular the experimental method
- "scientific" ways of thinking, in particular the inductive method

The learning content includes:

- a more in-depth examination of the organization of concepts related to matter and energy by means of an investigation of natural phenomena and chemistry-related technology.
- the concept of a model
- the nature of science itself

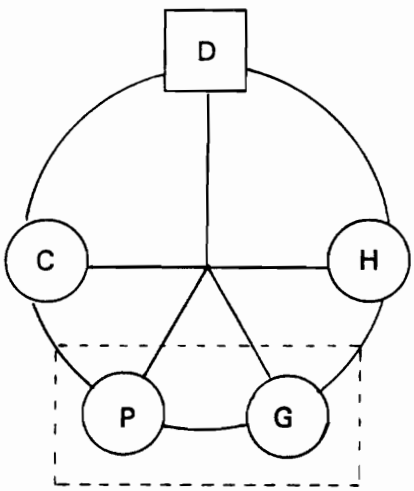
The students should construct the learning content by exploring their environment, examining the past and present interrelationships of science, technology and society, conducting laboratory experiments and working with computer simulations.

2.4 Learning Approach

To help students acquire the knowledge, skills and attitudes that will enable them to become more familiar with, and understand the concepts of energy and matter in their environment, this program advocates a problem-solving approach to the teaching of chemistry. The topics should be presented as problems to be solved so that students learn how to link familiar concepts with new experiences and deal with information that may contradict their own intuitive ideas about natural phenomena and chemistry-related technology. Students should be encouraged to discuss a problem among themselves, to try to find a solution using a variety of investigative techniques, then to analyze their results to see whether they are at variance with their predictions and draw their own conclusions. The knowledge, skills and attitudes they acquire through this exercise can help them deal with similar problems in or outside the classroom.

The following diagram illustrates the approach that this program advocates. The main points are explained in detail. Like the acquisition of knowledge, this process is not necessarily linear, cumulative, or free of error and failure, especially since the students' thought processes are not always consistent with the rationale of the model described below.

DIAGRAM OF THE PROBLEM-SOLVING APPROACH



Verification = Analysis

Legend D: Defining the Problem
C: Conclusion
P: Processing Data
G: Gathering Data
H: Formulating a Hypothesis

Defining the Problem

After observing natural or technological phenomena, taking measurements, doing experiments, reading on a subject, working with audio-visual materials and so on, students usually have a horde of questions. This is a sort of cognitive gap that students will attempt to bridge by trying to find the answers to these questions if they feel it is beneficial or to their advantage. The students begin by trying to define the problem as precisely as possible.

Formulating Hypotheses

The students formulate their reactions to the situation by proposing one or more solutions that they feel are plausible. These responses may be based on intuition, reasoning or explanations, but they should be regarded as tentative solutions to be analyzed and verified.

Gathering Data

The students research and examine the data or sources of information relating to the problem. This information is obtained through observations, measurements, experiments, investigations, library research or other relevant techniques.

Processing Data

The students organize, classify, compare and interpret their data, checking it against their hypotheses. They then relate the data to the goal they are pursuing.

Conclusion

After analyzing their data, the students evaluate their hypotheses and present the results by writing a report, developing a model, formulating a law or a theory or by using any other appropriate method. They review the entire learning situation, examining the process and the product. The students should then be able to apply the knowledge they have acquired to similar learning situations.

The above procedure is an attempt to describe how students learn through the problem-solving approach. They gradually become familiar with a work method that does not immediately provide an answer, but which enables them to acquire knowledge, skills and attitudes that will be invaluable throughout their lives.

This approach is analogous to the "scientific method" of inquiry. It is generally regarded as a problem-solving technique.

2.5 Teacher's Role (Instructional Approach)

Learning is defined as a dynamic process in which the students construct their own knowledge, guided by the teacher. The teacher's role is therefore to teach students first and foremost how to learn, not what to learn. The teacher should encourage the students to develop their talents by choosing the most appropriate teaching strategies and learning

activities. Teaching methods should be geared to the students' potential and should by no means be based on a single approach.

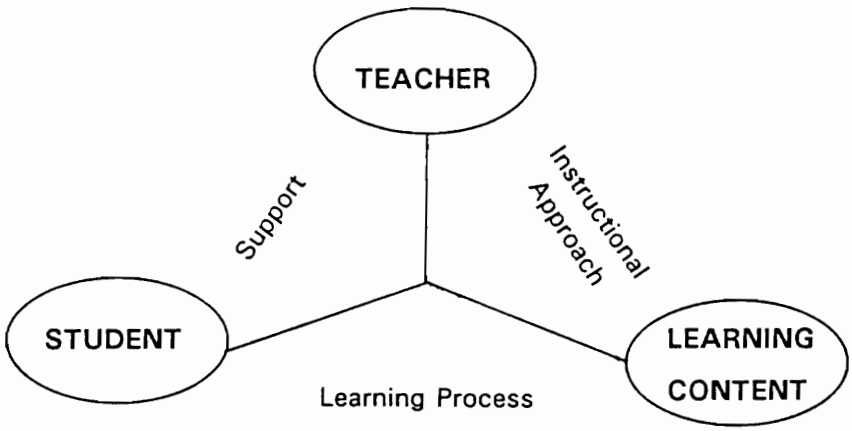
The challenge facing the teacher is to help students understand the principles of chemistry and chemistry-related technologies, while making the learning process a fascinating experience. The learning process would be more meaningful and fascinating for the students if the learning content were related to their own environment and if they grasped the connection between chemistry and technology. The teacher should devise and organize activities that are varied, concrete, adapted to the students' abilities and interests, and directly related to their life experiences. In addition, these activities should help develop in the students a concern for health and safety and for the environment.

In some ways, the teacher's role has been profoundly changed. Teachers are not expected to provide the correct answer or impose an approach to a problem, but rather to prepare learning situations with the students in mind, to guide them through the learning process, to support them and help them take stock of what they are doing and learning. The teacher is a sort of catalyst in this new approach to chemistry education.

Particular attention should be paid to the number of research and laboratory reports assigned as class work or homework. Too many written assignments could affect the quality of the students' work and cause them to lose interest in science. It also means that teachers will have to spend more time correcting papers. Teachers are encouraged to be creative and vary their requirements.

In short, this program advocates an interactive learning approach. The teacher is called upon to provide students with the best opportunity to experience the real world of science, to encourage them to work together and to help them discover how science relates to history, technology, social concerns, and environmental issues.

TEACHER'S ROLE



2.6 Students' Role (Learning Approach)

Students will learn to take responsibility for their own education by:

- participating in all proposed activities;
- contributing to group experiments;
- developing hypotheses and testing them;
- doing experiments using their own procedures or suggested procedures;
- proposing models and theories;
- sharing their conclusions;
- assessing the impact of their actions and those of scientists and technologists on the environment and the quality of life;
- formulating generalizations and laws;
- comparing their results with those of other students and of scientists;
- communicating their results in a variety of ways (e.g. written reports, oral presentations, exhibits).

In this program, students will be given the opportunity to apply what they have learned (i.e. knowledge, skills and attitudes) by carrying out a research project that simulates the work of a chemist.

2.7 Guiding Principles

The three guiding principles that reflect the results of the needs analysis and the foundations and orientations of this program are summarized below.

SOCIOLOGICAL PRINCIPLES

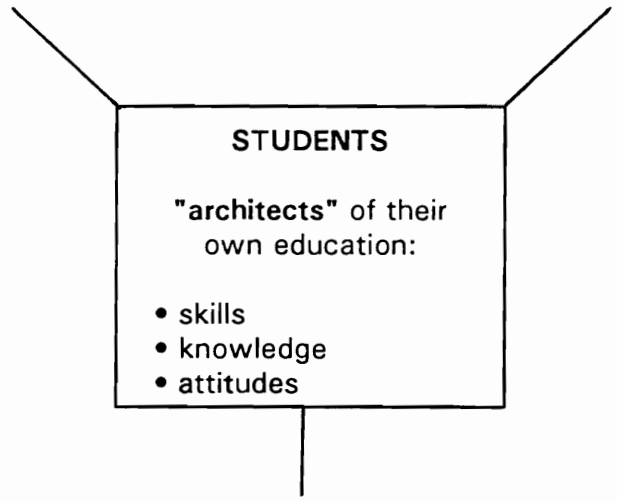
An instructional method that focuses on the integration of learning.

(Relationships among science, technology and society)

PEDAGOGICAL PRINCIPLES

An instructional method designed to help students use the scientific method to explore the phenomena in their environment.

(Experimental method)



EPISTEMOLOGICAL PRINCIPLES

An instructional method based on the concept of constructing knowledge.

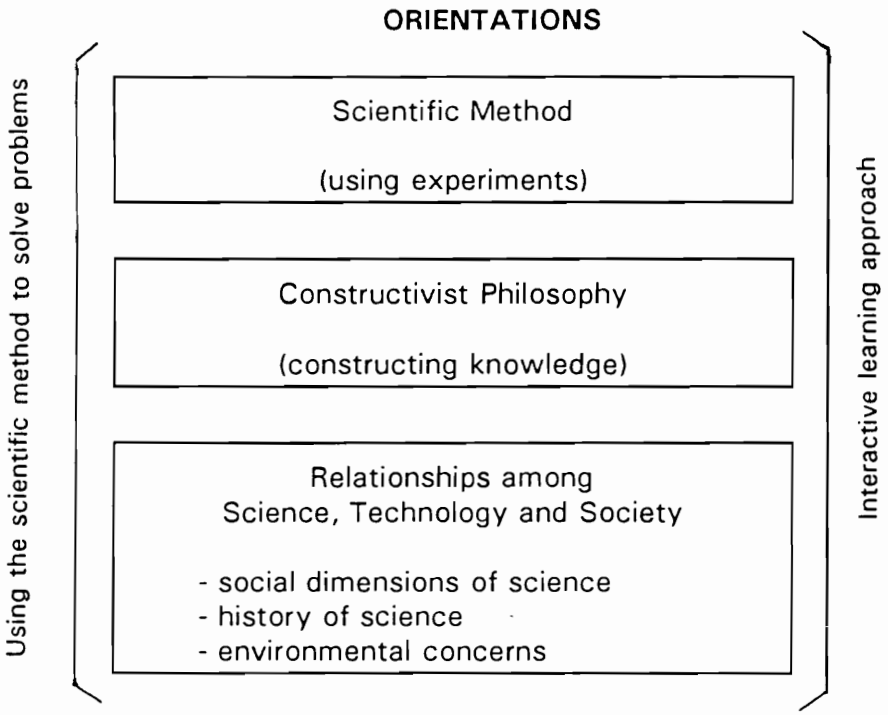
(Constructivism)

2.8 Summary of the Orientations of the Program

This program emphasizes the scientific method of inquiry, laboratory work and group work. Its goal is to provide students with a solid fundamental education and an excellent background in science.

The basic philosophy of this program is that knowledge is constructed. Scientific knowledge is constantly being modified through research and experiments aimed at developing a greater understanding of phenomena in the environment, based on knowledge already acquired. Students are therefore encouraged to construct their own knowledge by conducting research and experiments, modifying, improving, developing what they already know.

This program advocates an interactive learning approach in which the teacher guides the students through the learning process that is structured around the scientific method as a way of solving problems. This new approach to teaching chemistry enables students to become familiar with the relationships among chemistry, technology and society and to learn how to examine and explain how chemistry relates to the environment. The students learn to appreciate the strengths and limitations of scientific inquiry and ultimately gain a general understanding of the role of chemistry in modern society.



INTERACTIVE LEARNING

The students use the scientific method
to discover solutions to problems.

The teacher **guides** the students
through the learning process.

3. FOCUS OF LEARNING

3.1 Global Objective

Although this program is intended primarily for students who plan to study science at the post-secondary level, it is not aimed at producing specialists. Its main objectives are to foster the students' interest in chemistry, to help them adapt to the constant changes brought about by science, and to prepare them for a career in science or technology. This program will provide students with the opportunity to investigate natural and chemistry-related technological phenomena so that they continue to structure the concepts of matter and energy, to become aware of environmental issues and to study the relationships among science, technology and society.

The students will therefore construct the knowledge, intellectual and technical skills and attitudes that will help them to be informed citizens, well equipped to participate in the decision-making process that will affect the future of humanity.

The global objective of *Chemistry 534*, like the Physical Sciences 416-436 program, is above all to make students aware of the fundamentals of science.

3.2 Goals

In order to achieve the global objective of this program, students should develop the knowledge, skills and attitudes listed below.

KNOWLEDGE

This program will enable students to:

- develop a broader understanding of concepts studied in Secondary IV;
- structure the concepts, laws and principles that will enable them to understand and explain natural and chemistry-related technological phenomena;
- apply various theories based on the kinetic theory of matter;

- develop their knowledge and use of the molecular model of matter;
- become familiar with the nature of chemistry, its capabilities and its limitations;
- understand the limitations of measurements and techniques;
- understand the relationships between science, technology and society;
- develop communication skills.

SKILLS

This program will enable students to:

- refine the skills developed in Secondary IV;
- develop the skills required to be scientists;
- acquire the ability to think "scientifically";
- develop problem-solving abilities;
- learn how to work methodically and safely when doing scientific research;
- learn how to develop models;
- learn how to work in a team.

ATTITUDES

This program will enable students to:

- further develop the attitudes promoted in Secondary IV;
- learn how to objectively analyze chemistry and the work of chemists;
- develop "scientific" attitudes;
- develop ethics regarding social and environmental issues;
- develop an interest in scientific work and leisure-time activities related to chemistry.

3.3 Learning Content and Integrating Themes

The learning content of this program focuses on the following elements:

- principles relating to chemistry and associated with issues that concern the individual, society, the economy, the environment and technology;

- work and research methods that chemists use to discover and understand the behaviour of matter and the role of energy and applying this knowledge in different fields;

- attitudes that will help students prepare for a career and for life in society.

These elements have been integrated into the objectives of this program. The principles of chemistry are structured around the molecular theory, the kinetic theory and concepts of energy, while the development of skills and attitudes is achieved through learning activities for which the teaching strategies and instructional materials have been carefully selected.

The students therefore become familiar with numerous phenomena and techniques that will likely stimulate their interest and lead to further investigations. This approach to investigations is central to the program and gives students the opportunity not only to continue developing their knowledge, skills and attitudes, but also to examine the relationships among science, technology and society.

3.4 Objectives of the Program

The objectives of the program and the learning activities of the modules reflect the orientations of the program. There is little reference material on designing this type of program, as a result, the constructivist approach advocated here may seem somewhat awkward at first. What is important is to respect the philosophy of the program and to help students construct the learning content in accordance with that philosophy.

3.5 General Objectives

After field-testing the experimental version of this program and receiving feedback from specialists, five modules were selected for Chemistry 534. Modules 2, 3, 4 and 5 deal with concepts that enable the students to construct knowledge, skills and attitudes while Module 1 gives them the opportunity to apply the knowledge, skills and attitudes they have developed by carrying out a research project. The general objective of each module reflects the orientations of the program.

3.6 Specific Objectives

The general objective of each module is described in greater detail by means of terminal objectives. The order in which the terminal objectives are presented can be changed to reflect the students' interests, abilities and progress, or the teacher's personal style of teaching. The terminal objectives are formulated so as to help students construct the related content (i.e knowledge, skills and attitudes) according to the orientations of the program.

Each terminal objective is divided into intermediate objectives which are also presented in a sequence that can be adapted to the students' needs or to the situation in a particular school. Suggested learning activities and teaching plan define the scope of these intermediate objectives.

The terminal objectives (in boldface) are compulsory and will be evaluated by the Ministère. This evaluation should take into account the orientations of the program as reflected in the intermediate objectives, the learning activities and related content and should not extend beyond the scope of these three items. Intermediate objectives preceded by two asterisks (**) are suggested enrichment activities and should be evaluated by means of locally-prepared examinations.

The general and terminal objectives of each module are listed on the following pages.

MODULE 1: RESEARCH

General Objective

To reinforce and help broaden the students' scientific knowledge by means of a research project that will enable them to integrate what they have learned with environmental concerns.

Terminal Objectives

THE STUDENTS WILL LEARN HOW TO:

1. Communicate the results of an experimental or a documentary research project on a chemical phenomenon of their choice, using correct language and emphasizing either its history, technological applications or impact on society and the environment.

MODULE 2: GASES AND THEIR APPLICATIONS

General Objective

To investigate by means of the scientific method, the different phases of matter in order to establish a model, to understand some aspects of the behaviour of matter, and to become aware of the influence of matter on society and the environment.

Terminal Objectives

THE STUDENTS WILL LEARN HOW TO:

1. Illustrate the relationships among the following: the development of knowledge relating to the behaviour of gases, the use of gases, our quality of life, society and the environment.

2. Predict the behaviour of an "ideal" gas influenced by various factors, using mathematical models inferred from observing real-gas phenomena.

3. Explain natural or technologically-induced phenomena involving matter in its different phases, using the molecular model already explored and their knowledge of the behaviour of gases.

MODULE 3: ENERGY IN CHEMICAL REACTIONS

General Objective

To investigate by means of the scientific method, various chemical changes in order to discover their effects, to understand the resultant energy transfer and to become aware of the impact of these changes on society and the environment.

Terminal Objectives

THE STUDENTS WILL LEARN HOW TO:

1. Define different changes in substances, based on knowledge they have acquired from observing and analysing energy changes occurring during chemical and physical reactions.

2. Demonstrate the rules governing the transfer of energy that occurs during chemical reactions, based on their scientific work.

3. Describe the transfer of energy that occurs during chemical reactions, based on an analogical model that they have developed.

4. Illustrate, by means of an impact study, the relationships among the following: the development and use of knowledge relating to energy in a chemical reaction, science, technology, society and the environment.

MODULE 4: RATE OF CHEMICAL REACTIONS

General Objective

To investigate by means of the scientific method, various chemical changes in order to identify the factors that influence their reaction rate, to understand how they occur and to become aware of their impact on society and the environment.

Terminal Objectives

THE STUDENTS WILL LEARN HOW TO:

1. Describe the chemical changes in their environment, based on the reaction rates that they have observed and measured.

2. Analyse the factors that can influence the rate of the chemical reactions that they have discovered while doing scientific work.

3. Illustrate, by means of an impact study, the relationships among the following: the development and use of knowledge relating to the rate of chemical reactions, science, technology, society and the environment.

MODULE 5: EQUILIBRIUM IN CHEMICAL REACTIONS

General Objective

To investigate, by means of the scientific method, various chemical changes in order to identify the factors that influence their state of equilibrium, to understand how they occur, to discover their technological applications and to become aware of their impact on society and the environment.

Terminal Objectives

THE STUDENTS WILL LEARN HOW TO:

1. Carry out qualitative analyses of the behaviour of chemical systems subjected to factors likely to affect their equilibrium.

2. Carry out quantitative analyses of the equilibrium of various chemical systems, based on experiments or on given values.

3. Analyse various oxidation-reduction reactions, based on the results of their experiments.

4. Illustrate, by means of an impact study, the relationships among the following: the development and use of knowledge relating to equilibrium in chemical reactions, science, technology, society and the environment.

3.7 Learning Activities

The learning activities suggested for each intermediate objective can be used to help the students achieve the intermediate objective. Teachers may also propose other learning activities so long as they are consistent with the orientations of the program. All proposed activities must reflect the students' interests, abilities and styles of learning, and should enable the students to construct knowledge and solve problems by applying what they have learned to the investigation of their environment.

Themes or topics covered in previous courses and to be reviewed because they are deemed relevant to the objective are indicated at the beginning of the learning activities. They should be reviewed at the most appropriate point in the learning sequence.

3.8 Suggested Teaching Plan

The program-guide suggests elements that teachers may want to consider when planning their instructional approach for each intermediate objective.

PREREQUISITES

Objectives in this program that are prerequisites for the particular intermediate objective.

In addition, the themes and topics to be reviewed during the learning activities refer to knowledge that the students should have normally acquired in previous courses. This serves to remind teachers that they should help the students construct new learning content based on material already covered.

RELATED CONTENT

The skill, knowledge and attitude that students are expected to develop for each intermediate objective.

These elements should prove useful for determining instructional and evaluation methods.

Appendix I is a list of the skills and attitudes emphasized in this program. The alphanumeric code in parentheses refers to Appendix II, the taxonomy for natural sciences education.

TEACHING STRATEGY

Teaching/learning techniques that can be used individually, sequentially or concurrently.

The selection and sequence of these techniques constitute the teaching strategy for the particular objective. Regardless of the strategy selected, teachers should ensure that the students play an active role in the learning process.

DURATION

The amount of time it should take to help students attain the intermediate objective.

The terms **homework** and **free time** accounts for work (e.g. reading, developing experimental procedures, doing experiments, research, writing reports) that students are expected to do outside school hours.

EVALUATION

Suggested focus for formative evaluation to determine whether the students have attained the intermediate objective.

MATERIALS

Instruments, materials and substances that could be used depending on the learning activities.

The chemicals and concentrations have been carefully selected so that any harmful effects on health and the environment are minimized.

It is the teacher's responsibility to ensure that first aid equipment is available at all times, and that the students use it as required by the situation.

SAFETY MEASURES

Information on health and safety measures and environmental protection. Individual protective equipment should be selected accordingly.

See the following documents for details: *Health and Safety in the Natural Science Laboratory* and *Guide for Handling and Disposing of Hazardous Substances in the Schools* (See Chapter 9 for full references).

SUGGESTED REFERENCES

Alphanumeric codes referring to books, magazine articles, audio-visual materials and educational software pertaining to the particular objective.

Some of these references are for the teacher's use; others are suitable for students. The full bibliography for each code can be found in Appendix III. Teachers are also encouraged to complement these references as necessary.

TEACHER'S NOTES

The teacher can use this space to make additional notes on references, teaching strategies and so on appropriate to the intermediate objective. They may also indicate any information, based on their own experience, that could be useful to future teachers.

3.9 Students' Research Projects

Students are required to complete at least one research project of their choice during the school year. Topics that may be of interest to the students as well as research procedures are listed in Module I.

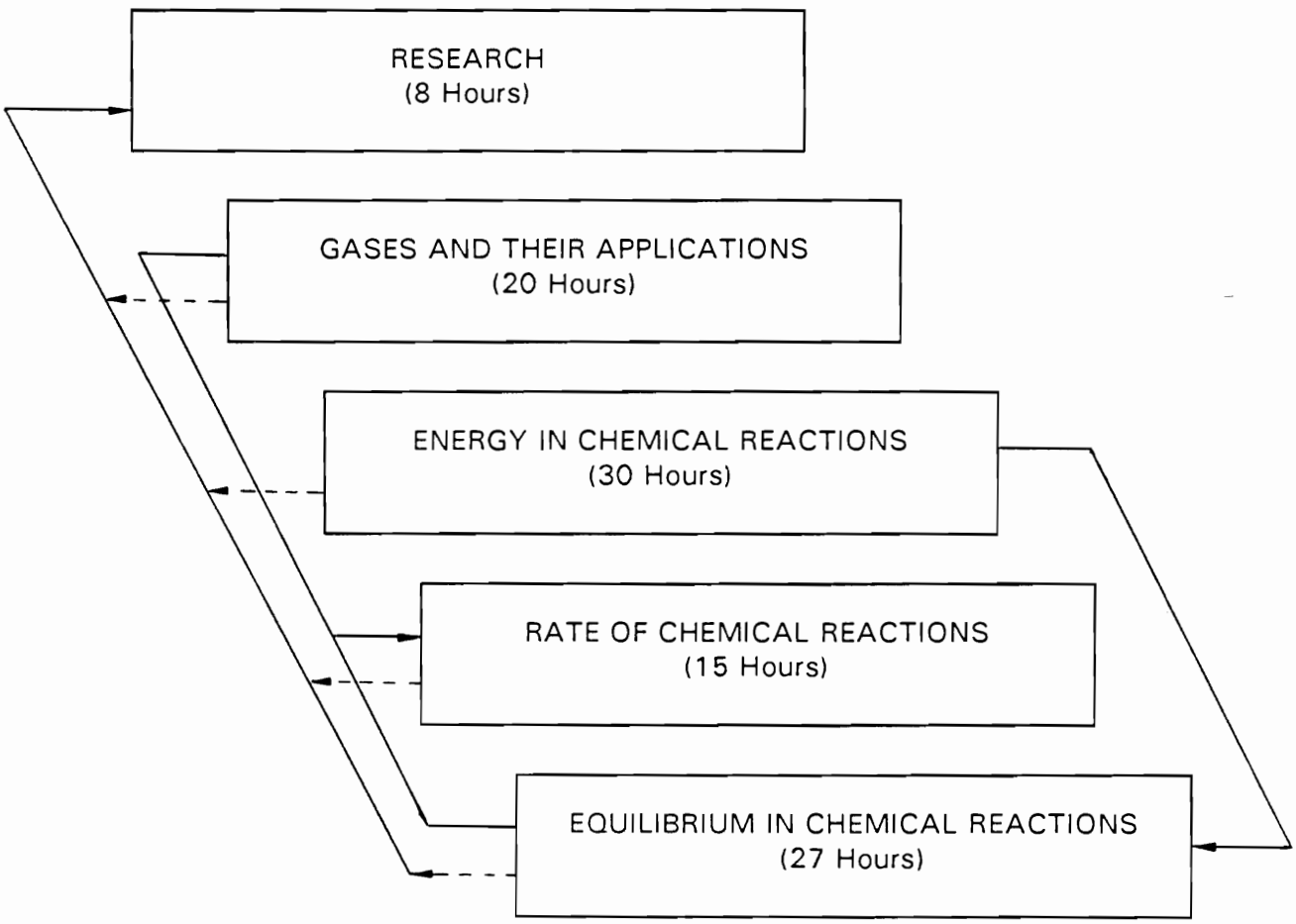
The students may carry out their projects individually or in small groups as class work, homework, extracurricular activities, any time during the school year. The students should be encouraged to present the results of their research project in class and if possible at a science fair. This will be a educational exercise both for the students giving the presentations and their audience.

4. STRUCTURE OF THE PROGRAM AND LEARNING CONTENT

This program-guide for *Chemistry 534: The Discovery of Matter and Energy* contains five compulsory modules. Module 1 requires the students to carry out a research project at some time during the school year. The learning content for each module is structured as a sequence of learning activities aimed at providing students with meaningful learning situations that reflect the orientations of the program.

4.1 Relationship Among the Modules

The following diagram illustrates the relationship among the five modules.



All the modules, except for *Module 1: Research*, propose enrichment objectives for students who attain the compulsory objectives in less than the 100 hours normally allotted to the required material. Teachers are encouraged to cover the suggested enrichment objectives with these students, to develop other enrichment objectives that reflect the students' specific interests, or to help students explore new topics that may be of interest to them. While preparing students for CEGEP is a commendable goal, it is equally important to maintain their interest in the sciences.

4.2 Module 1: Research

This module requires the students to carry out an experimental or a documentary research project on one or more topics of their choice, relating to the themes of Modules 2, 3, 4 and 5. In this research project the students will apply what they have already learned (i.e. skills, knowledge and attitudes) and use the scientific method to examine, perfect, reinforce or explore knowledge.

4.3 Module 2: Gases and Their Applications

The investigation of the different phases of matter, using the scientific method, will lead the students to question certain phenomena. Under the teacher's guidance, the students will understand some aspects of the behaviour of matter, propose a model and become aware of the relationships among science, technology, society and the environment.

4.4 Module 3: Energy in Chemical Reactions

Everyday we use various forms of chemical energy. This module will enable the students to develop specific measuring skills and discover the basic laws for determining heat of reaction. Imagination plays an important role in the understanding of the source and result of heat energy in chemical reactions. The teacher should encourage the students to use the scientific method to become more familiar with heat energy and to discover its technological applications.

4.5 Module 4: Rate of Chemical Reactions

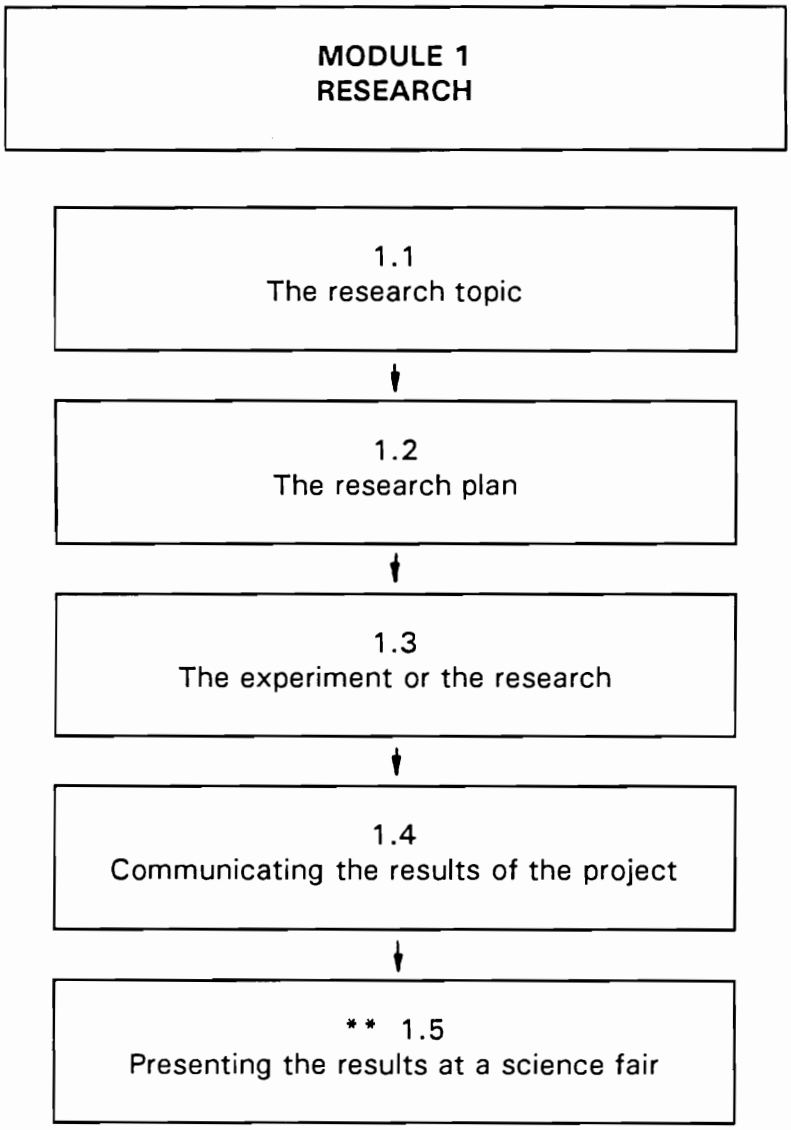
Chemical reactions can be classified according to the rate at which they occur. The students will investigate factors that influence reaction rates, learn to explain how they occur, determine the importance of each factor in a given reaction and discover technological applications and natural phenomena that involve chemical reactions. They will also become familiar with the relationships among science, technology, society and the environment.

4.6 Module 5: Equilibrium in Chemical Reactions

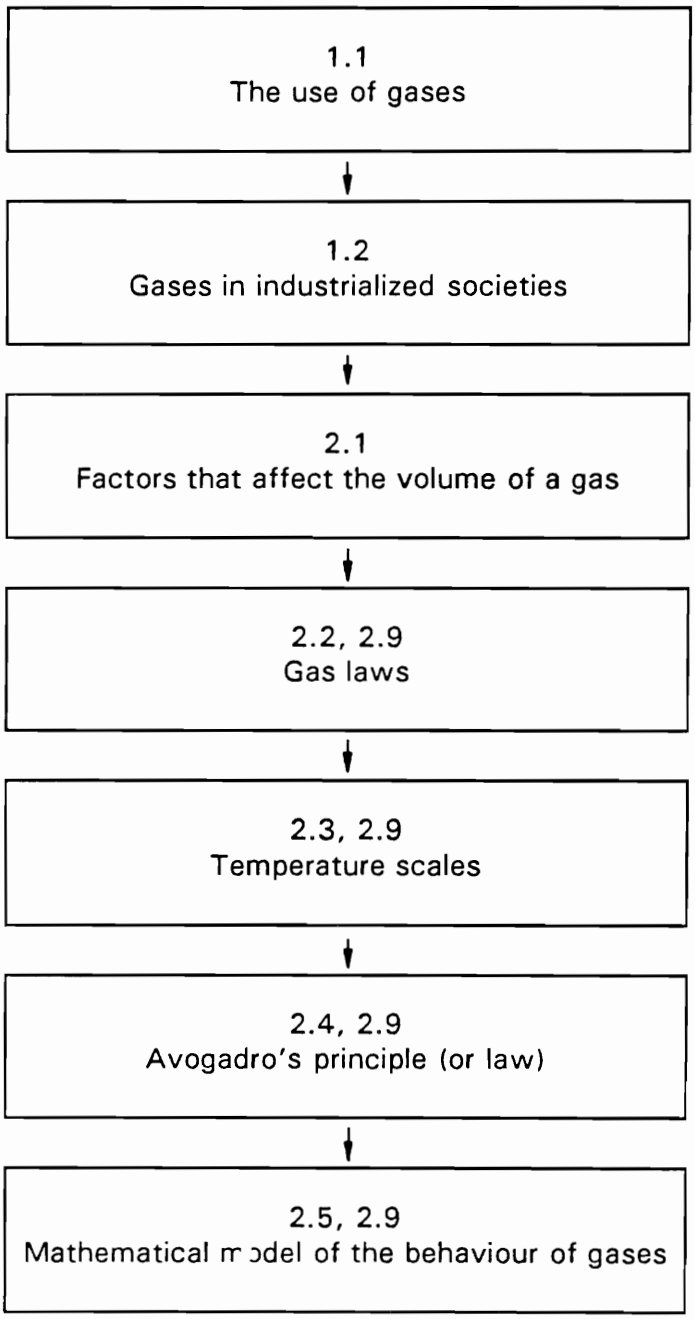
In this module, students learn how reactants or lack thereof affect chemical reactions in the environment or in the laboratory and to identify the factors that influence a chemical reaction and its equilibrium. The teacher helps the students to become aware of the rules developed by chemists for predicting the possibility of a chemical reaction and of how industries apply the concept of equilibrium in chemical reactions to product a desired chemical substance. Students will also become aware of the effects of certain chemical reactions, resulting from toxic leakages in the environment, on our health and on the ecosystem.

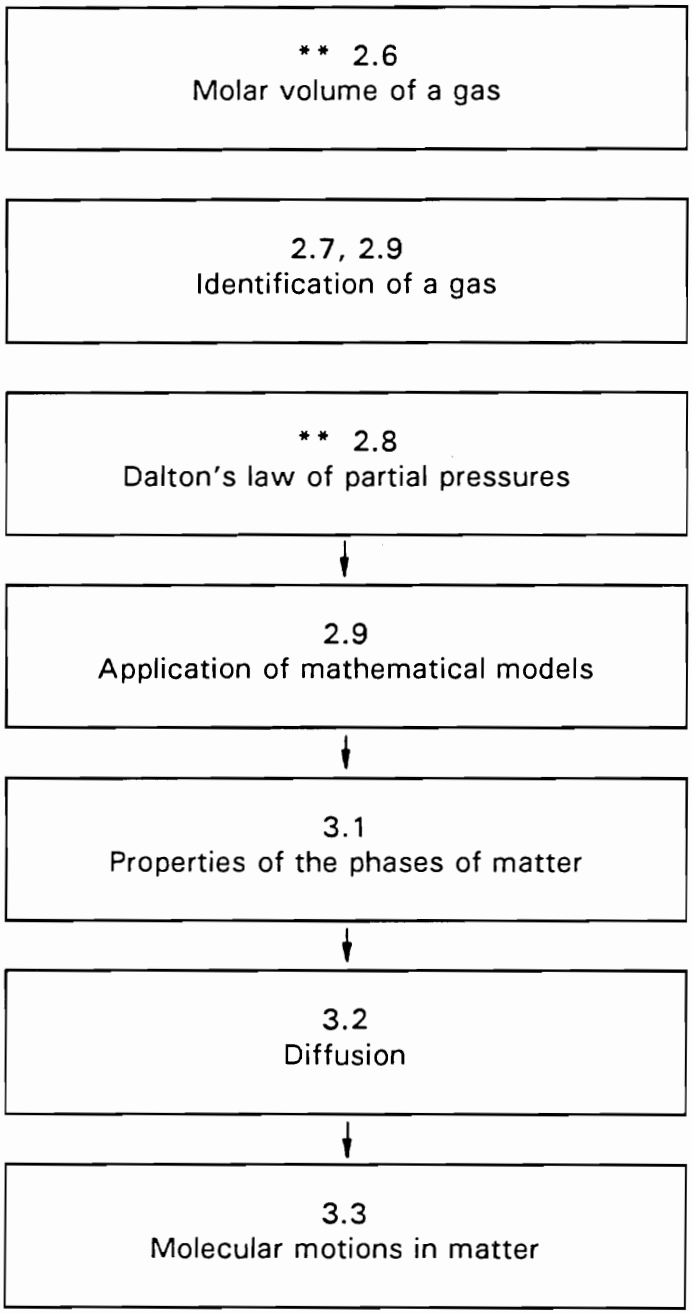
The five modules of this program provide a basic overview of chemistry and the discovery of matter and energy, and help to reinforce and broaden the students' scientific knowledge.

5. ORGANIZATION OF TOPICS

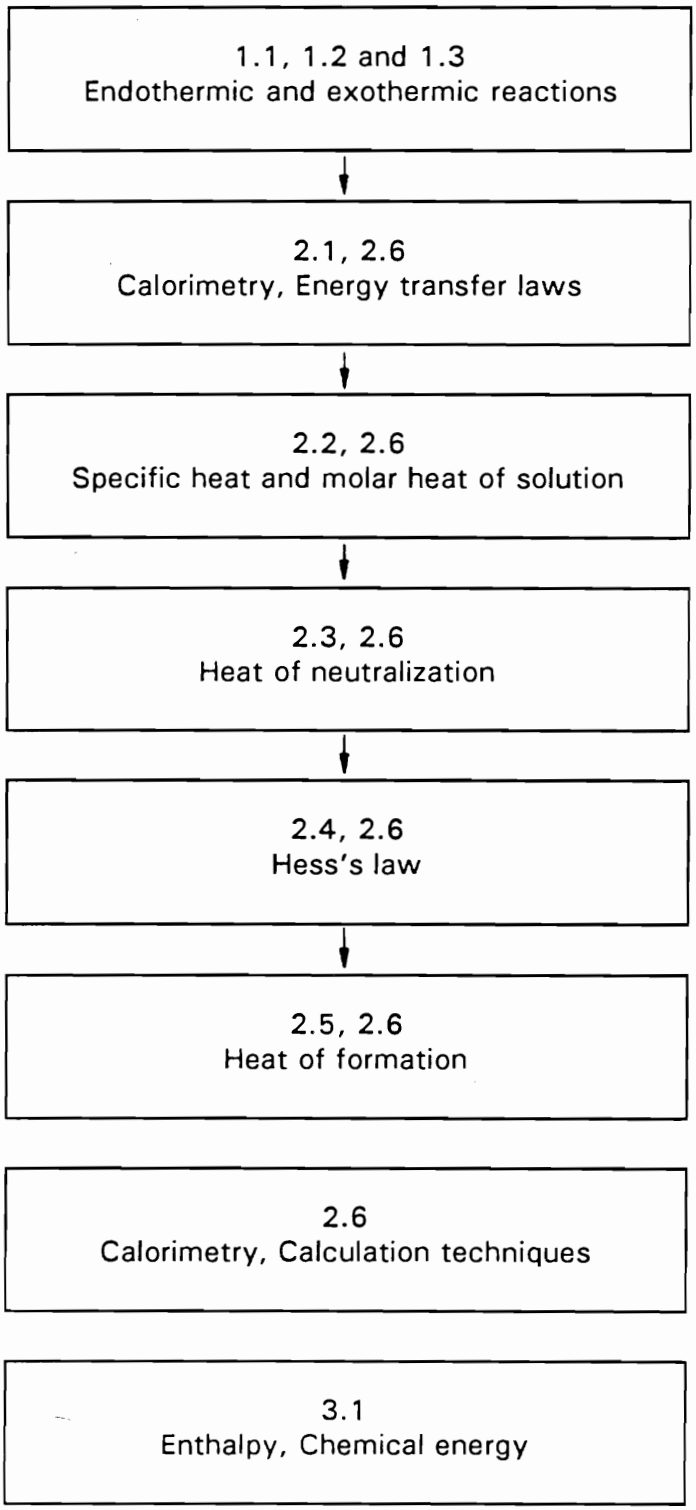


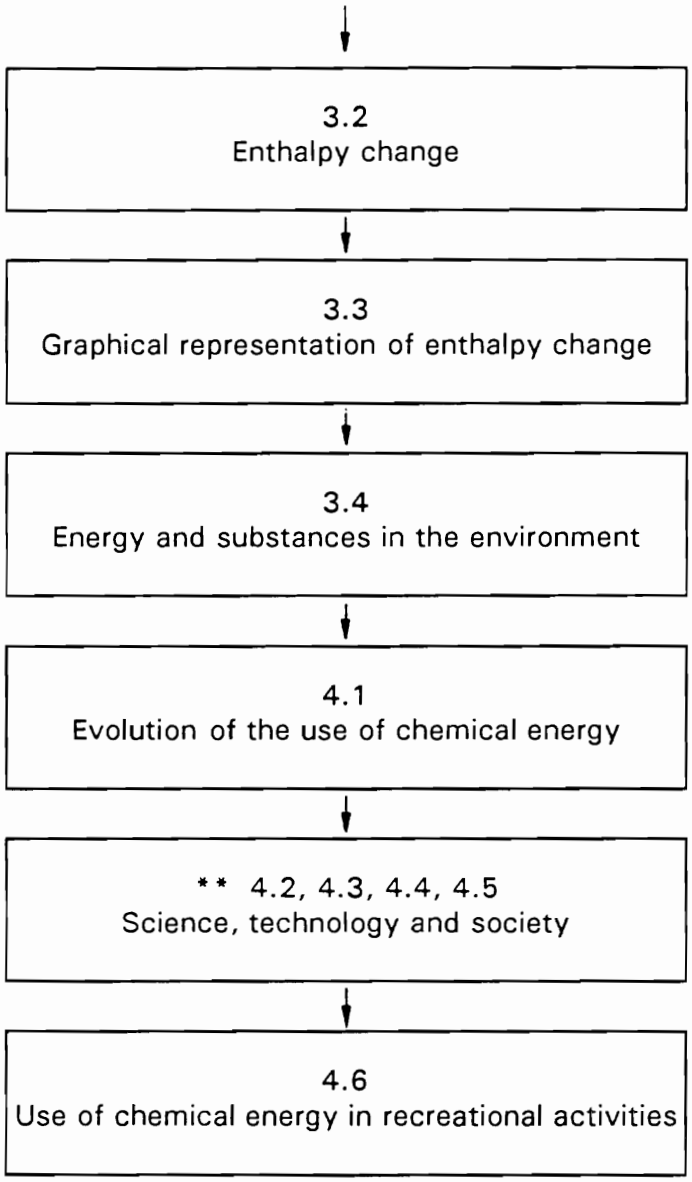
MODULE 2
GASES AND THEIR APPLICATIONS




** 2.6
Molar volume of a gas
2.7, 2.9
Identification of a gas
** 2.8
Dalton's law of partial pressures
2.9
Application of mathematical models
3.1
Properties of the phases of matter
3.2
Diffusion
3.3
Molecular motions in matter

MODULE 3
Energy in Chemical Reactions




3.2
Enthalpy change
3.3
Graphical representation of enthalpy change
3.4
Energy and substances in the environment
4.1
Evolution of the use of chemical energy
** 4.2, 4.3, 4.4, 4.5
Science, technology and society
4.6
Use of chemical energy in recreational activities

MODULE 4
Rate of Chemical Reactions

1.1
Classification of chemical changes by rate

↓

1.2
Measuring the rate of a reaction

↓

2.1
Factors influencing the rate of combustion

↓

2.2
Factors influencing the rate of reaction

↓

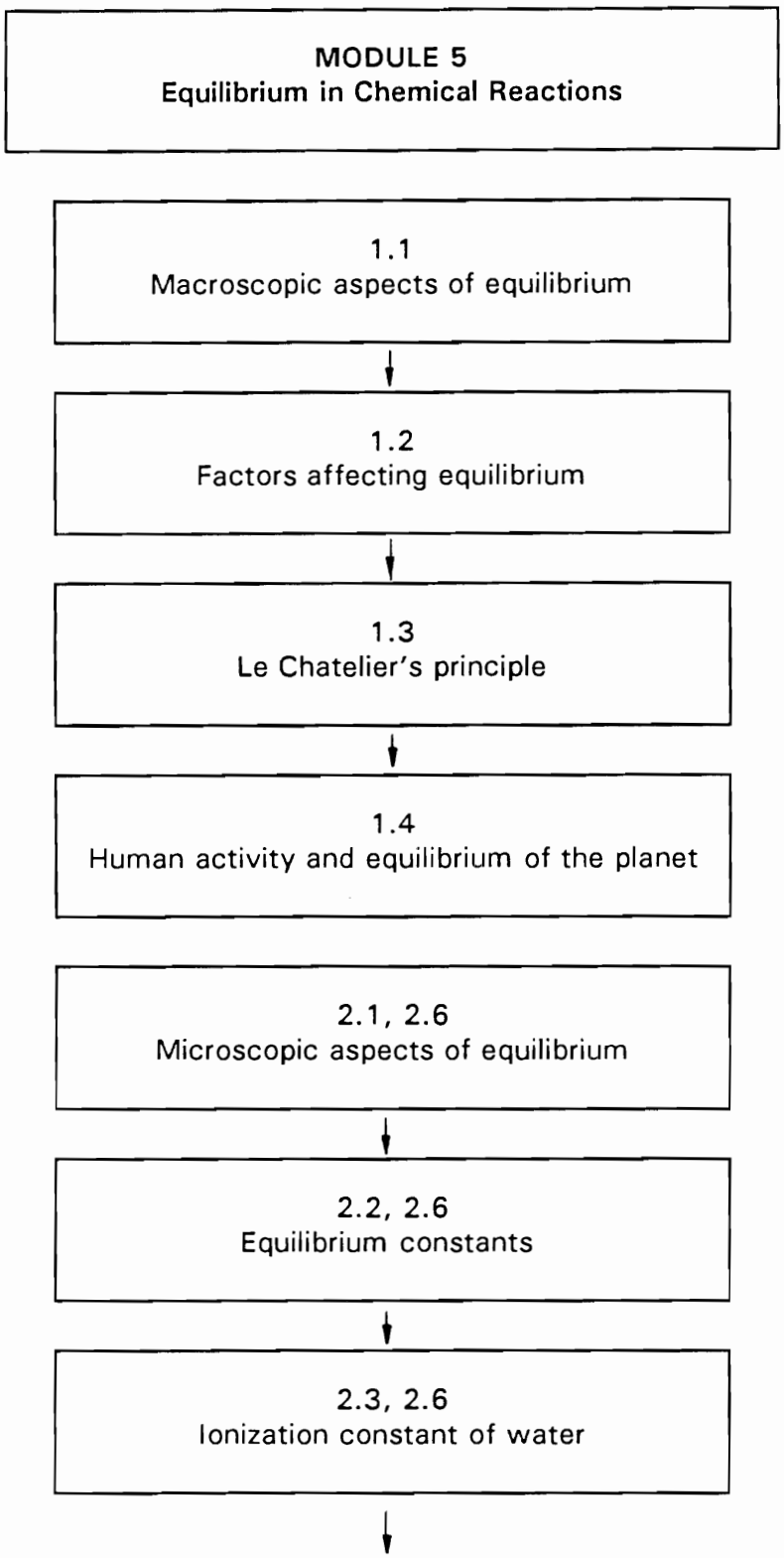
2.3
Kinetic energy, Collision theory

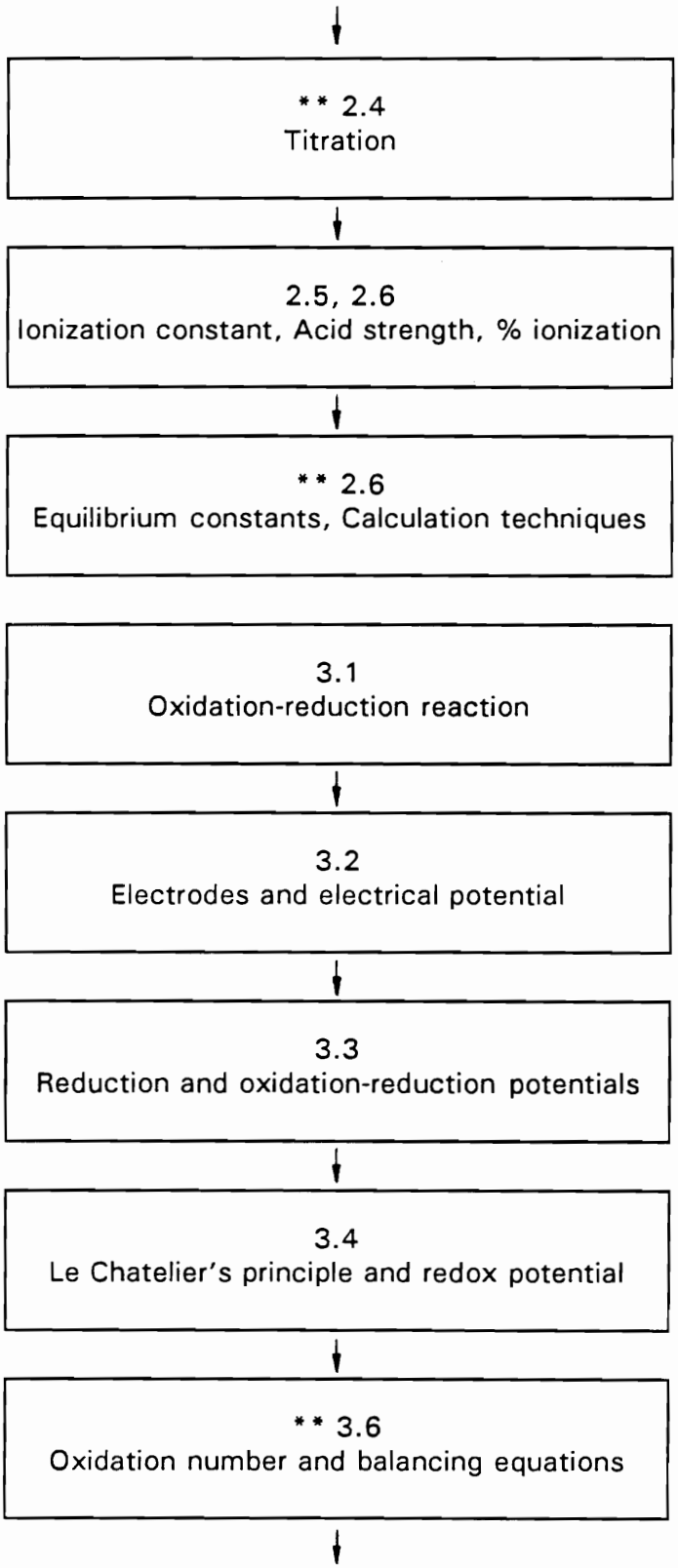
↓

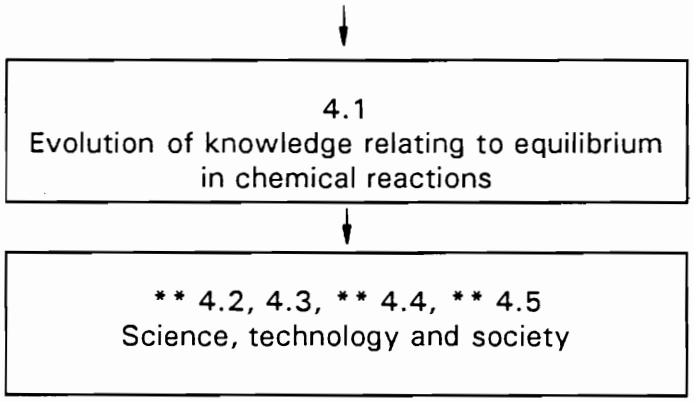
3.1
Evolution of knowledge of reaction rates

↓

** 3.2, 3.3, 3.4, ** 3.5
Science, technology and society


MODULE 5
Equilibrium in Chemical Reactions
1.1
Macroscopic aspects of equilibrium
1.2
Factors affecting equilibrium
1.3
Le Chatelier's principle
1.4
Human activity and equilibrium of the planet
2.1, 2.6
Microscopic aspects of equilibrium
2.2, 2.6
Equilibrium constants
2.3, 2.6
Ionization constant of water


** 2.4
Titration
2.5, 2.6
Ionization constant, Acid strength, % ionization
** 2.6
Equilibrium constants, Calculation techniques
3.1
Oxidation-reduction reaction
3.2
Electrodes and electrical potential
3.3
Reduction and oxidation-reduction potentials
3.4
Le Chatelier's principle and redox potential
** 3.6
Oxidation number and balancing equations


4.1
Evolution of knowledge relating to equilibrium in chemical reactions
** 4.2, 4.3, ** 4.4, ** 4.5
Science, technology and society

6. PROGRAM-GUIDE

MODULE 1: RESEARCH

MODULE 2: GASES AND THEIR APPLICATIONS

MODULE 3: ENERGY IN CHEMICAL REACTIONS

MODULE 4: RATE OF CHEMICAL REACTIONS

MODULE 5: EQUILIBRIUM IN CHEMICAL REACTIONS

MODULE 1

RESEARCH

GENERAL OBJECTIVE: To reinforce and help broaden the students' scientific knowledge by means of a research project that will enable them to integrate what they have learned with environmental concerns.

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

1. **Communicate the results of an experimental or a documentary research project on a chemical phenomenon of their choice, using correct language and emphasizing either its history, technological applications or impact on society and the environment.**

   1.1 Define the research topic.

PREREQUISITES

RELATED CONTENT

- **SKILL:** Recognizing a problem. (C-1)
- **KNOWLEDGE:** Research methodology. (A-7)
- **ATTITUDE:** Intellectual curiosity. (H-5)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Presentation, brainstorming, individual work and teamwork

B. **DURATION:** 50 minutes + homework

C. **EVALUATION:** Originality of the research topic

D. **MATERIALS:** List of research topics, appropriate reference material

E. **SAFETY MEASURES:** N/A

SUGGESTED REFERENCES

S-1, S-2, S-11, S-26, S-28, S-29, S-30, S-37, S-62

LEARNING ACTIVITIES

THE STUDENTS:

1.1.0	Review the research methodology outlined in *Physical Sciences 416-436,* Objective 1 of each module.
1.1.1	Become aware of the list of suggested research topics.
1.1.2	Suggest other research topics that interest them.
1.1.3	Formulate their research topic in terms of a problem to be solved.
1.1.4	Determine which aspects of the topic they will research.
1.1.5	Have their research project approved.

TEACHER'S NOTES

The following topics are grouped by module. Please note that they are only suggestions to which the teacher may refer. Students should draw up their own list of topics and the teacher may propose other relevant topics.

Module 2: Gases and their Applications

- Diffusion rate of a substance or of several substances in a fluid, at various temperatures.
- Quantity of gas in a receptacle (e.g. chemical extinguisher, diving equipment, medical apparatus, dirigible, hot-air balloon).
- Rate of change of the phases of a fluid (e.g. condensation, evaporation, liquefaction).
- Surface tension between various substances and a fluid.
- Gases used to lift large masses (e.g. shock absorber, pneumatic equipment, hot-air balloon).
- Role of gases in various objects (e.g. aerosol, rocket engine, jet engine, sounding balloon, food packaging, packaging of other substances, preservation and ripening of foods, tires, air bags, lamps).
- Role of gases in maintaining life, health, treatment of diseases (e.g. anesthesia, decompression sickness)
- Why some substances will explode if heated (e.g. tires, corn, salt crystals).
- Biographies of individuals who have increased our understanding of gases and who have contributed to the development of technologies that use gases (e.g. Otto von Guericke, Denis Papin, Schule, Joseph and Étienne de Montgolfier, William Murdoch, Arnauld and Giffard, Johannes Diderik Van der Waals, Charles Hermite, Von Linde, Zeppelin, Picard, Gustaf Dalen, Van Helmont, Daniel Bernouilli, John Dalton, Henri Regnault, James Maxwell, Ludwig Boltzman, Josiah Gibbs, James Duvor, Léon Brillouin).
- Any other suitable topic.

Module 3: Energy in Chemical Reactions

- Heat of combustion of different substances (e.g. propane, hexane, ethanol, methanol, vegetable oil, food substances).

- Temperatures in a cylinder (combustion chamber) of an internal combustion engine.

- Various molar heats of substances (e.g. combustion, dissolution, neutralization, reaction).

- Analysis and construction of a precision calorimeter.

- Production and use of different fuels and combustibles (e.g. aluminium, ethanol, hydrogen, oxygen).

- Evolution of the use of substances in chemical reactions.

- Evolution of the calorimeter since its invention.

- Biographies of individuals who have contributed to our understanding of the role of energy in chemical reactions (e.g. Antoine de Lavoisier, Germain Hess, Alfred Nobel, James Watt, Marcelin Berthelot, Robert Bunsen, Hermann von Helmholtz, Dulong and Petit, Pierre de Laplace, Robert Boyle, Joseph Black, Sadi Carnot, Marc Séguin, Walther Nernst).

- Any other suitable topic.

Module 4: Rate of Chemical Reactions

- Reaction rate of various organic and inorganic substances, influenced by different factors (e.g. catalyst, light, heat, concentration, solubility).

- Combustion of mixtures of different substances (e.g. sugar and ash).

- Oscillatory reactions and factors that can influence them.

- Stages in the development of the theory of activation in chemical reactions.

- Use of catalysts in the chemical industry (e.g. plastics, adhesives, petroleum, fibres, diamonds and other synthetic substances).

- Role of catalysts with regard to living beings (e.g. metabolism, digestion, growth), or biodegradable materials and substances (e.g. yogurt, compost).

- Relationship between the composition of a fuel and its octane number.

- Conditions conducive to fuel explosion and applicable safety measures (e.g. maintaining engines, gas stoves, barbecues in good working order).

- Importance of reaction rates with regard to pharmaceutical products (e.g. sun lotion, analgesics, antihistamines).

- Factors that change the reaction rate in the food preservation process.

- Biographies of individuals who have contributed to our understanding of reaction rates in chemical reactions, and who have become well-known for their application of this knowledge (e.g. Fahrenheit, Réamur, Kelvin, Bernard Palissy, Sainte-Claire, Deville, Louis Pasteur, Marcelin Berthelot, Fleming, Paul Sabatier).

- Any other suitable topic.

Module 5: Equilibrium in Chemical Reactions

- Factors that change the state of equilibrium of a chemical reaction.

- Analysis of titration curves of chemical substances (e.g. weak or strong acids and bases, polyacids).

- Study of various constants related to chemical substances: equilibrium constant (K), dissociation constants of acids (K_1), of bases (K_{11}), and of water (K_{111}), the solubility-product constant(K_{sp}), and so on.

- Laboratory experiments involving the concept of chemical equilibrium (e.g. using a battery, a storage cell, a galvanic cell).

- Examining natural or artificial phenomena in relation to the concept of equilibrium (e.g. oxygenation of blood, oxidation of foods and metals, aeration of drinks, formation of stalactites and stalagmites).

- Industrial manufacturing processes involving the concept of equilibrium (e.g. synthesis of chemical substances, metal refining, sacrificial anode, concept of efficiency in a reversible industrial process).

- Impact of Québec's chemical industries on the quality of life (environment and economy) and the development of knowledge (e.g. scientific, technological, sociological, demographical).

- Biographies of individuals who have contributed to our greater understanding of the concept of equilibrium, and who have contributed to the development of technological processes involving the principle of equilibrium (e.g. Marcelin Berthelot, Léon de Saint-Gilles, Henry le Chatelier, Wilhelm Ostwald, Humphry Davy, Michael Faraday, Alessandro Volta, Luigi Galvani, James Duvor, Jacobus Van't Hoff, Fritz Haber, Freiedrick Berjius, Charles Martin Hall).

- Any other suitable topic.

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

1.2 Develop a research plan.

PREREQUISITES

1.1

RELATED CONTENT

- **SKILL:** Developing an experimental procedure or research plan. (C-4)
- **KNOWLEDGE:** Writing an experimental procedure or research plan. (A-7)
- **ATTITUDE:** Willingness to clarify problems. (H-3)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Teamwork, individual work, student-teacher discussions

B. **DURATION:** 75 minutes + homework

C. **EVALUATION:** Quality of the procedure or plan

D. **MATERIALS:** Reference materials

E. **SAFETY MEASURES:** N/A

SUGGESTED REFERENCES

P-1, B-1

THE STUDENTS:

1.2.1	Determine the aim of their research project, specifying the aspects that they will be examining.
1.2.2	Draw up a list of the equipment, substances and reference materials (e.g. bibliography, audio-visual materials, publications, proofs, software) that may be useful to their research.
1.2.3	Determine how they will communicate the results of their research, taking into account the available resources.
1.2.4	Prepare a schedule of the work to be done, taking into account the time allocated.
1.2.5	Have their research plan approved.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

1.3 Carry out the experiment or the research.

PREREQUISITES

1.2

RELATED CONTENT

- **SKILL:** Organizing data. (D-1)
- **KNOWLEDGE:** Experimental and/or research procedures. (A-7)
- **ATTITUDE:** Objectivity. (H-3)

SUGGESTED TEACHING PLAN

A.	**TEACHING STRATEGY:**	Individual and teamwork, library research, laboratory work, interviews, visits
B.	**DURATION:**	175 minutes + homework
C.	**EVALUATION:**	Quality of work methods and techniques
D.	**MATERIALS:**	As required by the experiment or the research
E.	**SAFETY MEASURES:**	According to the materials and experimental procedures used

SUGGESTED REFERENCES

B-1

THE STUDENTS:

1.3.1	Obtain the materials (reference material, equipment for experiments, etc.) necessary for their research.
1.3.2	Consult resource persons, if necessary.
1.3.3	Gather relevant data.
1.3.4	Analyze the data in terms of the problem to be solved.
1.3.5	Draw conclusions based on their analyses and taking into account the aim of their research project.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

1.4 Communicate the results of a research project.

PREREQUISITES

1.3

RELATED CONTENT

- **SKILL:** Communicating. (F-4)
- **KNOWLEDGE:** Rules for writing a scientific report. (A-4)
- **ATTITUDE:** Conscientiousness. (H-3)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Presentation, demonstration, display

B. **DURATION:** 180 minutes + homework

C. **EVALUATION:** Quality of the presentation

D. **MATERIALS:** According to the method of communication used

E. **SAFETY MEASURES:** According to the method of communication used

SUGGESTED REFERENCES

AV-64

THE STUDENTS:

1.4.1	Become aware of the rules for writing a scientific report.
1.4.2	Write a report of the results of their research project according to the appropriate rules.
1.4.3	Use presentation aids (e.g. tables, diagrams, sketches).
1.4.4	Ensure, if necessary, that the material and equipment required for their presentation are available (e.g. projector, video-cassette recorder, films, video-cassettes, photos, slides).
1.4.5	Present and justify, if necessary, the results of their research.
1.4.6	Indicate the difficulties encountered during their research.
1.4.7	Indicate the means used to overcome these difficulties.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

**	1.5	Present the results of their experimental or documentary research at a science fair.

PREREQUISITES

1.4

RELATED CONTENT

-	SKILL:	Communicating. (F-4)
-	KNOWLEDGE:	Presentation methods and techniques applicable to a science fair, techniques for supporting arguments in public. (A-7)
-	ATTITUDE:	Intellectual curiosity. (H-5)

SUGGESTED TEACHING PLAN

A.	TEACHING STRATEGY:	Individual and teamwork, workshop sessions, presentation in public
B.	DURATION:	At least 400 minutes of extra-curricular activity
C.	EVALUATION:	Quality of presentation in accordance with criteria of the science fair
D.	MATERIALS:	According to project and exhibit
E.	SAFETY MEASURES:	According to project and exhibit

SUGGESTED REFERENCES

THE STUDENTS:

1.5.0	Review the methods and techniques for presenting a research report (*Physical Sciences 416-436,* Objective 1 of each module).
1.5.1	Set up their exhibit according to the criteria of the science fair.
1.5.2	Present the results of their work to visitors at the science fair.
1.5.3	Justify their results in discussions.

TEACHER'S NOTES

MODULE 2

GASES AND THEIR APPLICATIONS

GENERAL OBJECTIVE: To investigate by means of the scientific method, the different phases of matter in order to establish a model, to understand some aspects of the behaviour of matter, and to become aware of the influence of matter on society and the environment.

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

1. **Illustrate the relationships among the following: the development of knowledge relating to the behaviour of gases, the use of gases, our quality of life, society and the environment.**

   1.1 Demonstrate how the use of gases influences the development of knowledge relating to gases, our quality of life, society and the environment, using examples of natural phenomena and technological applications that they have observed directly, or that they have researched in reference documents.

PREREQUISITES

RELATED CONTENT

- **SKILL:** Formulating generalizations. (F-2)
- **KNOWLEDGE:** Areas in which gases are used (e.g. geology, industry, recreation, medicine, meteorology), influence of gases. (A-5)
- **ATTITUDE:** Intellectual curiosity. (H-5)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Brainstorming, individual work

B. **DURATION:** 75 minutes + homework

C. **EVALUATION:** Quality of the presentation

D. **MATERIALS:** Reference materials

E. **SAFETY MEASURES:** N/A

SUGGESTED REFERENCES

AV-18, AV-19, AV-20, P-2, P-3, P-4, P-5, P-6, B-3, B-6, B-7, B-8, B-13, B-82, B-83, B-84, B-85, B-86, B-87

LEARNING ACTIVITIES

THE STUDENTS:

1.1.1	Identify the natural phenomena and technological applications in their environment that involve gases.
1.1.2	Assess the economic and social impact of at least two of the examples identified.
1.1.3	Assess the influence of at least two of these examples on our quality of life.
1.1.4	Assess the impact of at least two of these examples on the biological and physical environment.
1.1.5	Assess the influence of at least two of these examples on the development of knowledge.
1.1.6	Write a report on their assessments.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

1.2 Describe the reciprocal influences of society and (the development of) knowledge relating to gases and their applications, using reference materials.

PREREQUISITES

1.1

RELATED CONTENT

- **SKILL:** Recognizing a problem. (C-1)
- **KNOWLEDGE:** Relationship between society and research (e.g. war and gases, energy and plasmas, the Montréal protocol on the use of CFCs). (A-1)
- **ATTITUDE:** Sense of responsibility. (I-5)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Brainstorming, individual work, presentation, class discussion

B. **DURATION:** 50 minutes + homework

C. **EVALUATION:** Quality of arguments

D. **MATERIALS:** Reference materials

E. **SAFETY MEASURES:** N/A

SUGGESTED REFERENCES

AV-8, AV-21, AV-22, AV-63, AV-64, P-4, P-7, P-17, P-49, P-54, B-9, B-10, B-11, B-12, B-13, B-14, B-15, B-16, B-17, B-18, B-19, B-85, B-86, B-87

LEARNING ACTIVITIES

THE STUDENTS:

1.2.1	Provide examples showing how individuals "in positions of power" in the private and public sector influence public opinion, and vice-versa.
1.2.2	Become aware that individuals "in positions of power" influence the creation and mission of research centres.
1.2.3	Illustrate how public opinion and political decisions can affect the development of research into gases, based on examples from early and recent history.
1.2.4	Become aware that scientists can influence the laws and regulations governing the use of gases.
1.2.5	Illustrate how knowledge of the behaviour of gases is used to charm spectators, based on examples from the history of magic.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

2. **Predict the behaviour of an "ideal" gas influenced by various factors, using mathematical models inferred from observing real-gas phenomena.**

   2.1 Identify factors that affect the volume of a gas, based on observations of technological applications or of natural phenomena.

PREREQUISITES

1.1

RELATED CONTENT

- **SKILL:** Observing. (B-1)
- **KNOWLEDGE:** Factors that affect the volume of a gas. (A-1)
- **ATTITUDE:** Objectivity. (H-3)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Brainstorming, demonstration, simulation, class discussion

B. **DURATION:** 50 minutes

C. **EVALUATION:** Quality of the observations

D. **MATERIALS:** Reference materials, balloon, double boiler, hot plate, compressed gases, bicycle pump, vacuum pump, air compressor, etc.

E. **SAFETY MEASURES:** Protection from heat

SUGGESTED REFERENCES

AV-1, AV-2, AV-3, S-5, S-6, S-7, P-8, P-39, B-8, B-9, B-16, B-20, B-21, B-22

THE STUDENTS:

2.1.0	Review the concept of pressure (*Physical Sciences*: Code 16-3174-01A, Module IV).
2.1.1	Think about factors that can influence the volume of a gas.
2.1.2	Discuss their ideas with their classmates.
2.1.3	Observe the effects of the pressure, temperature and quantity of a gas on its volume, using the appropriate means.
2.1.4	Discuss the combined effect of several of these factors on the volume of a gas.
2.1.5	Predict how changes in the volume of a gas will influence these factors.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

2.2 Analyse the effect of various factors on the volume of a gas, based on an experiment.

PREREQUISITES

2.1

RELATED CONTENT

- **SKILL:** Organizing data. (D-2)
- **KNOWLEDGE:** Gay-Lussac's law, Charles's law, Boyle-Mariotte's law, graphic interpretation of laws. (A-8)
- **ATTITUDE:** Sense of responsibility. (G-3)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Teamwork, group work in a laboratory, individual work, class discussion, simulation

B. **DURATION:** 150 minutes + homework

C. **EVALUATION:** Participation in the group experiment

D. **MATERIALS:** 5 mL, 10 mL, and 30 mL syringes, 30 cm of rubber tubing, 20 mL graduated cylinder, 250 mL and 600 mL beakers, water, thermometer, syringe plugs, ice, hot plate, 45 cm wire, buret clamps, universal support, set of hooked weights (200 - 1 000 g), no. 10 one-hole stopper, 10 cm of glass tube, serum stopper, syringe needles, plastic bag, elastic, reference materials

E. **SAFETY MEASURES:** For glassware, heat, needles

SUGGESTED REFERENCES

AV-4, AV-5, AV-8, AV-63, S-8, S-9, B-8, B-13, B-23, B-24, B-25

THE STUDENTS:

2.2.0	Review the concept of direct and inverse proportional equations (*Secondary School Curricula: Mathematics*). Review graphs of direct and inverse proportional equations. Review the concept of constant of proportionality.
2.2.1	Predict how each of the factors listed in 1.1 (p. 66) will affect the volume of a gas.
2.2.2	Propose a graph to illustrate the predicted effects.
2.2.3	Express their predictions as mathematical equations.
2.2.4	Justify their predictions to their classmates.
2.2.5	Verify their hypotheses by means of one of the suggested experimental procedures.
2.2.6	Compare their results with their hypotheses
2.2.7	Write their results in the table used to compile the group's results.
2.2.8	Discuss the differences in the results obtained by their classmates, if necessary.
2.2.9	Change the mathematical equations formulated in 2.2.3, if necessary.
2.2.10	Compare the mathematical equations suggested with the equations proposed by Boyle, Charles, Gay-Lussac and Mariotte, by referring to the history of the study of gases.
2.2.11	Become aware of the importance of observing safety rules when working in the laboratory, by reading about various incidents (e.g. Gay-Lussac's serious accidents which occurred in spite of his legendary abilities as a scientist.
2.2.12	Write a report of their laboratory work.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

2.3 Construct a temperature scale consisting of only positive values, based on the results obtained from their laboratory experiments.

PREREQUISITES

2.2

RELATED CONTENT

- **SKILL:** Interpreting data. (D-4)
- **KNOWLEDGE:** History of temperature scales, graphic extrapolation techniques, Kelvin scale (absolute).
- **ATTITUDE:** Willingness to solve problems. (H-3)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Class discussion, teamwork and individual work

B. **DURATION:** 50 minutes

C. **EVALUATION:** Quality of arguments

D. **MATERIALS:** Results of the experiment in 1.2

E. **SAFETY MEASURES:** N/A

SUGGESTED REFERENCES

S-10, S-11, S-12, S-20, P-9, P-10, P-11, B-24, B-25, B-26, B-27, B-28

THE STUDENTS:

2.3.1	Predict the values of the volume occupied by a gas at 0°C, and at temperatures below 0°C.
2.3.2	Justify their hypothesis to their classmates.
2.3.3	Determine the temperature at which the volume of the gas used in 2.2 would be zero, using a volume/temperature graph.
2.3.4	Compare the values of their extrapolations with those of their classmates.
2.3.5	Propose a temperature scale consisting of only positive values.
2.3.6	Compare their proposals with those of their classmates, and select one for further study.
2.3.7	Compare the selected proposal with Rudolf Clausius' theory (19th century).
2.3.8	Discuss the effects of knowing these values on Gay-Lussac's work.
2.3.9	Describe the history of the development of various temperature scales, using reference materials.
2.3.10	Identify scientists' contributions to the development of various temperature scales (e.g. Celsius, Clausius, Fahrenheit, Galileo, Rankine, Réaumur, Röwer, Thomson).

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

2.4 Use the appropriate means to establish a relationship between equal volumes of various gases and the number of molecules they contain, given the same temperature and pressure.

PREREQUISITES

2.2

RELATED CONTENT

- **SKILL:** Formulating a hypothesis. (C-2)
- **KNOWLEDGE:** Avogadro's principle (or law), reasons for the delay in adopting this principle. (A-8)
- **ATTITUDE:** Willingness to clarify a problem. (H-3)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Demonstration, teamwork, class discussion, simulation, presentation

B. **DURATION:** 100 minutes

C. **EVALUATION:** Validity of hypotheses

D. **MATERIALS:** Power source, rheostat, curved electrodes (platinium, stainless steel), connection wires with clamps, 600 mL beaker, 2 x 10 mL graduated cylinders, NaOH (2 mol/L), HCl (2 mol/L), colorant, reference materials

E. **SAFETY MEASURES:** For glassware, toxic substances

SUGGESTED REFERENCES

AV-8, AV-9, AV-10, AV-11, AV-63, S-13, S-14, S-15, S-16, P-12, B-14, B-15, B-17, B-29, B-30

LEARNING ACTIVITIES

THE STUDENTS:

2.4.0	Review Dalton's atomic model (*Physical Sciences 416-436*, Module I: 4.3). Review the concept of stoichiometry (*Physical Sciences 416-436*, Module III: 5.6). Review the results of water electrolysis (*Physical Sciences 416-436*, Module I: 6.1).
2.4.1	Predict the number of molecules in two equal volumes of different gases, after observing a demonstration.
2.4.2	Compare their predictions with those of their classmates.
2.4.3	Formulate a hypothesis regarding the number of molecules contained in two volumes of gas at different temperatures and pressures.
2.4.4	Discuss one another's hypotheses and select one for further study.
2.4.5	Verify the selected hypothesis, using the appropriate means (e.g. balanced equations, software, videos).
2.4.6	Compare the selected hypothesis with Avogadro's principle (18th - 19th century).
2.4.7	Identify the reasons why the scientific community of the early 19th century took a while to adopt Avogadro's principle, using the appropriate reference materials.
2.4.8	Briefly describe the roles that Ampere and Cannizzaro played in the development of Avogadro's principle.
2.4.9	Propose a rule for naming a principle, a law or a theory on which two or more scientists have worked.
2.4.10	Compare an application of their rule with existing examples (e.g. Boyle-Mariotte, Avogadro-Ampere, Charles-Gay-Lussac, Snell-Descartes, Dulong et Petit).

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

2.5 Express in the form of a single mathematical equation, the results of the analysis of the behaviours of a gas under different conditions.

PREREQUISITES

2.3, 2.4

RELATED CONTENT

- **SKILL:** Constructing a model. (E-2)
- **KNOWLEDGE:** Ideal gas law: $PV = nRT$, definition of an ideal gas, postulates of the kinetic theory relating to ideal gases. (A-9)
- **ATTITUDE:** Willingness to synthesize and apply knowledge. (I-1)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Class discussion, individual work, laboratory work, teamwork, simulation

B. **DURATION:** 150 minutes + homework

C. **EVALUATION:** Quality of arguments

D. **MATERIALS:** 5 mL, 10 mL, 30 mL syringes, 30 cm of rubber tubing, 20 mL graduated cylinder, 250 mL and 600 mL beakers, water, thermometer, syringe plugs, ice, hot plate, 45 cm wire, buret clamps, universal support, set of hooked weights (200 g - 1000 g), No. 10 one-hole stopper, 10 cm of glass tubing, serum stopper, syringe needles, plastic bag, elastic, reference materials

E. **SAFETY MEASURES:** N/A

SUGGESTED REFERENCES

S-11, S-16, S-17, S-18, S-20, AV-6, P-13, B-23, B-24, B-25, B-31

THE STUDENTS:

2.5.1	Formulate hypotheses regarding the behaviour of a gas under different conditions, based on the results obtained from the experiment in 2.2 and knowledge acquired in 2.4.
2.5.2	Compare one another's hypotheses and select some for further study.
2.5.3	Develop an experimental procedure to test each of the selected hypotheses.
2.5.4	Present their results in graphic form.
2.5.5	Determine the constant of proportionality in the mathematical equation that links all the factors influencing the behaviour of a gas, based on an analysis of the graphs.
2.5.6	Discuss their result with their classmates.
2.5.7	Find a conventional value for the constant of proportionality, based on the discussion.
2.5.8	Determine the unit of the constant of proportionality, baesd on an unit analysis of the values of the variables in the mathematical equation that was established.
2.5.9	Discuss the expression "ideal gas" or "perfect gas" used in the laws.
2.5.10	Write a report on their work.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

2.6 Determine the value of the ideal-gas constant, based on an experiment dealing with the volume occupied by one mole of gas.

PREREQUISITES

2.1, 2.4, 2.5

RELATED CONTENT

-	**SKILL:**	Measuring. (B-3)
-	**KNOWLEDGE:**	Avogadro's number (N), molar constant of gases (R), Boltzman's constant (k), techniques for measuring the molar volume of a gas, calculating the molar volume of a gas. (A-7)
-	**ATTITUDE:**	Creative approach to science. (H-3)

SUGGESTED TEACHING PLAN

A.	**TEACHING STRATEGY:**	Individual work, class discussion, group work in the laboratory
B.	**DURATION:**	125 minutes + homework
C.	**EVALUATION:**	Quality of the measurements
D.	**MATERIALS:**	140 mL syringe, nail, syringe plug (screw-type), O_2, N_2, CO_2, etc., balance ($\pm$ 0.01 g), thermometer, barometer, table for compiling the group's results
E.	**SAFETY MEASURES:**	For handling syringe needles, pressurized gas

SUGGESTED REFERENCES

AV-8, AV-11, AV-12, AV-63, S-19, P-14, P-15, B-13, B-14, B-15, B-27, B-32, B-33

THE STUDENTS:

2.6.0	Review the concept of atomic mass (*Physical Sciences 416-436*, Module I: 5.1).
	Review the concept of mole (*Physical Sciences 416-436*, Module III: 3.3).
	Review the concept of molar mass (*Physical Sciences 416-436*, Module III: 3.5).
2.6.1	Imagine the size of the volume occupied by one mole of gas.
2.6.2	Suggest means for determining the volume occupied by one mole of gas at surrounding temperature and pressure conditions.
2.6.3	Compare their suggestions with those of their classmates.
2.6.4	Develop an experimental procedure to verify one of the means suggested, taking into account the materials available.
2.6.5	Write their results in the table used to compile the group's results.
2.6.6	Determine the constant of proportionality in the relationship between the factors that influence the behaviour of one mole of gas, using the mathematical equation established in 2.5.
2.6.7	Compare their results with those of their classmates, and select one for further study.
2.6.8	Compare the selected value of the constant of proportionality with the generally accepted value.
2.6.9.	Change, if necessary, the mathematical equation established in 2.5.
2.6.10	Learn the value of Avogadro's constant.
2.6.11	Determine the unit of the constant of proportionality, by means of unit analysis.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

2.7 Identify an unknown gas by means of a group experiment or a simulation.

PREREQUISITES

2.5

RELATED CONTENT

- **SKILL:** Formulating generalizations. (F-1)
- **KNOWLEDGE:** Techniques for identifying a gas, molar mass and other properties of a gas, $PV = \frac{m}{M} RT$. (A-10)
- **ATTITUDE:** Willingness to synthesize and apply knowledge. (F-1)

SUGGESTED TEACHING PLAN

A.	**TEACHING STRATEGY:**	Individual work, laboratory work, simulation, class discussion
B.	**DURATION:**	100 minutes + homework
C.	**EVALUATION:**	Quality of the experimental procedure
D.	**MATERIALS:**	140 mL syringe, nail, syringe plug (screw-type), O_2, N_2, CO_2, etc., balance (± 0.01 g), test tubes (13 mm x 100 mm), rubber stoppers, limewater, wood splints, matches, reference materials
E.	**SAFETY MEASURES:**	For handling syringe needles, glassware, heat

SUGGESTED REFERENCES

AV-8, AV-63, S-12, B-8, B-13, B-14, B-15, B-24, B-30, B-31, B-32

THE STUDENTS:

2.7.0	Review the identification of substances on the basis of their characteristic properties (*Physical Sciences* 416-436, Module I: 2.1). Review the concept of molar mass (*Physical Sciences 416-436*, Module III: 3.5).
2.7.1	Discuss methods of identifying a gas and select some for further study.
2.7.2	Develop an experimental procedure to verify one of the selected methods.
2.7.3	Describe their results in the table used to compile the group's results.
2.7.4	Confirm their results by referring to another characteristic property of the gas.
2.7.5	Write a report on their work.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

** 2.8 Determine the total pressure of a gas mixture, based on an experiment.

PREREQUISITES

2.2, 2.4

RELATED CONTENT

- **SKILL:** Organizing data. (D-2)
- **KNOWLEDGE:** Dalton's law of partial pressures, use of a manometer. (A-8)
- **ATTITUDE:** Willingness to clarify problems. (H-3)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Teamwork, laboratory work, individual work, class discussion

B. **DURATION:** 150 minutes + homework

C. **EVALUATION:** Quality of the justifications for the prediction

D. **MATERIALS:** 250 mL filtering flask, one-hole stopper, 10 cm of glass tubing, serum stopper, 15 cm of rubber tubing, manometer, 30 mL syringe, universal support, buret clamps, aneroid barometer, He, O_2, reference materials

E. **SAFETY MEASURES:** For glassware, pressurized gas

SUGGESTED REFERENCES

AV-7, AV-8, AV-63, S-16, S-20, B-14, B-15, B-23, B-26, B-35

LEARNING ACTIVITIES

THE STUDENTS:

2.8.0	Review the concept of and unit of measurement for atmospheric pressure (*Physical Sciences* Code 16-3174-01A, Module I).
2.8.1	Predict the change in pressure that results from adding gas to a given volume maintained at a constant temperature.
2.8.2	Discuss one another's predictions and select some for further study.
2.8.3	Develop an experimental procedure to verify the selected predictions.
2.8.4	Identify the causes of possible errors other than those due to the calibration of the instruments.
2.8.5	Indicate the possible effect of these errors on the results of the measurements.
2.8.6	Propose a mathematical equation to represent the relationship between the total pressure of a gas mixture and the pressure of each gas.
2.8.7	Compare their proposal with those of their classmates and select one for further study.
2.8.8	Compare the selected proposal with Dalton's equation.
2.8.9	Describe how John Dalton contributed to developing scientific knowledge of the gaseous phase of matter.
2.8.10	Illustrate the technological applications of Dalton's law of partial pressures.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

2.9 Apply their knowledge of the behaviour of gases to solve problems and to do numerical and graphical exercises.

PREREQUISITES

2.2, 2.3, 2.4, 2.5, 2.6, 2.7

RELATED CONTENT

-	**SKILL:**	Interpreting data. (D-1)
-	**KNOWLEDGE:**	Application of mathematical models to the behaviour of gases. (A-7)
-	**ATTITUDE:**	Conscientiousness. (H-3)

SUGGESTED TEACHING PLAN

A.	**TEACHING STRATEGY:**	Individual work and teamwork, laboratory work, simulation
B.	**DURATION:**	100 minutes + homework
C.	**EVALUATION:**	Calculation techniques and graphic analysis
D.	**MATERIALS:**	According to the situations or problems presented, calculator (optional)
E.	**SAFETY MEASURES:**	According to the situations or problems presented

SUGGESTED REFERENCES

S-13, B-25, B-35, B-36

THE STUDENTS:

2.9.1	Read each problem carefully and identify the data needed to solve it.
2.9.2	Relate the appropriate units of measure to the physical quantities used in each problem.
2.9.3	Use mathematical operations correctly in solving problems.
2.9.4	Estimate the magnitude of the solution, by comparing the values stated.
2.9.5	Verify the plausibility of the solution, by means of unit analysis.
2.9.6	Verify the plausibility of the solution by order of magnitude.
2.9.7	Verify the plausibility of the solution by means of a simulation.
2.9.8	Present the most elegant solution.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

3. **Explain natural or technologically-induced phenomena involving matter in its different phases, using the molecular model already explored and their knowledge of the behaviour of gases.**

   3.1 Identify the uses of substances in a given phase, in natural or human-made objects, based on the characteristic properties of the phases of matter.

PREREQUISITES

2.2

RELATED CONTENT

- **SKILL:** Recognizing a problem. (C-1)
- **KNOWLEDGE:** Properties of the phases of matter. (A-1)
- **ATTITUDE:** Objectivity. (H-3)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Brainstorming, class discussion

B. **DURATION:** 50 minutes

C. **EVALUATION:** Quality of the justifications

D. **MATERIALS:** Reference materials

E. **SAFETY MEASURES:** N/A

SUGGESTED REFERENCES

AV-8, AV-63, S-8, S-22, S-23, P-17, P-18, P-19, P-46, P-47, B-7, B-14, B-15, B-18, B-26, B-28, B-37, B-38, B-39

THE STUDENTS:

3.1.0	Review the concept of the characteristic properties of matter (*Physical Sciences 416-436*, Module I: 2.2).
3.1.1	List the characteristic properties of each of the phases of matter.
3.1.2	Associate natural or technologically-induced phenomena with the properties listed.
3.1.3	Justify the use of substances in a given phase of matter, in natural or human-made objects, based on the characteristic properties of phases.
3.1.4	Predict the behaviour of the molecules in each phase of the matter used.
3.1.5	Compare their predictions with those of their classmates.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

3.2 Interpret the behaviour of matter in each of its phases, based on a molecular model and their knowledge of gases.

PREREQUISITES

3.1

RELATED CONTENT

- **SKILL:** Observing. (B-1)
- **KNOWLEDGE:** Brownian motion, diffusion. (A-7)
- **ATTITUDE:** Objectivity. (H-3)

SUGGESTED TEACHING PLAN

A.	**TEACHING STRATEGY:**	Demonstration, brainstorming, teamwork, group work in the laboratory, class discussion
B.	**DURATION:**	100 minutes
C.	**EVALUATION:**	Quality of the interpretation
D.	**MATERIALS:**	Mechanical model of the molecular motion, 100 mL beakers, water (at room temperature), hot water, test tubes (18 mm x 50 mm), colourless gelatin, $KMnO_4$ crystals, $CuSO_4$ crystals, $CoSO_4$ crystals, chronometer, thermometer, freshly-cut piece of metal from an old tin can, freshly-cut piece of metal from a recently manufactured tin can, microscope, apparatus to observe Brownian motion, vacuum pump and bell-jar, balloon-flask, metal can, elastic, steel ball, table to compile group's results, reference materials
E.	**SAFETY MEASURES:**	For glassware, chemical solutions

SUGGESTED REFERENCES

AV-2, AV-10, AV-13, S-24, S-25, P-20, P-21, P-22, P-53, B-8

THE STUDENTS:

3.2.0	Review the concept of atmospheric pressure (*Physical Sciences*: Code 16-3174-01A, Module I). Review the concept of homogeneous solution (*Physical Sciences*: Code 16-3174-01A, Module III) Review the concept of the discontinuous theory of the structure of matter (*Physical Science 416-436*, Module I: 4.1).
3.2.1	Observe the behaviour of a mechanical model simulating molecular motion in the gaseous phase, during a demonstration.
3.2.2	Predict the behaviour of the mechanical model in the other phases of matter.
3.2.3	Compare their predictions with those of their classmates.
3.2.4	Observe the phenomenon of substance diffusion in each of the phases of matter, using the appropriate means.
3.2.5	Propose a model to interpret their observations.
3.2.6	Describe how phase changes can be used to create illusions, using examples from stage shows (scenography).
3.2.7	List the arguments that Robert Brown used to support his theory regarding the motion of molecules in a fluid.
3.2.8	Discuss the diffusion rate of various substances.
3.2.9	Discuss, with their classmates, a model that can represent the displacement of molecules within a same substance.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

3.3 Illustrate possible molecular motions in the different phases of matter, using a molecular model.

PREREQUISITES

3.2

RELATED CONTENT

- **SKILL:** Constructing a model. (E-6)
- **KNOWLEDGE:** Molecular model of the translation, rotation and oscillation of molecules (vibration), history. (A-3)
- **ATTITUDE:** Creative approach to science. (H-3)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Individual work and teamwork, simulation, laboratory work, class discussion

B. **DURATION:** 75 minutes + homework

C. **EVALUATION:** Quality of the simulations

D. **MATERIALS:** Molecular models, materials required for the proposed experiments or demonstrations, reference materials

E. **SAFETY MEASURES:** According to the experiments and demonstrations carried out

SUGGESTED REFERENCES

AV-2, AV-12, AV-13, AV-37, AV-65, S-25, P-23, B-40, B-42

THE STUDENTS:

3.3.1	Become aware of mechanical representations that scientists have made of molecular motions for each phase of matter.
3.3.2	Propose demonstrations or experiments that simulate the existence of these different molecular motions in matter.
3.3.3	Discuss these proposals with their classmates.
3.3.4	Carry out some of these demonstrations or experiments.
3.3.5	Associate natural phenomena with these simulations.
3.3.6	Think about whether these simulations are valid ways of describing the behaviour of matter at extreme temperature/pressure conditions (e.g. plasmas, 0° on the Kelvin scale).
3.3.7	Show how the following individuals contributed to the development of the kinetic theory of matter: Daniel Bernouilli (18th-19th cent.), Robert Brown (18th-19th cent.), Sadi Carnot (18th-19th cent.), Rudolph Clausius (19th cent.), based on reference materials
3.3.8	Show how Ludwig Boltzman's work on the concept of statics bridged the gap between the classical theories (19th century) and the quantum theories (20th century) in explaining the properties of matter.
3.3.9	Comment on this statement: "The interpretation of a phenomenon is an abstract and symbolic representation corresponding to the theories acknowledged by the researcher."
3.3.10	Write a report on their work.

TEACHER'S NOTES

MODULE 3

ENERGY IN CHEMICAL REACTIONS

GENERAL OBJECTIVE: To investigate by means of the scientific method, various chemical changes in order to discover their effects, to understand the resultant energy transfer and to become aware of the impact of these changes on society and the environment.

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

1. **Define different changes in substances, based on knowledge they have acquired from observing and analysing energy changes occurring during chemical and physical reactions.**

   1.1 Identify chemical and physical changes that release more energy than they absorb, based on what they have observed in their environment and in the laboratory.

PREREQUISITES

RELATED CONTENT

- **SKILL:** Observing. (B-1)
- **KNOWLEDGE:** Energy released during chemical reactions. (A-1)
- **ATTITUDE:** Fascination with science. (H-3)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Brainstorming, individual work and teamwork, demonstration, class discussion

B. **DURATION:** 75 minutes + homework

C. **EVALUATION:** Quality of their observations

D. **MATERIALS:** According to chemical solution used

E. **SAFETY MEASURES:** According to the chemical solution used

SUGGESTED REFERENCES

AV-14, AV-15, AV-16, AV-17, S-7, S-26, S-27, S-28, S-30, B-8, B-9, B-11, B-16, B-20, B-21, B-24, B-33, B-34, B-43

THE STUDENTS:

1.1.0	Review the concept of energy transfer (*Secondary School Curricula: Ecology, Human Biology, General Biology 535-534*). Review the concepts of physical and chemical changes (*Physical Sciences 416-436*, Module I: 3.2). Review the concept of forms of energy (*Physical Sciences 416-436*, Module II: 6.1).
1.1.1	List the changes in matter from their environment that involve a release of energy.
1.1.2	Feel the energy released from a solution.
1.1.3	Classify these changes as either chemical or physical.
1.1.4	For each change listed above, indicate the form of energy released.
1.1.5	Identify the form of energy that is most often released when these changes occur.
1.1.6	Identify, from among the changes listed above, those that must be initiated by an energy source.
1.1.7	Briefly describe a change in matter that involves a release of energy.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

1.2 Identify, based on what they have observed in their environment and in the laboratory experiments, chemical and physical changes that absorb more energy that they release.

PREREQUISITES

RELATED CONTENT

- **SKILL:** Observing. (B-1)
- **KNOWLEDGE:** Energy absorption during chemical reactions. (A-1)
- **ATTITUDE:** Fascination with science. (H-3)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Brainstorming, individual work and teamwork, demonstration, class discussion

B. **DURATION:** 50 minutes + homework

C. **EVALUATION:** Quality of the description

D. **MATERIALS:** According to the chemical solution used

E. **SAFETY MEASURES:** According to the chemical solution used

SUGGESTED REFERENCES

AV-14, AV-15, AV-16, AV-17, S-7, S-26, S-27, S-28, S-30, B-8, B-9, B-11, B-16, B-20, B-21, B-28, B-42

THE STUDENTS:

1.2.1	List the changes in matter from their environment that absorb energy.
1.2.2	Feel the energy absorbed during a solution.
1.2.3	Classify these changes as being either chemical or physical.
1.2.4	Indicate the form of energy used to produce each change listed above.
1.2.5	Identify the form of energy that is most often used to produce these changes.
1.2.6	Briefly describe a change in matter that involves the absorption of energy.
1.2.7	Discuss the possibility that thermal energy could be simultaneously absorbed and released when a change in matter occurs.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

1.3 Classify chemical and physical changes as either exothermic or endothermic, after observing demonstrations and carrying out experiments.

PREREQUISITES

1.1, 1.2

RELATED CONTENT

- **SKILL:** Developing an experimental procedure. (C-4)
- **KNOWLEDGE:** Definitions of exothermic and endothermic reactions. (A-6)
- **ATTITUDE:** Willingness to interpret information. (H-3)

SUGGESTED TEACHING PLAN

A.	**TEACHING STRATEGY:**	Teamwork, laboratory work, demonstration, individual work, class discussion
B.	**DURATION:**	175 minutes + homework
C.	**EVALUATION:**	Quality of the classification
D.	**MATERIALS:**	Balance, scoop, thermometer, test tube (18 mm x 150 mm), water, Drano, soluble fertilizer, $NaNO_3$, hydrogen-filled balloon, string, 2 m rod, matches, 100 mL beaker, NH_4SCN, $Ba(OH)_2 .8H_2O$, stirring rod, thermometer, 250 mL beaker, NaCl, Mg strip, Cu wire (No. 16), quartz clock or small generating device, connection wire with clamps, overhead projector, petri dish, KI solution (1 mol/L), phenolphthalein, C electrodes, 6V power source, connection wire with clamps, reference materials
E.	**SAFETY MEASURES:**	For handling hydrogen, corrosive substances, glassware

SUGGESTED REFERENCES

AV-8, AV-63, P-23, P-43, B-8, B-9, B-14, B-15, B-26

LEARNING ACTIVITIES

THE STUDENTS:

1.3.1	Observe demonstrations of chemical and physical changes that involve heat energy.
1.3.2	Classify the changes observed as changes that either release or absorb heat energy.
1.3.3	Compare their classification with those of their classmates.
1.3.4	Develop an experimental procedure to determine whether chemical or physical changes release or absorb heat energy, using the material available.
1.3.5	Compare their results with those of their classmates.
1.3.6	Add the changes observed to their own classification.
1.3.7	Predict the source of the released energy or the destination of the absorbed energy for the changes observed.
1.3.8	Compare their predictions with those of their classmates.
1.3.9	Suggest definitions for exothermic and endothermic, based on etymology.
1.3.10	Validate their definitions by consulting reference books.
1.3.11	Find out when chemists first used these terms.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

2. **Demonstrate the rules governing the transfer of energy that occurs during chemical reactions, based on their scientific work.**

   2.1 Analyse the transfer of heat energy that occurs during the formation of a mixture, using measurements and calculations.

PREREQUISITES

1.3

RELATED CONTENT

- **SKILL:** Measuring. (B-3)
- **KNOWLEDGE:** Energy transfer laws: m_1, c_1, ΔT_1 = m_2, c_2, ΔT_2. (A-8)
- **ATTITUDE:** Self-confidence. (I-4)

SUGGESTED TEACHING PLAN

A.	**TEACHING STRATEGY:**	Brainstorming, teamwork, laboratory work, individual work, class discussion
B.	**DURATION:**	125 minutes + homework
C.	**EVALUATION:**	Quality of the report
D.	**MATERIALS:**	Polystyrene cups, 100 mL graduated cylinder, hot and cold water, thermometer, pieces of corrugated cardboard (15 cm x 15 cm) or cup lids
E.	**SAFETY MEASURES:**	For glassware, heat, recycling cups

SUGGESTED REFERENCES

AV-8, AV-63, S-11, S-31, S-32, S-33, P-24, B-11, B-14, B-15, B-16, B-20, B-21, B-24, B-32, B-33, B-44, B-60

THE STUDENTS:

2.1.0	Review the concept of mixtures (*Physical Sciences*: Code16-3174-01A, Module III). Review the concept of heat energy (*Physical Sciences 416-436*, Module II: 5.2).
2.1.1	List examples from everyday life in which heat energy is transferred from one substance to another.
2.1.2	Propose a description of what happens during these energy transfers.
2.1.3	Compare their proposals with those of their classmates.
2.1.4	Develop an experimental procedure to determine the amount of heat energy released and absorbed by each of the substances during the formation of a mixture.
2.1.5	Carry out the experiment.
2.1.6	Suggest a mathematical equation to represent the relationship between the amounts of energy transferred, based on the results of the experiment.
2.1.7	Discuss their suggestions with their classmates.
2.1.8	Write up a report on their work.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

2.2 Determine the amount of heat energy involved when one mole of a substance is dissolved, based on a laboratory experiment.

PREREQUISITES

2.1

RELATED CONTENT

-	**SKILL:**	Developing an experimental procedure. (C-4)
-	**KNOWLEDGE:**	Specific heat of solution (Δh), molar heat of solution (ΔH), techniques for determining the value of Δh and ΔH, heat capacity (C), molar heat capacity (Cm) of water, units of measurement. (A-7)
-	**ATTITUDE:**	Conscientiousness. (H-3)

SUGGESTED TEACHING PLAN

A.	**TEACHING STRATEGY:**	Teamwork, laboratory work, class discussion
B.	**DURATION:**	150 minutes + homework
C.	**EVALUATION:**	Quality of the experimental procedure.
D.	**MATERIALS:**	LiCl, $NaNO_3$, $NaOH_{(s)}$, water, polystyrene cups, pieces of corrugated cardboard (15 cm x 15 cm) or cup lids, thermometer, scoop, balance (± 0.01 g)
E.	**SAFETY MEASURES:**	For glassware, chemicals, recycling cups

SUGGESTED REFERENCES

AV-8, AV-63, S-22, S-26, S-29, S-34, B-14, B-15, B-21, B-24, B-32

LEARNING ACTIVITIES

THE STUDENTS:

2.2.0	Review the concept of solution (*Physical Sciences*: Code 16-3174-01A, Module III). Review the concept of specific heat of solution (*Physical Sciences*: Code 16-3174-01A, Module IV). Review the concept of electrolytic dissociation (*Physical Sciences 416-436*, Module III: 2.8) Review the concepts of mole and molar mass (*Physical Sciences 416-436*, Module III: 3.5)
2.2.1	Feel the heat released or absorbed by a solution.
2.2.2	Associate the heat released or absorbed with a transfer of heat energy.
2.2.3	Determine the amount of heat energy involved when a specific quantity of substance is dissolved, after carrying out an experiment based on a suggested procedure.
2.2.4	Based on the results of their experiments, calculate the amount of heat energy involved for one mole of each of the substances dissolved in 2.2.3.
2.2.5	Associate this value with what chemists call "molar heat of solution" or "heat of solution."
2.2.6	Associate molar heat of solution with heat of reaction.
2.2.7	Distinguish between molar heat of solution, and what chemists call "specific heat of solution."
2.2.8	Write up a report on their work.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

2.3 Determine the amount of energy involved in the neutralization of one mole of a substance, based on a laboratory experiment.

PREREQUISITES

2.2

RELATED CONTENT

- **SKILL:** Measuring. (B-3)
- **KNOWLEDGE:** Heat of neutralization, heat of reaction. (A-3)
- **ATTITUDE:** Conscientiousness. (H-3)

SUGGESTED TEACHING PLAN

A.	**TEACHING STRATEGY:**	Teamwork, laboratory work, class discussion
B.	**DURATION:**	100 minutes
C.	**EVALUATION:**	Quality of the interpretation
D.	**MATERIALS:**	Polystyrene cups, pieces of cardboard (15 cm x 15 cm) or cup lids, thermometers, balance (± 0.01 g), scoop, graduated cylinder (100 mL), HCl solution (1 mol/L), NaOH solution (1 mol/L) prepared in 2.2
E.	**SAFETY MEASURES:**	For glassware, neutralizing solutions, recycling cups

SUGGESTED REFERENCES

AV-8, AV-63, S-11, S-35, B-14, B-15, B-21, B-32

THE STUDENTS:

2.3.0	Review the nature of the products of a neutralization (*Physical Sciences 416-436*, Module III: 5.4).
2.3.1	Feel the heat released or absorbed during neutralization
2.3.2	Associate the heat released or absorbed with a transfer of heat energy.
2.3.3	Determine the amount of energy transferred during the neutralization of a specific quantity of a substance, after doing an experiment according to a suggested procedure.
2.3.4	Calculate the amount of heat energy involved for one mole of each of the substances neutralized, based on the results of their experiment.
2.3.5	Associate this value with what chemists call the "molar heat of neutralization" or the "heat of neutralization."
2.3.6	Associate heat of neutralization with heat of reaction
2.3.7	Distinguish between molar heat of neutralization and what chemists call specific heat of neutralization.
2.3.8	Add the results of their experiment to the report that they started in 2.2.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

2.4 Determine the heat of reaction for a series of chemical reactions carried out in the laboratory.

PREREQUISITES

2.2, 2.3

RELATED CONTENT

- **SKILL:** Formulating generalizations. (D-6)
- **KNOWLEDGE:** Hess's Law. (A-8)
- **ATTITUDE:** Fascination with science. (H-3)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Teamwork, laboratory work, class discussion

B. **DURATION:** 100 minutes

C. **EVALUATION:** Accuracy of measurements

D. **MATERIALS:** Polystyrene cups, pieces of cardboard (15 cm x 15 cm) or cup lids, thermometers, balance (± 0.01 g), scoop, 100 mL graduated cylinder, water, $NaOH_{(s)}$, HCl (1 mol/L)

E. **SAFETY MEASURES:** For glassware, neutralizing solutions, recycling cups

SUGGESTED REFERENCES

AV-8, AV-63, S-32, S-34, B-14, B-15, B-21, B-32

LEARNING ACTIVITIES

THE STUDENTS:

2.4.1	Estimate the overall heat of reaction for the two successive chemical reactions carried out in 2.2 and 2.3, based on their results.
2.4.2	Compare their estimates with those of their classmates and select one for further study.
2.4.3	Develop an experimental procedure to verify the estimate selected.
2.4.4	Carry out the experiment.
2.4.5	Compare their results with the estimate selected, observing the rule of significant figures.
2.4.6	Compare their results with the algebraic sum of the heats of reaction determined in 2.2 and 2.3.
2.4.7	Illustrate their results by means of a diagram.
2.4.8	Compare their results with Hess's results.
2.4.9	Represent the reactions carried out, using chemical equations.
2.4.10	Add the heat of reaction to each of the chemical equations.
2.4.11	Interpret these equations in terms of the overall heat of the reactions.
2.4.12	Describe the usefulness of Hess's proposal for determining heats of reaction, using reference materials.
2.4.13	Using reference materials, demonstrate that thermochemistry has its origins in the work begun by Lavoisier (18th century) and continued by Hess (19th century) in Russia, Fabre and Silberman in France.
2.4.14	Include the results of their experiment in the report that they started in 2.2 and 2.3.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

2.5 Determine the heat of formation of a substance, based on a series of chemical reactions whose heats of reaction were determined by means of an experiment or found in a manual.

PREREQUISITES

2.4

RELATED CONTENT

- **SKILL:** Formulating generalizations. (F-1)
- **KNOWLEDGE:** Heat of formation of a substance, application of Hess's Law. (A-7)
- **ATTITUDE:** Willingness to synthesize and apply knowledge. (F-1)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Demonstration, teamwork, laboratory work, individual work, class discussion

B. **DURATION:** 200 minutes

C. **EVALUATION:** Quality of the experiment

D. **MATERIALS:** Polystyrene cups, pieces of cardboard (15 cm x 15 cm) or cup lids, thermometer, balance (± 0.01 g), scoop, 50 mL graduated cylinder, stirring rods, HCl solution (1 mol/L), MgO, Mg, emery paper

E. **SAFETY MEASURES:** Glassware, neutralizing solutions, recycling cups

SUGGESTED REFERENCES

AV-8, AV-24, AV-63, B-14, B-15, B-21, B-26, B-27, B-32, B-45

THE STUDENTS:

2.5.0	Review the method of writing balanced equations for chemical reactions (*Physical Sciences 416-436*, Module III: 5.4).
2.5.1	Observe the formation of a substance during a demonstration.
2.5.2	Write the balanced chemical equation for the formation of a substance.
2.5.3	Discuss the difficulties of determining the heat of formation of the substance by means of an experiment.
2.5.4	Propose a series of chemical reactions that will enable them to form the same substance.
2.5.5	Identify, from among the reactions proposed, those that can be carried out in an experiment.
2.5.6	Develop an experimental procedure to determine the heats of reaction for the reactions identified in 2.5.5.
2.5.7	Locate, in a manual, the heats of reaction for the chemical reactions that could not be carried out in an experiment.
2.5.8	Calculate the heat of formation of the substance, based on the results obtained and observing the rule of significant figures.
2.5.9	Compare their results with those of their classmates.
2.5.10	Discuss the possibility of formulating a generalization regarding the concept of heat of reaction for any change in matter.
2.5.11	Find out about techniques used by scientists to determine heat of reaction values recorded in a manual.
2.5.12	Become aware that overall knowledge of a phenomenon is often constructed by accumulating knowledge of specific aspects of that phenomenon.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

2.6 Apply their knowledge of the transfer of heat energy to solve problems and do numerical and graphical exercises.

PREREQUISITES

2.1, 2.2, 2.3, 2.4, 2.5

RELATED CONTENT

- **SKILL:** Interpreting data. (D-1)
- **KNOWLEDGE:** Calculation techniques relating to calorimetry. (A-7)
- **ATTITUDE:** Conscientiousness. (H-3)

SUGGESTED TEACHING PLAN

A.	**TEACHING STRATEGY:**	Individual work and teamwork, laboratory work, simulation, class discussion
B.	**DURATION:**	250 minutes + homework
C.	**EVALUATION:**	Problem-solving techniques
D.	**MATERIALS:**	According to the situations or problems presented, calculators (optional)
E.	**SAFETY MEASURES:**	According to the situations or problems presented

SUGGESTED REFERENCES

AV-8, AV-25, AV-63, B-14, B-15, B-21, B-26, B-27, B-35

THE STUDENTS:

2.6.1	Read each problem carefully and identify the data needed to solve it.
2.6.2	Relate the appropriate units of measure to the physical quantities used in each problem.
2.6.3	Use mathematical operations correctly in solving problems.
2.6.4	Verify the plausibility of the solution by means of unit analysis.
2.6.5	Verify the plausibility of the solution by order of magnitude.
2.6.6	Verify the plausibility of the solution by means of an experiment or a simulation, if necessary.
2.6.7	Present the most elegant solution.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

3. **Describe the transfer of energy that occurs during chemical reactions, based on an analogical model that they have developed.**

   3.1 Associate the enthalpy of a substance with the kinetic and potential energy of its molecules.

PREREQUISITES

Module II: 2.2, 3.2, 3.3; Module III: 1.3, 2.4

RELATED CONTENT

- **SKILL:** Constructing a model. (E-2)
- **KNOWLEDGE:** Enthalpy of a substance, chemical energy. (A-3)
- **ATTITUDE:** Critical attitude. (H-3)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Brainstorming, demonstration, teamwork and individual work, class discussion

B. **DURATION:** 75 minutes

C. **EVALUATION:** Quality of the representation

D. **MATERIALS:** Reference materials, three-dimensional molecular model, elastic, spring, mouse trap, hammer, piece of metal, and any other necessary material

E. **SAFETY MEASURES:** For laboratory material and equipment

SUGGESTED REFERENCES

AV-13, AV-25, AV-26, AV-27, S-36, B-30

THE STUDENTS:

3.1.0	Review the concept of energy transformation (*Physical Sciences 416-436*, Module II: 6.1)
3.1.1	Represent a given substance by means of a molecular model
3.1.2	Observe the movements and decomposition of a model representing a molecule, during a demonstration.
3.1.3	Associate the movements and oscillations of the components of the molecular model with the internal energy of the molecule represented.
3.1.4	Compare their representation of the internal energy of a molecule with what scientists term "enthalpy."
3.1.5	Associate the enthalpy of a substance with chemical energy.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

3.2 Associate the heat of reaction of a chemical reaction with changes in the enthalpy of the reactants and the enthalpy of the products.

PREREQUISITES

3.1

RELATED CONTENT

- **SKILL:** Formulating generalizations. (F-1)
- **KNOWLEDGE:** Enthalpy change, heat of reaction. (A-3)
- **ATTITUDE:** Willingness to synthesize and apply knowledge. (H-3)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Teamwork, laboratory work, class discussion

B. **DURATION:** 50 minutes

C. **EVALUATION:** Quality of the predictions

D. **MATERIALS:** Three dimensional molecular model

E. **SAFETY MEASURES:** For laboratory material and equipment

SUGGESTED REFERENCES

B-21, B-26, B-27, B-32, B-45

THE STUDENTS:

3.2.0	Review the concept of molecular formula (*Physical Sciences 416-436*, Module I: 6.1).
3.2.1	Predict the behaviour of the components (atoms) of a molecule during a given chemical reaction.
3.2.2	Compare their predictions with those of their classmates.
3.2.3	Propose a representation of the given chemical reaction, based on the molecular model from 3.1.
3.2.4	Compare their proposals with those of their classmates, and select one for further study.
3.2.5	Illustrate the selected representation by means of a diagram.
3.2.6	Indicate the direction of energy transfer on their diagrams.
3.2.7	Describe the energy transfer in terms of the change in the enthalpy of the reactants and of the products.
3.2.8	Associate the energy transfer during a reaction with a heat of reaction.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

3.3 Illustrate, using graphs, the enthalpy change of substances in an endothermic chemical reaction and in an exothermic chemical reaction, after observing demonstrations.

PREREQUISITES

1.3, 3.2

RELATED CONTENT

- **SKILL:** Interpreting data. (E-1)
- **KNOWLEDGE:** Activation energy, reversibility of a reaction. (A-2)
- **ATTITUDE:** Willingness to interpret information. (H-3)

SUGGESTED TEACHING PLAN

A.	**TEACHING STRATEGY:**	Demonstration, teamwork, class discussion
B.	**DURATION:**	100 minutes
C.	**EVALUATION:**	Quality of the interpretation of the data
D.	**MATERIALS:**	1 000 mL Erlenmeyer flasks, two-hole stoppers, 30 cm glass tubes, 10 cm glass tubes, 45 cm transparent plastic tubing, 15 cm of plastic tubing, universal supports, buret clamps, coloured water, molecular models, reference materials
E.	**SAFETY MEASURES:**	For glassware

SUGGESTED REFERENCES

AV-8, AV-63, B-14, B-15, B-21, B-26, B-27, B-33, B-35

LEARNING ACTIVITIES

THE STUDENTS:

3.3.1	Observe a demonstration of an analogical model that simulates an exothermic reaction and an endothermic reaction.
3.3.2	Associate the potential energy of the substance representing the reactant in the model with the enthalpy of a substance reacting in a chemical change.
3.3.3	Express their observations in the form of a graph showing the enthalpy change of the reactant substance and of the product in relation to time.
3.3.4	Interpret the graph in terms of the activation energy of the reaction.
3.3.5	Formulate a hypothesis to explain the reversibility of given chemical reactions, based on the model observed.
3.3.6	List examples from everyday life in which a direct chemical reaction and a reverse chemical reaction occur simultaneously.
3.3.7	Describe one of the examples listed, based on the analogical model from 3.3.1.
3.3.8	Discuss the usefulness of an analogical model in representing a chemical phenomenon.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

3.4 Explain the presence and the transformation of substances in their environment based on the concept of energy.

PREREQUISITES

1.3, 3.4

RELATED CONTENT

- **SKILL:** Recognizing a problem. (C-1)
- **KNOWLEDGE:** Justifications for using or not using certain chemical substances in their environment (e.g. H_2, O_2,H_2O, SiO_2, Si and so on). (A-1)
- **ATTITUDE:** Willingness to apply and synthesize knowledge. (I-1)

SUGGESTED TEACHING PLAN

A.	**TEACHING STRATEGY:**	Individual work and teamwork, class discussion
B.	**DURATION:**	100 minutes + homework
C.	**EVALUATION:**	Quality of the arguments
D.	**MATERIALS:**	Reference materials
E.	**SAFETY MEASURES:**	N/A

SUGGESTED REFERENCES

P-25, B-8, B-9, B-42, B-46, B-47

THE STUDENTS:

3.4.1	Identify the most abundant elements and compounds on Earth, using reference materials.
3.4.2	Explain the natural or artificial presence of some of these elements and compounds, based on their knowledge of the behaviour of energy during a chemical reaction.
3.4.3	Identify the uses of these substances.
3.4.4	Justify some of these uses, based on their knowledge of the behaviour of energy during a chemical reaction.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

4. **Illustrate, by means of an impact study, the relationships among the following: the development and use of knowledge relating to energy in a chemical reaction, science, technology, society and the environment.**

   4.1 Illustrate, after consulting reference materials, the cause-and-effect relationships between society and the development and use of knowledge relating to energy in a chemical reaction, at different periods in history.

PREREQUISITES

1, 2, 3

RELATED CONTENT

- **SKILL:** Interpreting data. (D-4)
- **KNOWLEDGE:** Relationships between society and the development of scientific knowledge of chemical energy at different periods of history. (A-1)
- **ATTITUDE:** Constructivist view of science. (I-3)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Brainstorming, teamwork and individual work, class discussion

B. **DURATION:** 50 minutes + homework

C. **EVALUATION:** Quality of interpretations

D. **MATERIALS:** Reading materials

E. **SAFETY MEASURES:** N/A

SUGGESTED REFERENCES

AV-8, AV-28, AV-29, AV-63, P-26, P-27, P-50, B-3, B-4, B-5, B-6, B-14, B-15, B-22, B-25, B-30, B-46, B-48, B-49, B-50, B-51, B-52, B-53, B-54, B-55, B-87

LEARNING ACTIVITIES

THE STUDENTS:

4.1.0	Review the concepts relating to the history of science and technology (*Introduction to Technology*: Code 16-4888-01A, *General History*: Code 16-3658A, *History of Québec and Canada*: Code 10-3660A).
4.1.1	List works by ancient scientists that have had the effect of initiating the development of scientific knowledge relating to chemical energy.
4.1.2	Describe scientific work (e.g. by Brown, Hess, Helmholtz, Kelvin, Julius Thomson, Berthelot, Maxwell, Dewar, Nobel, Moissan, Linde) that has contributed to the development of scientific knowledge relating to chemical energy, using reference materials.
4.1.3	Write a summary of their research in a compendium of information prepared by the group.
4.1.4	Identify ways in which the development of knowledge relating to chemical energy has influenced society at different periods of history.
4.1.5	Imagine future technological projects relating to chemical energy.
4.1.6	Discuss how social evolution has influenced the development of knowledge and technology relating to chemical energy.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

**	4.2	Illustrate the cause-and-effect relationships between the development and use of knowledge relating to energy in a chemical reaction and our quality of life, based on observations of phenomena and using reference materials.

PREREQUISITES

4.1

RELATED CONTENT

-	**SKILL:**	Formulating generalizations. (F-1)
-	**KNOWLEDGE:**	Ways in which the development of technology relating to chemical energy affects our quality of life (e.g. health, comfort, access to consumer goods). (A-1)
-	**ATTITUDE:**	Sense of responsibility. (H-7)

SUGGESTED TEACHING PLAN

A.	**TEACHING STRATEGY:**	Brainstorming, teamwork and individual work, class discussion
B.	**DURATION:**	100 minutes + homework
C.	**EVALUATION:**	Quality of predictions
D.	**MATERIALS:**	Reference materials
E.	**SAFETY MEASURES:**	N/A

SUGGESTED REFERENCES

AV-22, B-3, B-4, B-5, B-6, B-14, B-15, B-22, B-25, B-30, B-46, B-48, B-49, B-50, B-51, B-52, B-53, B-54, B-55

THE STUDENTS:

4.2.1	List technological developments involving chemical energy that have had an influence on our quality of life at different periods of history.
4.2.2	Classify these technological developments according to their advantages and disadvantages.
4.2.3	Predict how future technological developments relating to chemical energy will affect our quality of life.
4.2.4	Discuss how our standard of living influences the development of knowledge and technology relating to chemical energy.
4.2.5	Write a short report on their work.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

4.3 Illustrate the cause-and-effect relationships between the development and use of knowledge relating to energy in a chemical reaction and the natural and artificial environment, based on observations of phenomena and using reference materials.

PREREQUISITES

4.1

RELATED CONTENT

- **SKILL:** Organizing data. (D-1)
- **KNOWLEDGE:** Ways in which the development of technology relating to energy in chemical reactions affects the environment, the evolution of environmental consciousness. (A-1)
- **ATTITUDE:** Sense of responsibility toward the environment. (H-7)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Brainstorming, teamwork and individual work, field trip, class discussion

B. **DURATION:** 50 minutes + homework

C. **EVALUATION:** Quality of the proposed means

D. **MATERIALS:** Reference materials

E. **SAFETY MEASURES:** Normal safety rules for field trips

SUGGESTED REFERENCES

AV-8, AV-32, AV-63, P-51, B-3, B-4, B-5, B-6, B-14, B-15, B-22, B-25, B-30, B-46, B-48, B-49, B-50, B-51, B-52, B-53, B-54, B-55, B-56

THE STUDENTS:

4.3.1	List technological developments relating to chemical energy that affect the environment.
4.3.2	Classify these technological developments according to their advantages and disadvantages.
4.3.3	Suggest means of reducing the harmful effects of technological developments that are considered dangerous for the environment.
4.3.4	Assess the feasibility of the suggested means.
4.3.5	Predict how future technological developments relating to chemical energy might affect the environment.
4.3.6	Discuss how the evolution of environmental consciousness has influenced research and the development of knowledge and technology relating to chemical energy.
4.3.7	Write a report on their research and include it in the group's compendium of information.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

4.4 Discuss Québec's role in research and development relating to energy in chemical reactions, after consulting reference materials.

PREREQUISITES

4.3

RELATED CONTENT

- **SKILL:** Recognizing a problem. (C-1)
- **KNOWLEDGE:** Québec organizations that carry out research relating to combustibles, combustibles produced in Quebec, preparation of hydrogen, social and economic consequences. (A-1)
- **ATTITUDE:** Sense of belonging. (H-7)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Individual work and teamwork, class discussion

B. **DURATION:** 75 minutes + homework

C. **EVALUATION:** Quality of the presentation

D. **MATERIALS:** Reference materials

E. **SAFETY MEASURES:** N/A

SUGGESTED REFERENCES

B-56, B-57

THE STUDENTS:

4.4.1	List advanced research on chemical energy carried out in the world, using reference materials.
4.4.2	Identify those research projects being carried out in Québec.
4.4.3	Name Québec businesses and institutions that contribute to the development of knowledge regarding chemical energy.
4.4.4	Describe at least one project or research on chemical energy carried out by a Québec business or institution.
4.4.5	Write their description in the group's compendium of information.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

**	4.5	Identify professions associated with the development of knowledge relating to energy in chemical reactions, using reference materials.

PREREQUISITES

RELATED CONTENT

-	SKILL:	Formulating generalizations. (F-2)
-	KNOWLEDGE:	Professions associated with the development of knowledge relating to chemical energy. (A-6)
-	ATTITUDE:	Fascination with science. (H-6)

SUGGESTED TEACHING PLAN

A.	TEACHING STRATEGY:	Brainstorming, teamwork and individual work, visits, interviews
B.	DURATION:	50 minutes + homework
C.	EVALUATION:	Quality of the description
D.	MATERIALS:	Reference materials
E.	SAFETY MEASURES:	N/A

SUGGESTED REFERENCES

B-58

THE STUDENTS:

4.5.0	Review the information documents on careers (*Career Choice Education*: Code 16-3800A).
4.5.1	List professions associated with the use of chemical energy and with the development of knowledge regarding chemical energy.
4.5.2	Describe at least one of the professions listed, using reference materials or based on an interview.
4.5.3	Write a report of their research.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

4.6 Describe the uses of chemical energy in recreational activities, using reference materials.

PREREQUISITES

1.3

RELATED CONTENT

- **SKILL:** Formulating generalizations. (F-3)
- **KNOWLEDGE:** Use of chemical energy in recreational activities. (A-1)
- **ATTITUDE:** Fascination with science. (H-3)

SUGGESTED TEACHING PLAN

A.	**TEACHING STRATEGY:**	Brainstorming, individual work and teamwork, laboratory work, class discussion
B.	**DURATION:**	75 minutes
C.	**EVALUATION:**	Quality of the tests
D.	**MATERIALS:**	Documentation, Bunsen burner, matches, glass rod with platinum or nichrome wire, salt solutions (1 mol/L) (e.g. NaCl, KCl, $NiCl_2$, $CuCl_2$, etc.)
E.	**SAFETY MEASURES:**	For heat, heavy metal salts, environmental protection

SUGGESTED REFERENCES

AV-8, AV-31, AV-63, P-28, P-44, P-45, B-8, B-9, B-14, B-15, B-33, B-59

THE STUDENTS:

4.6.1	List the uses of chemical energy in recreational activities.
4.6.2	Identify the social and environmental consequences of these uses.
4.6.3	Describe the operation of a technological invention that permits the use of chemical energy in recreational activities.
4.6.4	In a laboratory, conduct tests to determine the colours that different chemical substances impart to a Bunsen flame.
4.6.5	Identify chemical substances by the colour they produce in the flame.
4.6.6	Verify colouring substances used by pyrotechnists to produce their shows, using reference materials.

TEACHER'S NOTES

MODULE 4

RATE OF CHEMICAL REACTIONS

GENERAL OBJECTIVE: To investigate by means of the scientific method, various chemical changes in order to identify the factors that influence their reaction rate, to understand how they occur and to become aware of their impact on society and the environment.

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

1. **Describe the chemical changes in their environment, based on the reaction rates that they have observed and measured.**

   1.1 Compare the changes that substances in the environment undergo, according to the rate at which these changes occur.

PREREQUISITES

RELATED CONTENT

- **SKILL:** Recognizing a problem. (C-1)
- **KNOWLEDGE:** Rate of chemical changes, arbitrariness of a classification. (A-5)
- **ATTITUDE:** Constructivist view of science. (I-2)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Brainstorming, individual work, class discussion

B. **DURATION:** 50 minutes

C. **EVALUATION:** Quality of the classification

D. **MATERIALS:** N/A

E. **SAFETY MEASURES:** N/A

SUGGESTED REFERENCES

S-26, S-27, S-28, S-29, S-37, S-61, S-62, P-29, P-30, P-39, B-8, B-9, B-11, B-16, B-21, B-26, B-27, B-28, B-32, B-33, B-42, B-60, B-61, B-62, B-63

LEARNING ACTIVITIES

THE STUDENTS:

1.1.0	Review the concept of chemical change (*Physical Sciences 416-436*, Module I: 3.2)
1.1.1	List chemical changes occurring in their environment.
1.1.2	Describe these changes in their own words, taking into consideration the substances involved (reactants, products).
1.1.3	Arrange the rates of reaction for these changes in ascending or descending order.
1.1.4	Identify the changes that are slow, average, fast, explosive.
1.1.5	Discuss the arbitrariness or subjectivity of this classification.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

1.2 Measure the rate of a chemical reaction, using the procedures they have developed.

PREREQUISITES

1.1

RELATED CONTENT

- **SKILL:** Measuring. (B-5)
- **KNOWLEDGE:** Definition of reaction rate, techniques for measuring the rate of a reaction, units of measurement. (A-7)
- **ATTITUDE:** Willingness to clarify problems. (H-3)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Brainstorming, teamwork, laboratory work, class discussion

B. **DURATION:** 150 minutes + homework

C. **EVALUATION:** Quality of the experiments

D. **MATERIALS:** Mg, HCl solution (0.5 mol/L), chronometer, balance (± 0.01 g), scoop, test tube (18 mm x 150 mm), one-hole stopper, 10 cm glass tube, 50 cm of rubber tubing, 10 mL graduated cylinder, 50 mL gas buret, 400 mL beaker, 10 mL syringe, water, 125 mL Erlenmeyer flask, two-hole stopper, separatory funnel, bent glass tube (20 cm), 30 cm of rubber tubing, liquid manometer, universal support, buret clamps, pH meter or pH paper, thermometer

E. **SAFETY MEASURES:** For glassware, chemicals

SUGGESTED REFERENCES

AV-8, AV-63, S-38, P-55, B-9, B-14, B-15, B-20, B-32, B-61, B-63

THE STUDENTS:

1.2.0 Review the general equation representing the reaction between a metal and an acid (*Physical Sciences 416-436*, Module III: 2.1 and III: 5.4).

Review the theory of dissociation of ionic substances in an aqueous solution (*Physical Sciences 416-436*, Module III: 2.8).

Review the relationship between mass and mole (*Physical Sciences 416-436*, Module III: 3.5).

Review the relationship between the volume occupied by a gas and the mole (*Physical Sciences 416-436*, Module II: 1.6).

1.2.1 Propose ways of measuring the reaction rate of a chemical change.

1.2.2 Develop an experimental procedure to measure the reaction rate of a chemical change, taking into account the materials available.

1.2.3 Write their results in the table used to compile the group's results.

1.2.4 Discuss the differences among the results.

1.2.5 Write a report on their work.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

2. **Analyse the factors that can influence the rate of the chemical reactions that they have discovered while doing scientific work.**

   2.1 Identify the factors that can influence the rate of a combustion reaction, after doing an experiment according to a suggested procedure.

PREREQUISITES

1.2

RELATED CONTENT

- **SKILL:** Recognizing a problem. (C-1)
- **KNOWLEDGE:** Definitions of: combustion, combustible, combustion agent, fuel, fire triangle, means used to change combustion rate, role of catalysts and inhibitors. (A-3)
- **ATTITUDE:** Willingness to interpret information. (H-3)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Brainstorming, teamwork, laboratory work, demonstration, individual work, class discussion

B. **DURATION:** 175 minutes

C. **EVALUATION:** Quality of explanations

D. **MATERIALS:** Box of matches, test tubes (18 mm x 150 mm), test tube clamps, 10 mL graduated cylinder, limewater, cobalt chloride paper, alcohol burner or butane lighter, 1 000 mL beaker, ice, candle, 1 000 mL Erlenmeyer flask, rubber stopper, O_2, CO_2, Mg strip, crucible tongs, pieces of cloth (10 cm x 10 cm), H_3BO_3 solution (1 mol/L), bunsen burner, reference materials

E. **SAFETY MEASURES:** For fire, glassware

LEARNING ACTIVITIES

THE STUDENTS:

2.1.1	List examples of combustion occurring in the environment.
2.1.2	Define the terms "combustible," "fuel," "combustion agent," using a dictionary or an encyclopedia.
2.1.3	Describe the combustion process in their own words.
2.1.4	Identify the fuel, the combustion agent and the combustion products, based on an example of combustion.
2.1.5	Identify substances that can act as combustion agents to different fuels, using reference materials.
2.1.6	Identify the conditions required for combustion, after doing experiments according to suggested procedures.
2.1.7	Associate these conditions with the way in which a combustion reaction is represented in a fire triangle.
2.1.8	During a demonstration, observe how the variation of each of these conditions influences combustion.
2.1.9	Associate the variation of the conditions with the combustion rate.
2.1.10	Explain the role of the various means used to extinguish a fire, using the fire triangle.
2.1.11	Propose means for preventing fires in their environment.

SUGGESTED REFERENCES

AV-8, AV-32, AV-33, AV-63, S-39, S-61, P-31, P-32, B-14, B-15, B-20, B-28, B-63

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

2.2 Determine the effect of factors that influence the rate of a chemical reaction, after doing experiments according to a suggested procedure.

PREREQUISITES

1.1, 2.1

RELATED CONTENT

- **SKILL:** Recognizing a problem. (C-1)
- **KNOWLEDGE:** Effect of factors influencing the rate of a chemical reaction, definitions for: catalyst, catalytic activity. (A-1)
- **ATTITUDE:** Creative approach to science. (F-2)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Brainstorming, teamwork, laboratory work, individual work, simulation, class discussion

B. **DURATION:** 225 minutes + homework

C. **EVALUATION:** Ability to recognize the effect of a factor

D. **MATERIALS:** Dropper bottle, washing bottle, graduated cylinder, test tubes, beakers, rubber stoppers, thermometer, chronometer, balance, hot plate, wood splint, oleic acid (0.5% in alcohol), HCl (0.5 mol/L and 1 mol/L), KIO_3 solution (15 g in 1 000 mL water), starch solution (4 g in 500 mL water), different catalysts (metals, metal oxides, etc.), $KNaC_4H_4O_6$, $CoCl_2$, H_2O_2 (3% and 6%), Mg strip, Mg powder, etc., reference materials

E. **SAFETY MEASURES:** For heat, glassware, chemicals

SUGGESTED REFERENCES

AV-8, AV-34, AV-35, AV-36, AV-63, S-35, S-39, P-33, P-34, P-52, P-55, B-8, B-9, B-14, B-15, B-21, B-28, B-32, B-33, B-42, B-61, B-62, B-63, B-64, B-65, B-66

LEARNING ACTIVITIES

THE STUDENTS:

2.2.1	Propose factors that are likely to vary the reaction rate of a chemical change.
2.2.2	Compare their proposals with those of their classmates and select some for further study.
2.2.3	Discuss, with their classmates, the effect of each of the factors selected in 2.2.1.
2.2.4	Verify the effect of one of the factors selected, by doing an experiment according to a suggested procedure.
2.2.5	Write the results of their observations in the table used to compile the group's results.
2.2.6	Propose practical applications that involve the factors influencing the rate of a chemical reaction, based on an analysis of the results in the table.
2.2.7	Illustrate everyday situations or phenomena that can be explained by one of the factors influencing the rate of a chemical reaction.
2.2.8	Write a report on their work.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

2.3 Illustrate the effect of factors that influence the rate of a chemical reaction, using an analogical model.

PREREQUISITES

Module 3: 3.3, Module 4: 2.2

RELATED CONTENT

- **SKILL:** Constructing a model. (E-6)
- **KNOWLEDGE:** Explanatory model (collision theory), graphs of: the distribution of kinetic energy of a molecule, enthalpy change, minimum molecular energy. (A-9)
- **ATTITUDE:** Critical attitude. (H-3)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Brainstorming, demonstration, teamwork, individual work, class discussion

B. **DURATION:** 200 minutes + homework

C. **EVALUATION:** Ability to construct models

D. **MATERIALS:** Projectile launcher, projectiles, moveable screen, carbon paper, graph paper

E. **SAFETY MEASURES:** For using projectiles

SUGGESTED REFERENCES

AV-13, S-41, B-26, B-27

THE STUDENTS:

2.3.1	Predict the effect of each of the factors identified in 2.2 on the velocity of the molecules of the reactants and the products in a chemical reaction.
2.3.2	Compare their predictions with those of their classmates.
2.3.3	During a simulation, observe the pattern made by a cluster of particles thrown towards a moving screen.
2.3.4	Illustrate how the particles of the cluster are distributed on the target, by means of a graph.
2.3.5	Associate the distribution of the particles with the distribution of kinetic energy of the particles.
2.3.6	Discuss how one of the factors identified in 2.2 will affect the cluster.
2.3.7	Illustrate the expected effect of this factor on the behaviour of the particles of the cluster.
2.3.8	Draw a graph of the expected distribution of particles on the target.
2.3.9	Compare their expectations with those of their classmates and select some for further study.
2.3.10	Simulate the effect of this factor on the behaviour of the particles.
2.3.11	Compare the selected expectations with the results of the simulation.
2.3.12	Correct their graphs, if necessary.
2.3.13	Repeat this procedure for each of the other factors.
2.3.14	Associate the physical qualities related to the cluster of particles with the characteristics of a reaction subject to the same factors.
2.3.15	Discuss the importance of using physical phenomena to illustrate properties of matter and to construct an explanatory model in chemistry.
2.3.16	Write a report on their work.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

** 2.4 Determine the influence of the contact area and the concentration of the reactants on the rate of a chemical reaction, based on experiments.

PREREQUISITES

Module 3: 3.2, Module 4: 2.3

RELATED CONTENT

- **SKILL:** Interpreting data. (E-2)
- **KNOWLEDGE:** Relationship between reaction rate and the factors that influence it. (A-5)
- **ATTITUDE:** Willingness to interpret information. (H-3)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Teamwork, laboratory work, individual work, class discussion

B. **DURATION:** 200 minutes + homework

C. **EVALUATION:** Quality of the interpretation

D. **MATERIALS:** Test tube (18 mm x 150 mm), one-hole stopper,, Mg strip, emery paper, 10 mL graduated cylinder, HCH_3CO_2 (1.0 mol/L and 0.50 mol/l), rubber tubing, 10 mL glass syringe, universal support, buret clamps, chronometer

E. **SAFETY MEASURES:** For glassware, chemicals

SUGGESTED REFERENCES

See 2.3

THE STUDENTS:

2.4.0	Review the theory of ionic dissociation (*Physical Sciences 416-436*, Module III: 2.8).
2.4.1	Predict the effect of varying the surface of a solid on the rate of a chemical reaction.
2.4.2	Predict the effect of varying the concentration of a solution on the rate of a chemical reaction.
2.4.3	Justify their predictions.
2.4.4	Develop an experimental procedure to verify their predictions, using the materials available.
2.4.5	Carry out the experiment.
2.4.6	Write the results in the table used to compile the group's results.
2.4.7	Compare the results obtained with their predictions.
2.4.8	Write a report on their work.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

3. **Illustrate, by means of an impact study, the relationships among the following: the development and use of knowledge relating to the rate of chemical reactions, science, technology, society and the environment.**

   3.1 Illustrate, after consulting reference materials, the cause-and-effect relationships between society and the development and use of knowledge relating to the rate of chemical reactions, at different periods of history.

PREREQUISITES

1, 2

RELATED CONTENT

-	**SKILL:**	Interpreting data. (D-4)
-	**KNOWLEDGE:**	Relationship between society and the development of scientific knowledge relating to the rate of chemical reactions. (A-1)
-	**ATTITUDE:**	Constructivist view of science. (I-3)

SUGGESTED TEACHING PLAN

A.	**TEACHING STRATEGY:**	Brainstorming, teamwork, individual work, class discussion
B.	**DURATION:**	50 minutes + homework
C.	**EVALUATION:**	Quality of the interpretation
D.	**MATERIALS:**	Reference materials
E.	**SAFETY MEASURES:**	N/A

SUGGESTED REFERENCES

S-4, S-44, B-6, B-8, B-14, B-15, B-22, B-44, B-50, B-53, B-56, B-57, B-60, B-67, B-68, B-69

LEARNING ACTIVITIES

THE STUDENTS:

3.1.0	Review the concepts relating to the history of science and technology (*General History*: Code 16-3658A, *Introduction to Technology*: Code 16-4888A, *History of Québec and Canada*: Code 16-3660A).
3.1.1	List work by ancient scientists that had the effect of initiating the development of scientific knowledge relating to the rate of chemical reactions.
3.1.2	Describe the work of scientists who have contributed to the development of scientific knowledge relating to the rate of chemical reactions, using reference materials.
3.1.3	Write the summary of their research in the group's compendium of information.
3.1.4	Identify ways in which the development of knowledge relating to the rate of chemical reactions has influenced society, at different periods of history (e.g. health, arms, agriculture).
3.1.5	Comment on Thomas Hood's desperate appeal during the 1840s' famines: Lord, why is bread so dear, while flesh and blood cost so little. (Free translation).
3.1.6	Imagine future technological developments relating to the rate of chemical changes.
3.1.7	Discuss how social evolution has influenced the development of knowledge and technology relating to the rate of chemical reactions.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

**	3.2	Illustrate the cause-and-effect relationships between the development and use of knowledge relating to the rate of chemical reactions and our quality of life, based on observations of phenomena and using reference materials.

PREREQUISITES

3.1

RELATED CONTENT

-	**SKILL:**	Formulating generalizations. (F-1)
-	**KNOWLEDGE:**	Ways in which the development of technology relating to the rate of chemical reactions affect our quality of life (e.g. health, comfort, access to consumer goods), societal influences. (A-1)
-	**ATTITUDE:**	Sense of belonging. (H-7)

SUGGESTED TEACHING PLAN

A.	**TEACHING STRATEGY:**	Brainstorming, teamwork, individual work, class discussion
B.	**DURATION:**	100 minutes + homework
C.	**EVALUATION:**	Logic of predictions
D.	**MATERIALS:**	Reference materials
E.	**SAFETY MEASURES:**	N/A

SUGGESTED REFERENCES

See 3.1

THE STUDENTS:

3.2.1	List technological developments relating to the rate of a chemical reaction that have influenced our quality of life at different periods in history.
3.2.2	Classify these technological developments according to their advantages and disadvantages.
3.2.3	Predict how future technological projects relating to the rate of chemical reactions will affect our quality of life.
3.2.4	Discuss how our standard of living influences the development of knowledge and technology relating to the rate of chemical reactions.
3.2.5	Write a brief report on their work.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

3.3 Illustrate the cause-and-effect relationships between the development and use of knowledge relating to the rate of chemical reactions and the natural and artificial environment, based on observations of phenomena and using reference materials.

PREREQUISITES

3.1

RELATED CONTENT

- **SKILL:** Organizing data. (D-1)
- **KNOWLEDGE:** Ways in which the development of technology relating to the rate of chemical reactions affect the environment, evolution of environmental consciousness. (A-1)
- **ATTITUDE:** Sense of responsibility toward the environment. (H-7)

SUGGESTED TEACHING PLAN

A.	**TEACHING STRATEGY:**	Brainstorming, teamwork and individual work, field trip, class discussion
B.	**DURATION:**	50 minutes + homework
C.	**EVALUATION:**	Quality of proposed means
D.	**MATERIALS:**	Reference materials
E.	**SAFETY MEASURES:**	Normal safety rules for field trips

SUGGESTED REFERENCES

AV-30, AV-38, P-35, P-36, B-8, B-44, B-50, B-53, B-68, B-69

THE STUDENTS:

3.3.1	List technological developments relating to the rate of a chemical reaction that affect the environment.
3.3.2	Classify these technological developments according to their advantages and disadvantages.
3.3.3	Propose means of reducing the harmful effects of technological developments that are considered detrimental to the environment.
3.3.4	Assess the feasibility of the proposed means.
3.3.5	Predict how future technological projects relating to the rate of chemical reactions might affect the environment.
3.3.6	Discuss how the evolution of environmental consciousness has influenced research and development of knowledge and technology relating to the rate of chemical reactions.
3.3.7	Write a report on their research and include it in the group's compendium of information.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

**	3.4	Discuss Québec's role in research and development relating to the rate of chemical reactions, using reference materials.

PREREQUISITES

3.3

RELATED CONTENT

-	**SKILL:**	Recognizing a problem. (C-1)
-	**KNOWLEDGE:**	Québec organizations that carry out research relating to combustibles, combustibles produced in Québec, social and economic consequences. (A-1)
-	**ATTITUDE:**	Sense of belonging. (H-7)

SUGGESTED TEACHING PLAN

A.	**TEACHING STRATEGY:**	Individual work, teamwork, class discussion
B.	**DURATION:**	75 minutes + homework
C.	**EVALUATION:**	Quality of the report
D.	**MATERIALS:**	Reference materials
E.	**SAFETY MEASURES:**	N/A

SUGGESTED REFERENCES

B-56, B-57

THE STUDENTS:

3.4.1	List advanced research on the rate of chemical reactions that has been carried out in the world, using reference materials.
3.4.2	Identify those research projects being carried out in Québec.
3.4.3	Name Québec businesses and institutions that contribute to the development of knowledge relating to the rate of chemical reactions.
3.4.4	Describe at least one project or piece of research on the rate of chemical reactions that has been carried out by a Québec business or institution.
3.4.5	Write their description in the group's compendium of information.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

** 3.5 Identify professions associated with the development of knowledge relating to the rate of chemical reactions, using reference materials.

PREREQUISITES

RELATED CONTENT

- **SKILL:** Formulating generalizations. (F-2)
- **KNOWLEDGE:** Professions associated with the development of knowledge relating to chemical energy. (A-6)
- **ATTITUDE:** Fascination with science. (H-6)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Teamwork and individual work, visits, interviews

B. **DURATION:** 50 minutes + homework

C. **EVALUATION:** Quality of the description

D. **MATERIALS:** Reference materials

E. **SAFETY MEASURES:** N/A

SUGGESTED REFERENCES

B-70

THE STUDENTS:

3.5.0	Review the information documents on careers (*Career Choice Education*: Code 16-3800A).
3.5.1	List professions associated with the development of knowledge relating to the rate of chemical reactions.
3.5.2	Describe at least one of the professions listed, using reference materials or based on interviews.
3.5.3	Write a report on their research.

TEACHER'S NOTES

MODULE 5

EQUILIBRIUM IN CHEMICAL REACTIONS

GENERAL OBJECTIVE: To investigate, by means of the scientific method, various chemical changes in order to identify the factors that influence their state of equilibrium, to understand how they occur, to discover their technological applications and to become aware of their impact on society and the environment.

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

1 **Carry out qualitative analyses of the behaviour of chemical systems subjected to factors likely to affect their equilibrium.**

1.1 Distinguish between a chemical reaction occurring in a closed environment and one occurring in an open environment, based on observations of the macroscopic behaviour of matter.

PREREQUISITES

Physical Sciences 436, Module I: 3.2

RELATED CONTENT

- **SKILL:** Observing. (B-1)
- **KNOWLEDGE:** Definition of: complete reaction, open system, closed system, balanced system. (A-3)
- **ATTITUDE:** Willingness to interpret information. (H-3)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Team work, laboratory work, individual work, class discussion

B. **DURATION:** 100 minutes + homework

C. **EVALUATION:** Quality of the hypotheses

D. **MATERIALS:** Bottles of soft drink, bottle cap, 100 mL graduated cylinder, water, Alka Seltzer tablets.

E. **SAFETY MEASURES:** For glassware, pressurized gas

SUGGESTED REFERENCES

AV-39, AV-40, AV-41, B-21, B-26, B-27, B-32, B-33, B-61, B-71

THE STUDENTS:

1.1.0	Review the concept of systems (*Ecology*: 16-3143-01A, *Physical Science*: 16-3174-01A, *General Biology*: 16-3151-01A).
1.1.1	Predict the behaviour of matter during the same chemical reaction occurring in a closed system and in an open system.
1.1.2	Discuss their predictions with the other students.
1.1.3	Develop an experimental procedure to verify their predictions, using the materials available.
1.1.4	Define "complete reaction," "closed system," "open system," "balanced system" based on their observations.
1.1.5	Compare their definitions with those of their classmates.
1.1.6	Compare their definitions with the generally accepted definitions, using reference materials.
1.1.7	Illustrate applications of open systems, closed systems and balanced systems in everyday life.
1.1.8	Think about industrial processes that exploit the concepts of open system, closed system and balanced system.
1.1.9	Write a report on their work.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

1.2 Determine the effect of various factors on the equilibrium of a chemical system, based on experiments.

PREREQUISITES

Module 2: 2.2, Module 4: 2.2, Module 5: 1.1

RELATED CONTENT

- **SKILL:** Observing. (B-1)
- **KNOWLEDGE:** Factors that affect the equilibrium of a chemical system: concentration, temperature, reaction time, pressure; Le Chatelier's principle. (A-8)
- **ATTITUDE:** Willingness to clarify problems. (H-3)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Individual work, team work, laboratory work, class discussion

B. **DURATION:** 150 minutes + homework

C. **EVALUATION:** Quality of the procedures

D. **MATERIALS:** KSCN solution (.002 mol/L), solution of $Fe(NO_3)_3$ (0.20 mol/L), distilled water, 50 mL graduated cylinder, test tubes (18 mm x 150 mm), dropper bottle, Fe^{3+} solution (0.20 mol/L), $FeCl_3$ crystals, KSCN crystals, Na_2HPO_4 crystals, glass stirring rod, 250 mL beakers, ice cubes, hot plate, NO_2, drying tube with $CaCl_2$, plastic bag, 20 mL syringe, screw-type syringe stopper.

E. **SAFETY MEASURES:** For syringes, glassware, heat, toxic gas

SUGGESTED REFERENCES

AV-8, AV-39, AV-63, B-14, B-15, B-21, B-32, B-33, B-71

LEARNING ACTIVITIES

THE STUDENTS:

1.2.0	Review the concept of stoichiometry (*Physical Sciences 416-436*, Module III: 5.6).
1.2.1	List factors that can affect the equilibrium of a chemical system.
1.2.2	Compare their predictions with their classmates.
1.2.3	Predict the effect of each of the factors listed on the concentration of the chemicals and on the direction of the shift in equilibrium.
1.2.4	Express their predictions in the form of chemical equations.
1.2.5	Develop experimental procedures to verify their predictions, using the materials available.
1.2.6	Discuss their procedures with their classmates.
1.2.7	Compare the results of the experiments with their predictions.
1.2.8	Formulate a hypothesis to explain the results obtained.
1.2.9	Discuss their hypotheses with their classmates.
1.2.10	Compare the hypothesis selected with Le Chatelier's statement (19th-20th century) that if the conditions of a system in equilibrium were changed, the system would tend to react, in part, against the change.
1.2.11	Become aware of the "animisme" attitude, developed toward the end of the 19th century, which attributed a soul to material things, by referring to the hypotheses previously stated.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

1.3 Predict the effect of various factors on the concentration of substances and on the direction of the shift in the equilibrium of a chemical system, based on Le Chatelier's principle.

PREREQUISITES

1.2

RELATED CONTENT

- **SKILL:** Formulating generalizations. (F-1)
- **KNOWLEDGE:** Le Chatelier's principle, techniques for applying Le Chatelier's principle, natural and technological applications. (A-10)
- **ATTITUDE:** Willingness to synthesize and apply knowledge. (F-2)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Laboratory work, individual work, class discussion, simulation

B. **DURATION:** 150 minutes + homework

C. **EVALUATION:** Mastery of techniques for applying Le Chatelier's principle

D. **MATERIALS:** According to the predictions to be verified in the laboratory, reference materials

E. **SAFETY MEASURES:** According to laboratory experiment

SUGGESTED REFERENCES

AV-40, AV-45, S-38, S-47, B-8, B-9, B-72, B-73, B-33, B-71, B-74

THE STUDENTS:

1.3.1	Apply Le Chatelier's principle, by processing equations, to predict the effect of temperature on the concentration of chemical substances of balanced systems used in industry or observed in the environment.
1.3.2	For each system, predict the direction of the reaction in attaining a new equilibrium.
1.3.3	Repeat 1.3.1 and 1.3.2 for each system to predict the effect of a change in the concentration of one of the reactants.
1.3.4	Repeat 1.3.1 and 1.3.2 to predict the effect of the pressure exerted on a gaseous system, taking into account the number of molecules in the reactant and in the product.
1.3.5	Compare their predictions with their classmates and select some for further study.
1.3.6	Compare the predictions with processes used in industry or observed in the environment, using reference materials.
1.3.7	Verify one of the situations described, if necessary, by means of an experiment or a simulation.
1.3.8	Write a report on their work.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

1.4 Illustrate the relationship between our use of the earth's natural resources and the physical and biological equilibrium of the planet, using reference materials.

PREREQUISITES

1.3

RELATED CONTENT

- **SKILL:** Formulating generalizations. (F-2)
- **KNOWLEDGE:** Consequences of the use of pesticides: destruction of certain species and proliferation of others, excessive use of wood resources: reduction of O_2, increase of CO_2, greenhouse effect, consequences of excessive population increase: depletion of natural resources, extinction of various species. (A-1)
- **ATTITUDE:** Sense of responsibility. (H-8)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Brainstorming, teamwork, individual work, class discussion

B. **DURATION:** 75 minutes + homework

C. **EVALUATION:** Quality of arguments

D. **MATERIALS:** Reference materials

E. **SAFETY MEASURES:** N/A

SUGGESTED REFERENCES

AV-19, AV-46, S-48, S-49, S-50, P-38, P-39, B-70, B-75, B-76, B-77

LEARNING ACTIVITIES

THE STUDENTS:

1.4.0	Review the concept of equilibrium in nature (*Ecology*: Code 16-3143-01A, Module 4).
1.4.1	List examples of the uses of substances that have an impact on the equilibrium of the planet.
1.4.2	Describe the impact of the use of one of these substances on the equilibrium of the planet.
1.4.3	Using reference materials, predict the potential effects of excessive population increase on the consumption of natural resources and on the physical and biological equilibrium of the planet.
1.4.4	Propose solutions to the potential effect of excessive human population.
1.4.5	Discuss their proposals with their classmates and select some for further study.
1.4.6	Distinguish the solutions that concern the individual from the solutions that concern society as a whole.
1.4.7	Become aware of Rachel Carson's view of the equilibrium of the planet.
1.4.8	Formulate a response to Barbara Ward's question, "Have you the courage, the vision and the will needed to mould new relationships in the human environment, so that human beings can live productively in the natural environment on which they depend?" (Free translation)

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

2 **Carry out quantitative analyses of the equilibrium of various chemical systems, based on experiments or on given values.**

2.1 Represent, by means of a molecular model and based on an experiment, the the dynamic microscopic aspect of a balanced system so as to understand how it functions.

PREREQUISITES

Module 3: 3.3, Module 5: 1.1

RELATED CONTENT

- **SKILL:** Recognizing the problem. (C-1)
- **KNOWLEDGE:** Conditions for the equilibrium of a system, symbol used to represent a reversible reaction that can attain equilibrium. (A-3)
- **ATTITUDE:** Constructivist view of science. (H-2)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Brainstorming, demonstration, laboratory work, team work, class discussion, simulation

B. **DURATION:** 150 minutes

C. **EVALUATION:** Quality of the hypothesis

D. **MATERIALS:** 100 mL, 250 mL and 1 000 mL beakers, test-tubes (13 mm x 100 mm), 2 x 25 mL graduated cylinders, funnel, filter paper, funnel stand, universal support, dropper bottle, $Ba(NO_3)_2$ saturated solution (1 mol/L), Na_2CO_3 solution (1 mol/L), anhydrous $CaCl_2$ solution (1 mol/L), anhydrous Na_2SO_4 solution (1 mol/L), anhydrous $CaSO_4$ solution (1 mol/L), NaCl, distilled water, transparent plastic cups, reference materials

E. **SAFETY MEASURES:** For glassware, heat, chemicals

LEARNING ACTIVITIES

THE STUDENTS:

2.1.0	Review the value of constructing a model (*Physical Sciences 416-436*, Module I: 4.2). Review the techniques for determining ionic charge (*Physical Sciences 416-436*, Module III: 2.6).
2.1.1	During a demonstration, observe the effects of the simultaneous reversibility of a phenomenon on a system.
2.1.2	List reversible phenomena in their environment for which reverse processes occur simultaneously.
2.1.3	Carry out a precipitation reaction in a closed system, based on the suggested experimental procedure.
2.1.4	Write a net ionic equation for the given precipitation reaction.
2.1.5	Justify their equations.
2.1.6	Carry out the reverse reaction of the precipitation reaction proposed in 2.1.3, using the suggested experimental procedure.
2.1.7	Associate the reverse reaction of a precipitation reaction with dissociation reaction.
2.1.8	Discuss the possibility of simultaneous reversibility of precipitation and dissociation reactions with their classmates.
2.1.9	Associate the simultaneous reversibility with the equilibrium of a reaction.
2.1.10	Propose a conventional representation of a chemical reaction in equilibrium.
2.1.11	Compare their proposal with the generally used convention.
2.1.12	Suggest a hypothesis to explain the chemical equilibrium of a system, based on the collision theory and the concept of reaction rate.
2.1.13	Discuss their hypotheses with their classmates.
2.1.14	Become aware of Claude Bertholet's definition for the saturation of a solution (18th to 19th century).

SUGGESTED REFERENCES

AV-8, AV-42, AV-43, AV-63, S-45, P-37, B-11, B-14, B-15, B-71

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

2.2 Establish a mathematical equation for the concentrations of products and reactants in a balanced chemical reaction, at constant temperature.

PREREQUISITES

1.3

RELATED CONTENT

- **SKILL:** Constructing a model. (E-2)
- **KNOWLEDGE:** Law of equilibrium or mass action. (A-8)
- **ATTITUDE:** Conscientiousness. (H-3)

SUGGESTED TEACHING PLAN

A.	**TEACHING STRATEGY:**	Teamwork, laboratory work, class discussion
B.	**DURATION:**	175 minutes + homework
C.	**EVALUATION:**	Quality of the mathematical equation
D.	**MATERIALS:**	100 mL graduated cylinder, 250 mL beaker, washing bottle, stirring rod, titration plate (for cups), dropper, universal indicator, buffer solutions, $NaCH_3CO_2$ solution (1 mol/L), HCl (1 mol/L), $HCH_3CO_2(aq)$ solution (1 mol/L), pH conversion table in molar concentrations, calculator (optional)
E.	**SAFETY MEASURES**	For glassware, corrosive solutions

SUGGESTED REFERENCES

AV-8, AV-39, AV-47, AV-63, B-14, B-15, B-25, B-27, B-33

LEARNING ACTIVITIES

THE STUDENTS:

2.2.0	Review the difference between a strong and a weak electrolyte (*Physical Sciences 416-436*, Module III: 2.8). Review the concept of concentration: c = n/V (*Physical Sciences 416-436*, Module III: 3.6). Review the use of an indicator mixture for measuring the pH of a solution (*Physical Sciences 416-436*, Module III: 4.4). Review the relationship between the pH and the molar concentration in hydrogen ions (*Physical Sciences 416-436*, Module III: 4.6). Review the concept of stoichiometry (*Physical Sciences 416-436*, Module III: 5.6).
2.2.1	Write a net ionic equation for a given chemical reaction.
2.2.2	Propose means of changing the equilibrium of the suggested chemical system and of identifying the direction of the shift in equilibrium.
2.2.3	Compare their proposals with their classmates and select some for further study.
2.2.4	Verify their proposals by carrying out an experiment according to a suggested experimental procedure.
2.2.5	Propose a mathematical equation for the concentrations of the reactants and the products in the balanced chemical system, at constant temperature, based on their experiments.
2.2.6	Compare their equations with their classmates and select one for further study.
2.2.7	Compare the selected equation with the conventional statement of the law of mass action developed by Guldberg and Waage (19th and 20th century).
2.2.8	Demonstrate that the discovery of the law of equilibrium or of mass action is the source of quantitative analyses of chemical equilibrium, using reference materials.
2.2.9	Discuss the need to specify the temperature value when expressing the value of an equilibrium constant.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

2.3 Calculate the value of the ionization constant of water at 25°C, based on their knowledge of equilibrium.

PREREQUISITES

2.2

RELATED CONTENT

- **SKILL:** Interpreting data. (E-2)
- **KNOWLEDGE:** Ionization constant of water at 25°C. (A-4)
- **ATTITUDE:** Self confidence. (H-3)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Teamwork, individual work, class discussion

B. **DURATION:** 75 minutes

C. **EVALUATION:** Quality of the interpretations

D. **MATERIALS:** Table of equilibrium constants

E. **SAFETY MEASURES:** N/A

SUGGESTED REFERENCES

S-53, B-23, B-25, B-26, B-27, B-78

LEARNING ACTIVITIES

THE STUDENTS:

2.3.0	Review the value of the molar concentration of H^+ and OH^- ions in pure water at 25°C (*Physical Sciences 416-436*, Module III: 4.7). Review the relationship between the molar concentration, the number of moles of a substance and the volume of the solution (*Physical Sciences 416-436*, Module III: 3.6).
2.3.1	Write a balanced chemical equation for the ionic dissociation of pure water.
2.3.2	Suggest a mathematical expression for the ionization constant, K_w, of pure water, based on the law of mass action.
2.3.3	Discuss their suggestions with their classmates.
2.3.4	Calculate the molar concentration of water molecules in pure water.
2.3.5	Calculate the value of the ionization constant, K_w, of pure water.
2.3.6	Compare this result with the generally accepted value.
2.3.7	Suggest an explanation for the difference, if any.
2.3.8	Reformulate, if necessary, the mathematical equation for the ionization constant, K_w, of pure water.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

**	2.4	Carry out, in the laboratory, titrations of acids and bases of various concentrations.

PREREQUISITES

2.2

RELATED CONTENT

-	SKILL:	Observing. (G-2)
-	KNOWLEDGE:	Titration techniques, interpreting titration curves, techniques for selecting an indicator, definition of titration, turning point, equivalence point. (A-7)
-	ATTITUDE:	Critical attitude. (H-3)

SUGGESTED TEACHING PLAN

A.	TEACHING STRATEGY:	Teamwork, laboratory work, simulation
B.	DURATION:	300 minutes
C.	EVALUATION:	Titration techniques
D.	MATERIALS:	50 mL buret, funnel, universal support, buret tongs, 10 mL pipette, 50 mL Erlenmeyer flask, 100 mL beaker, magnetic stirrer, pH meter or pH paper, pipette pump, solutions: NaOH (0.10 mol/L), HCl (0.1 mol/L), HCH_3CO_2 (0.1 mol/L), indicators: phenolphthalein, methyl orange.
E.	SAFETY MEASURES:	For glassware, corrosive substances

SUGGESTED REFERENCES

AV-8, AV-48, AV-49, AV-50, AV-63, S-51, S-52, S-54, S-55, B-14, B-15

LEARNING ACTIVITIES

THE STUDENTS:

2.4.0	Review the concept of indicator (*Physical Sciences 416-436*, Module III: 4.2 and 4.3). Review the concept of neutralization (*Physical Sciences 416-436*, Module III: 5.2).
2.4.1	Predict the shape of the curve of the pH variation of a strong acid of unknown concentration to which a strong base has been added.
2.4.2	Compare their predictions with their classmates and select one for further study.
2.4.3	Verify the hypothesis selected by carrying out an experiment according to a suggested procedure.
2.4.4	Modify the proposed curve, if necessary.
2.4.5	Indicate, on the curve, the turning point of the indicator and the equivalence point.
2.4.6	Write a balanced net ionic equation for the neutralization reaction.
2.4.7	Calculate the concentration of the acid used, based on the results of the experiment.
2.4.8	Repeat the above steps, in the laboratory or by means of a simulation, to titrate acids and bases of various concentrations.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

2.5 Compare the strength of various acids, based on experiments and using simulations.

PREREQUISITES

2.2

RELATED CONTENT

- **SKILL:** Interpreting data. (E-2)
- **KNOWLEDGE:** Technique for determining the value of the ionization constant of an acid, definition and process of dissociation of polyacids, definition of the strength of an acid. (A-6)
- **ATTITUDE:** Willingness to clarify problems. (H-3)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Teamwork, group work in laboratory, class discussion, simulation, individual work

B. **DURATION:** 150 minutes + homework

C. **EVALUATION:** Quality of the report

D. **MATERIALS:** pH paper or pH meter, test tube (13 mm x 100 mm), 10 mL graduated cylinder, 0.10 mol/L of each of the following: HCl, HCH_3CO_2, $H(CO_2)_2H$, H_3PO_4, NaH_2PO_4, thermometer, calculator with logarithmic functions (optional), pH conversion table with molar concentrations, table to compile the group's results

E. **SAFETY MEASURES:** For glassware, chemicals

SUGGESTED REFERENCES

AV-8, AV-51, AV-63, S-56, B-14, B-15, B-79

THE STUDENTS:

2.5.1	Develop an experimental procedure to determine the value of the ionization constant, K_2, of a mono-acid of a known initial concentration, using the materials available.
2.5.2	Calculate the dissociation constant of the acid.
2.5.3	Write their results in the table used to compile the group's results.
2.5.4	Compare the values obtained in the experiments with the values obtained by simulation.
2.5.5	Explain the difference, if any.
2.5.6	Classify the acids studied in decreasing order of strength.
2.5.7	Repeat these steps for polyacids.
2.5.8	Write a report on their experiments.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

**	2.6	Solve problems, numerical exercises and graphs concerning the equilibrium of a chemical system.

PREREQUISITES

2.1, 2.2, 2.3, 2.5

RELATED CONTENT

-	**SKILL:**	Interpreting data. (D-1)
-	**KNOWLEDGE:**	Calculation techniques relating to equilibrium of a chemical system. (A-7)
-	**ATTITUDE:**	Conscientiousness. (H-3)

SUGGESTED TEACHING PLAN

A.	**TEACHING STRATEGY:**	Individual work, teamwork, laboratory work, simulation, class discussion
B.	**DURATION:**	200 minutes + homework
C.	**EVALUATION:**	Problem-solving techniques
D.	**MATERIALS:**	Depending on problems/situations presented, calculator (optional)
E.	**SAFETY MEASURES:**	N/A or depending on problems to be solved

SUGGESTED REFERENCES

S-57, B-25, B-35

LEARNING ACTIVITIES

THE STUDENTS:

2.6.1	Identify the data needed to solve the problems, by reading the questions carefully.
2.6.2	Associate the fixed units with the physical quantities in the problem.
2.6.3	Use mathematical operations correctly in solving each problem.
2.6.4	Give the answer, taking into account the significant figures.
2.6.5	Verify the plausibility of the answer, by means of unit analysis.
2.6.6	Verify the plausibility of the answer by order of magnitude.
2.6.7	Verify the plausibility of the answer by means of an experiment or simulation, if necessary.
2.6.8	Present the most elegant solution.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

3 **Analyze various oxidation-reduction reactions, based on the results of their experiments.**

3.1 Describe, based on the concept of energy, the behaviour of substances in a given oxidation-reduction reaction.

PREREQUISITES

RELATED CONTENT

- **SKILL:** Observing. (B-2)
- **KNOWLEDGE:** Process of half-reaction, definitions of half-reaction of oxidation, half-reaction of reduction, spontaneous reaction, oxidizing agent, reducing agent. (A-7)
- **ATTITUDE:** Concern for the use of correct language. (F-4)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Brainstorming, teamwork, laboratory work, class discussion

B. **DURATION:** 125 minutes

C. **EVALUATION:** Quality of the hypotheses

D. **MATERIALS:** Pieces of Zn, Cu, 0.10 mol/L of each of the following: $Zn(NO_3)_2$, $Cu(NO_3)_2$, test tubes (13 mm x 100 mm), test tube stand, emery paper, 10 mL graduated cylinder, wax pencil, documentation

E. **SAFETY MEASURES:** For glassware, chemicals

SUGGESTED REFERENCES

AV-8, AV-52, AV-53, AV-54, AV-55, AV-63, S-58, P-39, P-40, B-14, B-15, B-28, B-42, B-80

LEARNING ACTIVITIES

THE STUDENTS:

3.1.0	Review Rutherford-Bohr atomic model (*Physical Sciences 416-436*, Module I: 4.9).
3.1.1	List examples of chemical reactions in their environment that seem to occur without external energy.
3.1.2	Associate these types of reactions with spontaneous reaction.
3.1.3	Classify given chemical reactions of metals and metal salts as spontaneous or non-spontaneous reactions.
3.1.4	Justify their classifications by means of ionic equations.
3.1.5	Compare their classifications with their classmates.
3.1.6	Develop an experimental procedure to verify their hypotheses, taking into account the materials available.
3.1.7	Propose balanced equations, based on the concept of energy, to represent the change in the metal and in the metallic ion.
3.1.8	Compare their proposals with their classmates and select some for further study.
3.1.9	Compare the equations selected with half-reactions.
3.1.10	Distinguish the oxidizing agent from the reducing agent, based on the appropriate definitions.
3.1.11	Suggest an explanation for spontaneous reactions and non-spontaneous reactions, based on the concept of energy transfer.
3.1.12	Compare their hypothesis with their classmates and select one for further study.
3.1.13	Compare the hypothesis selected with the generally acepted one.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

3.2 Determine the pair of electrodes that offer the greatest electrical potential, based on experiments.

PREREQUISITES

3.1

RELATED CONTENT

- **SKILL:** Measuring. (G-2)
- **KNOWLEDGE:** Classification of half-reactions of reduction, effect of the nature of electrodes on the electrical potential of a battery. (A-4)
- **ATTITUDE:** Willingness to interpret information. (H-3)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Brainstorming, individual work, team work, laboratory work, class discussion, simulation

B. **DURATION:** 150 minutes

C. **EVALUATION:** Quality of laboratory work

D. **MATERIALS:** 100 mL beaker, graduated cylinders, washing bottle, NaCl solution (0.5 mol/L), electrodes: Cu, Mg strip, Ag, Pb, connecting wires with clips, voltmeter (0-5 V), emery paper

E. **SAFETY MEASURES:** For glassware, chemicals

SUGGESTED REFERENCES

AV-8, AV-57, AV-63, S-59, S-60, B-14, B-15, B-32, B-80

LEARNING ACTIVITIES

THE STUDENTS:

3.2.0	Review the concept of potential difference (*Physical Sciences 416-436*, Module II: 3.12 and 4.4).
	Review the techniques for using a voltmeter (*Physical Sciences 416-436*, Module II: 3.4).
	Review the concept of electrolytes (*Physical Sciences 416-436*, Module III: 2.7).
3.2.1	List means of producing electricity by chemical reaction.
3.2.2	Express their idea of an electrochemical cell.
3.2.3	Differentiate batteries by the nature of their electrodes and their voltage.
3.2.4	Predict from among the electrodes provided, the pair that will produce the greatest and the smallest potential difference.
3.2.5	Verify their predictions by means of an experiment for which they have developed a procedure.
3.2.6	Write balanced ionic equations to represent the half-reactions produced.
3.2.7	Identify the reducing agent and the oxidizing agent for each reaction.
3.2.8	Classify the half-reactions in decreasing order of their standard electrode potential.
3.2.9	Discuss their classifications with their classmates.
3.2.10	Compare the classification selected with the conventional classification.
3.2.11	Discuss the possibility of constructing a battery with electrodes that are not contained in the same cell.
3.2.12	Differentiate the following: model, experimental facts and convention.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

3.3 Calculate the potential diference of various oxidation-reduction reactions, based on a table of standard electrode potentials.

PREREQUISITES

3.2

RELATED CONTENT

- **SKILL:** Interpreting data. (D-4)
- **KNOWLEDGE:** Techniques for calculating oxidation-reduction potentials, meaning of the redox potential sign. (A-7)
- **ATTITUDE:** Constructivist view of science. (H-3)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Individual work, teamwork, class discussion

B. **DURATION:** 125 minutes

C. **EVALUATION:** Calculation techniques

D. **MATERIALS:** Results from 3.2, table of standard electrode potentials

E. **SAFETY MEASURES:** N/A

SUGGESTED REFERENCES

AV-58, AV-59, B-80

THE STUDENTS:

3.3.1	Discuss the necessity of defining a reference point on a scale or a table (e.g. temperature, pH, equilibrium constant).
3.3.2	Become aware of the reference potential used in establishing a conventional table of reduction potentials.
3.3.3	Interpret the reduction potential signs.
3.3.4	Calculate the potential difference of the various batteries, based on values from a table of standard electrode potentials (reduction potentials).
3.3.5	Write equations representing oxidation-reduction reactions.
3.3.6	Identify the reducing agent and the oxidizing agent in each equation.
3.3.7	Calculate the potential difference of oxidation-reduction reactions, based on values from a table of standard electrode potentials (reduction potentials).
3.3.8	Indicate whether they are spontaneous or non-spontaneous reactions.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

3.4 Explain the variation in the oxidation-reduction potential of an electrochemical cell, based on Le Chatelier's principle.

PREREQUISITES

1.2, 3.3

RELATED CONTENT

- **SKILL:** Formulating generalizations. (F-2)
- **KNOWLEDGE:** Variation of the potential of an electrochemical cell, electrolyte bridge. (A-1)
- **ATTITUDE:** Willingness to synthesize and apply knowledge. (F-2)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Teamwork, group work in the laboratory, simulation, class discussion

B. **DURATION:** 100 minutes

C. **EVALUATION:** Qualities of the arguments

D. **MATERIALS:** Pieces of Zn and Cu, 250 mL beakers, 100 mL graduated cylinder, 0.10 mol/L of each of the following solutions: $Zn(NO_3)_2$, $Cu(NO_3)_2$, 2.0 mol/L of each of the following solutions: $Zn(NO_3)_2$, $Cu(NO_3)_2$, electrolyte bridge with KNO_3 (1.0 mol/L), connecting wires with clips, voltmeter (0-5 V), table used to compile group's results

E. **SAFETY MEASURES:** For glassware, chemicals

SUGGESTED REFERENCES

AV-8, AV-60, AV-63, B-14, B-15, B-25

LEARNING ACTIVITIES

THE STUDENTS:

3.4.1	Write an equation representing the oxidation-reduction reaction occurring in a given electrochemical cell.
3.4.2	Propose a hypothesis to explain the "death" of a battery.
3.4.3	Justify their hypothesis, by referring to Le Chatelier's principle.
3.4.4	Develop an experimental procedure to verify their hypothesis, using the materials available.
3.4.5	Write their results in the table used to compile the group's results.
3.4.6	Propose an explanation as to why the potential of a battery diminishes with time.
3.4.7	Discuss their proposal with their classmates.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

**	3.5	Balance the equation for an oxidation-reduction reaction, based on the oxidation-number method.

PREREQUISITES

3.1

RELATED CONTENT

-	SKILL:	Interpreting data. (D-3)
-	KNOWLEDGE:	Definition of oxidation number, rules for determining oxidation numbers, balancing redox equations using the oxidation-number method. (A-7)
-	ATTITUDE:	Conscientiousness. (H-3)

SUGGESTED TEACHING PLAN

A.	TEACHING STRATEGY:	Teamwork, individual work, presentation
B.	DURATION:	300 minutes
C.	EVALUATION:	Techniques for balancing redox equations
D.	MATERIALS:	Reference materials
E.	SAFETY MEASURES:	N/A

SUGGESTED REFERENCES

P-41, P-42, B-32

THE STUDENTS:

3.5.0	Review the magnitude and sign of the charge of metallic and non-metallic ions (*Physical Sciences 416-436*, Module III: 2.5). Review the concept of electroneutrality (*Physical Sciences416-436*, Module I: 4.9, Module III: 2.6).
3.5.1	Predict the electric charge carried by an atom of an element, by a molecule and by an ion.
3.5.2	Predict the electric charge carried by each atom of a compound.
3.5.3	Justify their predictions.
3.5.4	Compare their predictions with the conventional rules for determining oxidation numbers.
3.5.5	Determine the oxidation number of each atom represented in a redox equation, based on the rules selected.
3.5.6	Determine the reducing agent and the oxidizing agent in the proposed equation.
3.5.7	Balance the proposed redox equation.
3.5.8	By referring to the three methods used to identify chemical compounds, become aware of Stock's method (20th century) which uses the oxidation number of the main element or ion.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

4. **Illustrate, by means of an impact study, the relationships among the following: the development and use of knowledge relating to equilibrium in chemical reactions, science, technology, society and the environment.**

   4.1 Illustrate, based on reference materials, the cause-and-effect relationships between the development and use of knowledge relating to equilibrium in chemical reactions and society, at different periods of history.

PREREQUISITES

1, 2, 3

RELATED CONTENT

- **SKILL:** Interpreting data. (D-4)
- **KNOWLEDGE:** Development of scientific knowledge relating to equilibrium in chemical reactions, societal influences. (A-1)
- **ATTITUDE:** Constructivist views of science. (I-3)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Brainstorming, teamwork, individual work, class discussion

B. **DURATION:** 50 minutes + homework

C. **EVALUATION:** Quality of the interpretations

D. **MATERIALS:** Reference materials

E. **SAFETY MEASURES:** N/A

SUGGESTED REFERENCES

THE STUDENTS:

4.1.0	Review the concepts relating to the history of science and technology (*General History*: Code 16-3658A, *History of Québec and Canada*: Code 16-3660A, *Introduction to Technology*: Code 16-4888A).
4.1.1	List works by ancient scientists that have had the effect of initiating the development of scientific knowledge relating to equilibrium in chemical reactions.
4.1.2	Describe scientific works that have contributed to the development of scientific knowledge relating to equilibrium in chemical reactions, based on reference materials (e.g. work by Kirchhoff, Wollaston, Gerhardt, Le Chatelier, Haber, Van't Hoff, Volta).
4.1.3	Write a summary of their research in the group's compendium of information.
4.1.4	Identify ways in which the development of knowledge relating to equilibrium in chemical reactions has influenced society at different periods of history.
4.1.5	Think about future technological developments relating to equilibrium in chemical reactions.
4.1.6	Discuss how social evolution has influenced the development of knowledge and technology relating to equilibrium in chemical reactions.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

**	4.2	Illustrate the cause-and-effect relationships between the development and use of knowledge relating to equilibrium in chemical reactions and our quality of life, based on observations of phenomena and using reference materials.

PREREQUISITES

4.1

RELATED CONTENT

-	**SKILL:**	Formulating generalizations. (F-1)
-	**KNOWLEDGE:**	Ways in which the development of technology relating to equilibrium in chemical reactions affect our quality of life (e.g. health, comfort), societal influences (A-1)
-	**ATTITUDE:**	Sense of belonging. (H-7)

SUGGESTED TEACHING PLAN

A.	**TEACHING STRATEGY:**	Brainstorming, teamwork, individual work, class discussion
B.	**DURATION:**	50 minutes + homework
C.	**EVALUATION:**	Quality of the predictions
D.	**MATERIALS:**	Reference materials
E.	**SAFETY MEASURES:**	N/A

SUGGESTED REFERENCES

LEARNING ACTIVITIES

THE STUDENTS:

4.2.1	List technological developments relating to equilibrium in chemical reactions that have influenced our quality of life at different periods in history.
4.2.2	Classify these technological inventions according to their advantages and disadvantages.
4.2.3	Predict how future technological developments relating to equilibrium in chemical reactions will affect our quality of life.
4.2.4	Discuss how standard of living influences the development of knowledge and technology relating to equilibrium in chemical reactions.
4.2.5	Become aware of the guiding principles concerning the management of chemicals, proposed by the Canadian Chemical Producers' Association, using reference materials.
4.2.6	Write a short report on their work.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

4.3 Illustrate the cause-and-effect relationships between the development and use of knowledge relating to equilibrium in chemical reactions and the natural and human-made environment, based on observations of phenomena and using reference materials.

PREREQUISITES

4.1

RELATED CONTENT

- **SKILL:** Organizing data. (D-1)
- **KNOWLEDGE:** Ways in which the development of technology relating to equilibrium in chemical reactions affects the environment, the evolution of environmental consciousness. (A-1)
- **ATTITUDE:** Sense of responsibility toward the environment. (H-7)

SUGGESTED TEACHING PLAN

A. **TEACHING STRATEGY:** Brainstorming, teamwork, individual work, field trips, class discussion

B. **DURATION:** 45 minutes + homework

C. **EVALUATION:** Quality of proposed means

D. **MATERIALS:** Reference materials

E. **SAFETY MEASURES:** Normal safety rules for field trips

SUGGESTED REFERENCES

THE STUDENTS:

4.3.1	List technological developments relating to equilibrium in chemical reactions that have effects on the environment.
4.3.2	Classify these technological developments according to their advantages and disadvantages.
4.3.3	Propose means of reducing the harmful effects of technological developments that are considered harmful to the environment.
4.3.4	Assess the feasibility of the proposed means.
4.3.5	Predict how future technological developments relating to equilibrium in chemical reactions might affect the environment.
4.3.6	Discuss how the evolution of environmental consciousness influences research and development of knowledge and technology relating to equilibrium in chemical reactions.
4.3.7	Become aware of the guiding principles concerning the management of chemicals, proposed by the Canadian Chemical Producers' Association, using reference materials.
4.3.8	Write a report on their research in the group's compendium of information.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

**	4.4	Discuss Québec's role in research and development relating to equilibrium in chemical reactions, using reference materials.

PREREQUISITES

4.3

RELATED CONTENT

-	SKILL:	Recognizing a problem. (C-1)
-	KNOWLEDGE:	Québec organizations involved in chemical research, social and economic consequences. (A-1)
-	ATTITUDE:	Sense of belonging. (H-3)

SUGGESTED TEACHING PLAN

A.	TEACHING STRATEGY:	Individual work, teamwork, class discussion
B.	DURATION:	75 minutes + homework
C.	EVALUATION:	Quality of the reports
D.	MATERIALS:	Reference materials
E.	SAFETY MEASURES:	N/A

SUGGESTED REFERENCES

THE STUDENTS:

4.4.1	List advanced research on equilibrium in chemical reactions carried out in the world, using reference materials.
4.4.2	Identify those research projects carried out in Québec.
4.4.3	Name Québec businesses and institutions that contribute to the development of knowledge relating to equilibrium in chemical reactions.
4.4.4	Describe at least one project or piece of research on chemical equilibrium carried out by a Québec business or institution.
4.4.5	Write their description in the group's compendium of information.

TEACHER'S NOTES

SPECIFIC OBJECTIVES
(Terminal and Intermediate Objectives)

THE STUDENTS WILL LEARN HOW TO:

**	4.5	Identify professions associated with the development of knowledge relating to equilibrium in chemical reactions, using reference materials.

PREREQUISITES

RELATED CONTENT

- **SKILL:** Formulating generalizations. (F-2)
- **KNOWLEDGE:** Professions associated with the development of knowledge relating to chemical equilibrium. (A-6)
- **ATTITUDE:** Fascination with science. (H-6)

SUGGESTED TEACHING PLAN

A.	**TEACHING STRATEGY:**	Teamwork, individual work, visits, interviews
B.	**DURATION:**	50 minutes + homework
C.	**EVALUATION:**	Quality of the description
D.	**MATERIALS:**	Reference materials
E.	**SAFETY MEASURES:**	N/A

SUGGESTED REFERENCES

THE STUDENTS:

4.5.0	Review information documents on careers (*Career Choice Education*: Code 16-3800A)
4.5.1	List professions associated with the development of knowledge relating to chemical equilibrium.
4.5.2	Describe at least one of the professions listed, using reference materials or based on interviews
4.5.3	Write a report on their research.

TEACHER'S NOTES

7. EVALUATION

Evaluation is an integral part of the teaching and learning process. It is first and foremost a way of determining whether students are ready to learn new material, or whether they need remedial activities. Evaluation therefore serves to improve the quality of education and to ensure a favorable learning environment for the students.

Formative and summative evaluation must be consistent with the orientations and the guiding principles of the program. Both should verify the degree to which students have assimilated the learning content (skills, knowledge and attitudes) within the framework provided by the terminal objective and defined by the intermediate objectives and the suggested learning activities.

7.1 Evaluation in Accordance with the Principles of the Program

Examinations, be they ministerial or local, are known to condition teaching. For this reason, evaluation methods should, as much as possible, take into account the orientations and the related learning content (i.e. skills, knowledge and attitudes) of the program. Since this program proposes a teaching/learning approach based on the scientific method, the students' approach to solving a problem as well as their answer to the problem should be evaluated.

All the components of this program must be properly implemented if students are to benefit from this new approach to teaching chemistry. The methods for evaluating student learning, for both formative and summative evaluation, are essential elements of this new approach.

7.2 Responsibility for Evaluation

Evaluation for the terminal objectives of Modules 2, 3, 4 and 5 of this program will be carried out by means of a ministry-prepared examination. The Ministère will do its best to ensure that this evaluation is consistent with the orientations of the program. The

ministry-prepared examination accounts for 50% of the students' final mark and should consist of two parts: one administered in class, the other in the laboratory.

The partial summative evaluations carried out by either the teacher, the school or the school board during the school year will account for the other 50% of the students' final mark.

Evaluation for all enrichment activities (objectives marked ** and other optional objectives) is the responsibility of the school and/or the school board.

8. IMPLEMENTING THE PROGRAM

The new approach to the teaching of Chemistry will only be successful if the implementation of this program takes into account all of the following elements.

8.1 Target Population

In order to take this course, students must have sucessfully completed Physical Sciences 436, the enriched path of Physical Sciences 416-436.

8.2 Students' Responsibility

Students are ultimately responsibile for their own education in that they are the only ones who can decide whether they are going to make the effort to learn. By being active participants in the learning process rather than passive recipients of a flood of information, they will be able to construct the knowledge needed to meet the challenges of everyday life and to go on to further studies in Natural Sciences.

Students are expected to do the required classroom work and complete their homework assignments to the best of their abilities. If they have any difficulties, they should approach competent resource persons for assistance.

8.3 Parents' Responsibility

Parents are expected to take an interest in their children's education and, if necessary, provide them with essential materials that are not supplied by the school, thereby helping to promote the importance of a sound scientific background at a time when science and technology are playing a crucial role in all areas of activity.

8.4 Teachers' Responsibility

Although our society and schools have tended to take a relatively elitist approach to the teaching of chemistry, this subject should be an integral part of all students' general

education. This course is open to all students even if its main goal is to prepare students for chemistry or chemistry-related studies at the college level.

Science teachers are the primary resource persons and it is their responsibility to guide students through the learning process. They should integrate the suggested learning activities into their courses, or propose others, depending on the students' abilities.

Teachers must evaluate student learning and, if necesary, decide upon remedial activities. Stimulating instruction and questions that reflect real life experiences usually motivate students at this level.

8.5 School Administrators' Responsibility

School administrators must ensure that this program is implemented in accordance with the orientations it emphasizes. They must also ensure that all lower-level science programs, especially the physical sciences programs for Secondary II and Secondary IV, are implemented accordingly. In this way, students will have already been introduced to the approach emphasized in this chemistry program.

The school administration is responsible for providing students and teachers with educational materials (e.g. textbooks, laboratory equipment, reference materials, computers, software, audio-visual materials) that best reflect the orientations of this program and that facilitate students' assimilation of the learning content.

The professional development of teachers is essential to this new approach to teaching chemistry. The school administration should provide solid pedagogical support to ensure that teachers upgrade their skills in teaching natural sciences.

8.6 Teachers' Qualifications

Chemistry should be taught by teachers who have an excellent scientific background and a university degree in science. Most teachers start out with this prerequisite, however, many may not have upgraded their pedagogical skills since the end of the 1960s when

they would have been trained to use the CHEM STUDY method developed in the United States.

This chemistry program is not based on the CHEM STUDY method, nor are its orientations the same. Therefore, in order to be completely familiar with the new approach, teachers need to adapt their pedagogical skills and to practise applying this new method. In-service training for current and future teachers should begin at the same time as the implementation sessions for this program, and be completed in subsequent follow-up sessions.

8.7 Support Staff

At least half the objectives of this program must be attained through laboratory work. Laboratory experiments require special and careful preparation and the help of support staff. Some activities (e.g. handling chemicals, using a bunsen burner) present potential dangers to students' health and safety. It is therefore important that teachers be assisted by qualified technicians who can help students use the laboratory materials properly.

8.8 Organization of Class Time

The learning situations that will help students attain the objectives of the program in a manner consistent with its orientations call for regular class periods of sufficient duration for students to complete their work.

8.9 Evaluation of Learning

Local and ministry-prepared examinations must take into account the learning content and the orientations set out in the program.

8.10 Laboratory Work

Since one of the goals of this program is to enable students to become familiar with ways of thinking and work methods necessary to scientific research, students must have access

to laboratories where they can carry out the experimental procedures that they have developed, or that were developed beforehand. The school must provide students in this course with the laboratories needed for their experiments.

The standards pertaining to the design and organization of these laboratories are outlined in a *Guide d'aménagement* published by the Ministère (See Chapter 9 for full reference).

8.11 Equipment

Laboratories must be equipped with hot and cold water, electricity and gas and enough quality materials (e.g. measuring and observation instruments, chemicals) for all students. It is also important that teachers be provided with funds to replace perishable and other materials; these purchases must conform to CSST standards and environmental guidelines.

The Fédération des commissions scolaires catholiques du Québec with the assistance of the Direction de la formation générale has published a catalogue of materials and products that can be used for this program. The catalogue is available to school boards and private schools (See Chapter 9 for full reference).

9. RELATED DOCUMENTS

The ministère de l'Éducation has provided the following documents to help teachers and school administrators implement this program in accordance with the orientations it emphasizes. This list may be updated as necesary.

Catalogue d'équipement: Chimie 534. Québec: la Fédération des commissions scolaires catholiques du Québec, 1991.

Guide d'aménagement de classes-laboratoires, Sciences physiques, 4e secondaire. Québec: ministère de l'Éducation, Direction des équipements scolaires, 1990.

Définition du domaine: Chimie 534. Québec: ministère de l'Éducation, Direction de la formation générale des jeunes, 1991.

Guide de soutien à la mise en oeuvre du programme de Chimie 534. Québec: ministère de l'Éducation, Direction de la formation générale des jeunes, 1991.

Recueil de textes. Québec: ministère de l'Éducation, Direction de la formation générale de jeunes, 1991.

Cadre de référence à l'intention des auteurs et des évaluateurs du matériel didactique conçu en fonction du programme d'études Chimie 534. Québec: ministère de l'Éducation, 1991.

Santé, sécurité, environnement: les substances dangereuses. Video, no. 3130. Québec: ministère de l'Éducation, octobre 1989.

Pourquoi. Video, no. 1200 S092. Québec: ministère de l'Éducation, n.d.

L'enseignement des sciences de la nature: une nouvelle approche. Video. Québec: ministère de l'Éducation, 1992.

Health and Safety in the Natural Science Laboratory. Secondary School, Information Document, Code 16-3100A. Québec: ministère de l'Éducation, December 1985.

Guide de manipulation et d'élimination des substances dangereuses dans les établissements secondaires. Code 73-0018. Québec: ministère de l'Éducation, 1989.

Physical Sciences 416-436. Secondary School Curriculum, Code 16-3175A. Québec: ministère de l'Éducation, 1990.

APPENDIX I

LIST OF SKILLS AND ATTITUDES[1]

[1]This is a list of the main skills and attitudes that the student should normally continue to develop if this program is implemented in accordance with the orientations outlined in this document. This classification of skills, attitudes and related indicators should be regarded as a list of suggestions. Teachers may modify it depending on their own preferences or the specific classroom situation.

SKILLS (AND RELATED INDICATORS)

Terminal Skills	Intermediate Skills	Indicators
1. Defining a problem (C)	A. Recognizing a problem (C-1)*	• Asking how and why new phenomena occur • Formulating a question or a problem clearly • Identifying all the variables to be measured • Re-examining a question or a problem in the light of new data • Examining the way in which one variable influences another • Identifying the data relevant to the problem
	B. Formulating a hypothesis (Predicting) (C-2)	• Proposing one or more answers to a question • Formulating new hypotheses • Proposing explanations (how, why) for a phenomenon or an observation • Proposing a model • Selecting hypotheses that are consistent with his/her observations • Predicting the influence of one variable on another
	C. Developing an experimental procedure (C-3, C-4)	• Determining the experiments required to test a hypothesis • Determining the variables to be kept constant • Determining the experimental conditions • Identifying sources of danger to human health and safety • Identifying potential dangers for the environment • Selecting appropriate materials and measuring instruments
2. Gathering Information (B, G)	A. Observing (B-1, B-2, G-1, G-2, G-3)	• Using his/her senses (smell, sight, touch...) • Using instruments to supplement his/her observations • Taking precautionary safety measures when observing • Following the established procedure • Working methodically, maintaining order and cleanliness

* The alphanumeric code in parentheses refers to the taxonomy in Appendix II.

Terminal Skills	Intermediate Skills	Indicators
	B. Measuring (B-3, B-4, B-5, G-1, G-2)	• Identifying sources of error • Taking into account the precision of the instrument • Using SI units to measure physical quantities • Reading a measuring instrument correctly • Estimating the absolute error in the measurement of a physical quantity • Interpreting the scale of a measuring instrument • Taking into account significant figures • Monitoring the variables to be kept constant
3. Processing Data (D, E, G)	A. Organizing Data (D-1, D-2, G-2)	• Classifying his/her observations according to one or more specified criteria • Arranging his/her observations, measurements, or data according to specified criteria • Using tables to present numerical data • Using graphs to present numerical data • Proposing a classification system • Constructing a model based on a diagram • Correcting a diagram based on a model
	B. Interpreting Data (D-3, D-4, D-5, E-1, E-2)	• Establishing a relationship between two variables • Interpreting a graph • Representing a phenomenon by means of a mathematical equation • Applying the correct mathematical operators to the data obtained • Selecting observations that are relevant to the research topic • Drawing inferences from the data • Extrapolating beyond actual observations • Interpolating between observations • Taking into account absolute and relative errors when making calculations • Taking into account significant figures when making calculations • Incorporating units of measure into a calculation • Checking whether the result is plausible by analyzing the units used to quantify a physical quantity • Correcting a diagram

Terminal Skill	Intermediate Skills	Indicators
4. Concluding (B, D, E, F)	A. Formulating Generalizations (B-2, D-6, F-1 to F-4)	• Formulating a working definition of an object, a substance or a phenomenon • Describing an object, a substance, or a phenomenon, using models • Identifying an object, a substance, or a phenomenon based on its definition or description • Associating the same explanation with different phenomena • Drawing conclusions • Formulating generalizations based on sufficient data • Formulating a theory • Formulating a law • Identifying everyday phenomena and technological inventions that can be explained through interpretation, a hypothesis, a model, a theory • Identifying phenomena associated with a particular law • Using a model
	B. Constructing a Model (E-1 to E-6)	• Recognizing the need to develop a model • Constructing a physical model on paper or using a three-dimensional building set • Constructing a mathematical model • Writing an equation that represents a transformation • Writing a balanced equation that represents a transformation • Improving a model • Representing an object • Assessing a model • Describing a model
	C. Communicating (F-4)	• Using internationally-accepted terminology and symbols • Presenting work orally and in writing • Communicating using correct language

ATTITUDES (AND RELATED INDICATORS)

1. Fascination with science (H-3, H-4, H-6, H-8)	• Open (spiritually, intellectually, emotionally, sensorially) to exploring environmental phenomena • Enjoys learning and experimenting • Interested in pursuing a career in science and technology
2. Intellectual curiosity (H-2, H-3, H-4, H-5, I-4)	• Keen on acquiring knowledge • Attracted to the unknown • Confident in his/her ability to find a rational explanation for various phenomena • Interested in research • Interested in scientific activities
3. Willingness to clarify problems (H-3)	• Inclined to define the scope of a question in order to formulate a more clear and precise description of the problem • Inclined to define the scope of a question in order to formulate a description which makes it possible to find a plausible solution based on fact
4. Creative approach (ingenuity) (H-3, F-2)	• Inclined to formulate hypotheses or problem-solving strategies • Capable of drawing a variety of verifiable conclusions based on these hypotheses or problem-solving strategies • Tends to apply common sense (characteristic of a self-confident, assertive person who accepts ambiguity, who is not afraid to take risks or to rely on intuition)
5. Critical attitude (H-3, H-7, H-8)	• Inclined to question any assertion or proposition • Inclined to regard an assertion or proposition as a hypothesis • Inclined to organize and conduct experiments to test a hypothesis
6. Objectivity (H-3)	• Inclined to consider only known or verifiable data • Inclined to dismiss subjective data and preconceptions
7. Willingness to interpret information (H-3)	• Inclined to look for a logical line of reasoning, trends, or important characteristics when faced with raw data or seemingly unconnected pieces of information • Inclined to look for the meaning in given information • Inclined to analyze information

8. Willingness to compare ideas (H-3)	• Inclined to compare his/her work with that of others and with reality in order to assess its merit • Inclined to accept suggestions that could improve the quality of his/her work
9. Willingness to synthesize and apply knowledge (H-3, F-1, F-2, F-3, I-1, I-4)	• Inclined to assess what he/she has learned in order to understand how it relates to other topics • Inclined to apply what he/she has learned to other relevant situations
10. Concern for the use of correct language (F-4)	• Concerned about using the proper word or expression • Always interested in the meaning of the words or symbols used by other people • Concerned with communicating clearly and concisely
11. Constructivist view of science (H-1, H-2, I-1, I-2, I-3, I-4, I-5)	• Inclined to regard knowledge as the product of intellectual activity, something that must be constructed • Inclined to regard truth as relative and often subject to change • Inclined to regard scientists as fallible human beings who conduct research • Inclined to regard the scientific method as a way of thinking • Inclined to regard scientific knowledge as a system that is constantly evolving • Inclined to regard science as a product of history • Inclined to consider the social dimension of science
12. Sense of responsibility (concern for health and safety, the environment) (G-3, I-4, F-3, H-3, H-4, H-7, H-8)	• Inclined to keep in the best possible physical condition both for his/her own health and for the general health of society • Inclined to take precautionary measures when doing laboratory or field work • Inclined to act in an environmentally conscious manner • Inclined to recognize the social consequences of scientific and technological development
13. Sense of belonging (H-3, H-7)	• Aware that he/she is a member of a community • Inclined to act for the good of the community
14. Self-confidence (H-3)	• Inclined to express his/her opinions confidently • Inclined to discuss issues confidently • Inclined to defend his/her opinions
15. Conscientiousness (H-3)	• Concerned about producing quality work • Perseverant • Organized • Disciplined

APPENDIX II

TAXONOMY[2] FOR NATURAL SCIENCES EDUCATION

[2]This taxonomy is based on the taxonomy developed by Bloom, Hastings and Madaus (See *Handbook on Formative and Summative Evaluation of Student Learning*. 1971) and on the taxonomy developed by L. E. Klopfer (1971). The authors of this program have made some modifications.

A. Knowledge and Comprehension

- A-1 Knowledge of specific facts
- A-2 Knowledge of terminology
- A-3 Knowledge of concepts of science
- A-4 Knowledge of conventions
- A-5 Knowledge of trends and sequences
- A-6 Knowledge of classification, categories and criteria
- A-7 Knowledge of procedures and techniques
- A-8 Knowledge of principles and laws
- A-9 Knowledge of theories or major conceptual schemes
- A-10 Identifying knowledge in a new context
- A-11 Translating knowledge from one symbolic form to another

B. Observing and Measuring

- B-1 Observing objects and phenomena
- B-2 Describing observations
- B-3 Measuring objects and changes
- B-4 Selecting appropriate instruments
- B-5 Estimating measurements and recognizing limits in accuracy

C. Defining a Problem

- C-1 Recognizing a problem
- C-2 Formulating a hypothesis
- C-3 Selecting a test of a hypothesis
- C-4 Designing procedures for performing experiments

D. Interpreting Data and Formulating Generalizations

- D-1 Processing data
- D-2 Presenting data in the form of functional relationships
- D-3 Interpreting data
- D-4 Extrapolating and interpolating
- D-5 Testing a hypothesis
- D-6 Formulating generalizations

E. Constructing a Model

- E-1 Recognizing the need for a theoretical model
- E-2 Formulating a theoretical model
- E-3 Specifying relationships satisfied by a model
- E-4 Deducing new hypotheses
- E-5 Evaluating a model
- E-6 Formulating a revised or refined model

F. Applying Knowledge and Methods

- F-1 Applying knowledge and methods to new problems in the same field of science
- F-2 Applying knowledge and methods to new problems in a different field of science
- F-3 Applying knowledge and methods to problems outside of science and technology
- F-4 Using the written and spoken language specific to a discipline

G. Manual Skills

- G-1 Developing skills in using equipment normally used in laboratory or field work
- G-2 Doing laboratory or field work methodically
- G-3 Doing laboratory or field work carefully and safely

H. Attitudes and Interests

- H-1 Manifesting objective attitudes towards science and scientists
- H-2 Accepting scientific inquiry as a way of thought
- H-3 Adopting "scientific attitudes"
- H-4 Enjoying science learning experiences
- H-5 Developing interests in science and science-related activities
- H-6 Developing an interest in pursuing a career in science or technology
- H-7 Developing a sense of ethics with regard to social issues
- H-8 Showing a concern for the environment

I. Epistemological Orientations

- I-1 Recognizing relationships among various types of statements in science
- I-2 Recognizing the influence and limitations of scientific inquiry
- I-3 Historical perspective: recognizing the background of science
- I-4 Understanding the relationships among science, technology, and society
- I-5 Becoming aware of the social and moral implications of scientific inquiry and its results

APPENDIX III

SUGGESTED REFERENCE MATERIALS

AV: Audio-visual Materials
S: Software
P: Periodicals
B: Books

AUDIO-VISUAL MATERIALS (Films, videos)

AV-1 **Gases and How They Combine.** Ward's Natural Science, Video: 22 min. 1840 Mattawa Avenue, Mississauga, Ontario, L4X 1K1.

AV-2 **Gas Pressure and Molecular Collisions.** Ward's Natural Science, Video: 21 min. Op. cit.

AV-3 **Kinetic Molecular Theory of Gases.** Ward's Natural Science, Solo-learn Sound Filmstrip. Op. cit.

AV-4 **Experiments in Chemistry Series: Boyle's Law.** Educational Images Ltd., Filmstrip. P.O. Box 3456, Westside, Elmira NY 14905.

AV-5 **Experiments in Chemistry Series: Charles's Law.** Educational Images Ltd., Filmstrip. Op. cit.

AV-6 **Introduction to the Behavior of Gases.** Ward's Natural Science, Solo-learn Sound Filmstrip. Op. cit.

AV-7 **Gaseous mixtures.** Ward's Natural Science, Solo-learn Sound Filmstrip. Op. cit.

AV-8 **Safety in the Chem Lab.** Boreal, Filmstrip. 399 Vansickle Road, St Catharines, Ontario, L2S 3T4.

AV-9 **The Mole Concept: Combining Gas Volumes.** TVO (Radio-Québec), Video: 10 min. 600 Fullum Street, Suite 5.03, Montréal, H2K 3L6.

AV-10 **The Mole Concept: Avogadro's Hypotheses.** TVO (Radio-Québec), Video: 10 min. Op. cit.

AV-11 **Introduction to the Laws of Chemistry.** Ward's Natural Science, Solo-learn Sound Filmstrip. Op. cit.

AV-12 **Experiments in Chemistry Series: Molar Volume of a Gas,** Educational Images Ltd. Filmstrip. Op. cit.

AV-13 **Eureka.** TVO (Radio-Québec), 3 Video-cassettes: 30 programs of 4 min 55 s each. Op.cit.

AV-14 **Matter. Part III.** Boreal, Video: 10 min. Op. cit.

AV-15 **All About Matter.** Boreal, Video. Op. cit.

AV-16 **Chemical Reactions.** Boreal, Video: 22 min. Op. cit.

AV-17 **Introduction to the Classification of Matter.** Ward's Natural Science, Solo-learn Sound Filmstrip. Op. cit.

AV-18 **Fields of Space.** NFB, Video: 19 min. Complex Guy-Favreau, East Tower, Suite 005, 200 René-Lévesque Blvd. West, Montréal, H2A 1Y4, 1969.

AV-19 **The Green House Effect,** CBC (Radio-Canada), Video: 15 min. P.O. Box 6000, Montréal, H3C 3A8.

AV-20 **Radon.** Films for the Humanities & Sciences, Video: 20 min. P.O. Box 2053, Princeton, NJ 08543-2053.

AV-21 **Deadly Winds: Chemical Weapons.** Films for the Humanities & Sciences, Video: 26 min. Op. cit.

AV-22 **Out of the Air 1.** Films for the Humanities & Sciences, Video: 20 min. Op. cit.

AV-23 **Concepts in Science: Reaction Kinetics.** TVO (Radio-Québec), Video: 10 min. Op. cit.

AV-24 **Temperature and Kinetic Theory**. Films for the Humanities & Sciences, Video: 15 min. Op. cit.

AV-25 **Experiments in Chemistry Series: Energy of Reaction**. Educational Images Ltd., Filmstrip. Op. cit.

AV-26 **Chemical Reactions**. Educational Images Ltd., Filmstrip: 2 Parts. Op. cit.

AV-27 **Introduction to Reaction Kinetics**. Ward's Natural Science, Video: 13 min. Op. cit.

AV-28 **Tomorrow's Energy Today**. NFB, Video: 32 min. Op. cit.

AV-29 **Chemistry: Journey to the Future**. Dow Chemicals, Louisiana Division, Video. P.O. Box 150, Plaquminel, LA 70765-0150.

AV-30 **Energy Alternatives: Fusion**. Films for the Humanities & Sciences, Video: 26 min. Op. cit.

AV-31 **Hypothermia: The Cold Facts.** Minnesota Sea Grant Extension Program, Video. Duluth, Minn. USA.

AV-32 **Hot Stuff**. NFB, Video: 9 min. Op. cit.

AV-33 **Blow Hard**. NFB, Video: 10 min. Op. cit.

AV-34 **Experiments in Chemistry Series: Reaction Rates.** Educational Images Ltd., Filmstrip. Op. cit.

AV-35 **Rates of Chemical Reactions**. Ward's Natural Science, Video: 17 min. Op. cit.

AV-36 **Catalysis**. Ward's Natural Science, Video: 17 min. Op. cit.

AV-37 **Molecular Motions.** Ward's Natural Science, Video: 13 min. Op. cit.

AV-38 **Energy Alternatives: Solar.** Films for the Humanities & Sciences, Video: 26 min. Op. cit.

AV-39 **Introduction to Equilibrium Concepts.** Ward's Natural Science, Solo-learn Sound Filmstrip. Op. cit.

AV-40 **Equilibrium.** Ward's Natural Science, Video: 19 min. Op. cit.

AV-41 **Equilibrium: Unsteady Steadiness.** TVO (Radio-Québec), Video: 10 min. Op. cit.

AV-42 **Dynamic Equilibrium.** TVO (Radio-Québec), Video: 10 min. Op. cit.

AV-43 **Reaction Rates and Equilibrium.** Coronet, Video. 3771 Victoria Park, Scarborough, Ontario, M1W 2P9.

AV-44 **Reaction Tendencies.** TVO (Radio-Québec), Video: 10 min. Op. cit.

AV-45 **The Haber Process.** TVO (Radio-Québec), Video: 10 min. Op. cit.

AV-46 **The Dimensions of Science: A Question of Balance.** TV Ontario, Video: 29 min.

AV-47 **The Equilibrium Constant,** TVO (Radio-Québec), Video: 10 min. Op. cit.

AV-48 **Acid-base Indicators.** Ward's Natural Science, Video: 19 min. Op. cit.

AV-49 **All About Acids and Bases: Focus Media.** Boreal, Video. Op.cit.

AV-50 **Introduction to Titration.** Pre-lab. EME, Video: 23 min. Old Mill Plain Road, P.O. Box 2805, Danbury, Connecticut 06813-2805.

AV-51 **Introduction to Acid-Base Theory**. Ward's Natural Science, Solo-learn Sound Filmstrip. Op. cit.

AV-52 **Experiments in Chemistry Series: Oxidation-Reduction Reactions**. Educational Images Ltd., Filmstrip. Op. cit.

AV-53 **Introduction to Oxidation-Reduction Chemistry**. Ward's Natural Science, Solo-learn Sound Filmstrip. Op. cit.

AV-54 **Electrochemical Cells**. Ward's Natural Science, Video: 22 min. Op. cit.

AV-55 **Electrochemistry: The Foundation of Electrochemistry**. TVO (Radio-Québec), Video: 10 min. Op. cit.

AV-56 **The Dimension of Science: A Transformation Agent**. TV Ontario, Video: 29 min. Op. cit.

AV-57 **Electrochemistry: Electrochemical Cells**. TVO (Radio-Québec), Video: 10 min. Op. cit.

AV-58 **Electrochemistry: Construction of Electrochemical Cells**. TVO (Radio-Québec), Video: 10 min. Op. cit.

AV-59 **Experiments in Chemistry Series: Electrochemistry**. Educational Images Ltd., Film strip. Op. cit.

AV-60 **Application of an Electrochemical Cell**. Films for the Humanities & Sciences, Video: 20 min. Op. cit.

AV-61 **Electrochemistry: Commercial Electrochemical Cells**. TVO (Radio-Québec), Video: 10 min. Op. cit.

AV-62 **Aluminium**. Films for the Humanities & Sciences. Video: 20 min. Op. cit.

AV-63 **Safety in the Science Lab.** EME, Video: 30 min. Op. cit.

AV-64 **Careers in Science. Part III.** EME, Video: 11 min. Op. cit.

AV-65 **The World of Absolute Zero.** Films for the Humanities & Sciences, Video: 26 min. Op. cit.

SOFTWARE

S-1 **Doing Chemistry**. (Tutorial) Macintosh, videodisk. American Chemical Society Office, 1155-16th Street, NW Washington, DC 20036.

S-2 **Science Toolkit Plus Master Module**. (Data Processor) MS/DOS, Tandy, Apple II. Borderbund Software-Direct, P.O. Box 12947, San Rafael, CA 94913-2947.

S-3 **Self Help Physics: Stoechiometry**. Disk #5 (Tutorial, Exercises) MS/DOS, Macintosh, Tandy, Apple. Science-Soft & MathSoft, Personalized Programming Service Inc., P.O. Box 406, Woodbury, NY 11797.

S-4 **Time Table of History**. (Data Bank) Macintosh-ROM. Xiphias, 8758 Venice Boulevard, Los Angeles, CA 90034.

S-5 **How Engines Work 2.** (Demonstration) Macintosh. Somestack Industries, 188 Sippewissett Road, Falmouth, MA 02540.

S-6 **Introduction to Chemistry--Ideal Gas.** Disk #7 Apple II, 48K. Ward's Natural Science, 1840 Mattawa Avenue, Mississauga, Ontario, L4X 1K1.

S-7 **Discovering Matter.** (Data Bank) Macintosh. Le groupe Micro-Intel Inc., 3155 Hochelaga Street, Montréal, H1W 1G4.

S-8 **Physical Science Multimedia Library**. (Data Bank, Demonstration) Macintosh, videodisk. Optical Data, 30 Technology Drive, P.O. Box 4919, Warren NJ 07080.

S-9 **Gas Laws and Kinetic Molecular Theory**. Apple II, 48K. Boreal, 399 Vansickle Road, St Catharines, Ontario, L2S 3T4.

S-10 **Boyle's and Charles' Laws.** Apple. Prentice-Hall Co., Prentice-Hall Building, Englewood Cliffs, NJ 07632.

S-11 **Self Help Physics: Help and Kinetic Theory**. Disk #3 (Tutorial, Exercises) MS/DOS, Macintosh, Tandy, Apple. ScienceSoft and MathSoft, Personalized Programming Service Inc. Op. cit.

S-12 **Gas Laws.** (Independent Learning) Macintosh. J & S Software, 135 Haven Avenue, P.O. Box 1276, Port Washington, NY 11050-1276.

S-13 **Gas Laws and the Mole**. (Simulation, Tutorial) Apple. Prentice-Hall Division of Simon and Schuster, Englewood Cliffs, NJ 07632.

S-14 **Boyle, Charles, Gay-Lussac and others.** (Data Bank) Macintosh. Le Groupe Micro-Intel Inc. Op. cit.

S-15 **Ideal Gases**. Disk #7 Apple II, 48K. Boreal. Op. cit.

S-16 **Chemistry V-3**. (Exercises) Macintosh. Educrop, 7434 Trade Street, San Diego, CA 92121-2410.

S-17 **Boyle's and Charles's Laws.** Apple. Prentice-Hall Co. Op. cit.

S-18 **Exploring Gas Laws**. Apple, 128K. Mecc, 3490 Lexington Avenue North, St Paul, Minnesota 55126.

S-19 **Chemistry I Series: Molar Volume of a Gas.** Apple II, +48K. Ward's Natural Science. Op. cit.

S-20 **Ideal Gas.** (Simulation, Exercises) MS/DOS, ICON. Gemini Education Group, Unisys Canada Inc., 740 Notre Dame Street West, Montréal, H3C 3X6.

S-21 **Gas Laws and the Mole**. (Application Software, Data Processor) Macintosh. Stella High Performance Systems, 13 Darmouth College Highway, Lyme, NH 03768.

S-22 **SensorNet.** (Interface) Macintosh. Lew & Associates, 200 California Avenue., Suite 217, Palo Alto, CA 94306-1618.

S-23 **Living Textbook: Geology and Meteorology.** (THE) Apple II, Macintosh videodisk, CD-ROM. Perceptix Inc., Suite 1014, 111 Richmond Street West, Toronto, Ontario, M5H 2J5.

S-24 **Dynamic Gas Behaviour.** (Animation) Apple. Deadalus, P.O. Box 307, Mequon, WI 53092.

S-25 **Vibration and Bent Triatomic Molecules: An Illustration of Normal Mode.** (Simulation) Apple. Educational Images Ltd., P.O. Box 3456, West Side, Elmira, NY 14905.

S-26 **MI-1000 Multifunction,** (Data Processor) Macintosh. SciMaTech, 558 Cabridge Avenue, Palo Alto, CA 94306.

S-27 **KC? Discoverer: Exploring the Periodic Table.** (Data Bank) MS/DOS. JCE Software, Department of Chemistry, University of Wisconsin, 1101 University Avenue, Madison, WI 53706.

S-28 **Data Insights.** (Data Bank) MS/DOS, IBM Ps/2, Tandy, Apple II. Sunburst Communications, P.O. Box 3240, Station F, Scarborough, Ontario, M1W 9Z9.

S-29 **Multifunction.** (Interface) Macintosh. SciMaTech. Op. cit. (Refer to S-26)

S-30 **SimEarth.** (Simulation) MS/DOS, Tandy, Apple II. Borderbund Software-Direct. Op. cit.

S-31 **Temperature Interface.** Apple IIe. EME, Old Mill Plain Road, P.O. Box 805, Danbury, Connecticut 06813-2805.

S-32 **Self Help Chemistry: Disk #1, Matter and Energy.** (Tutorial, Exerciser) MS/DOS, Macintosh, Tandy, Apple. ScienceSoft & MathSoft, Personalized Programming Service Inc., Op. cit.

S-33 **Calorimetry and Thermodynamics.** Apple II. EME, Op. cit.

S-34 **Chem Lab Simulation 3: Calorimetry.** (Simulation) Apple. High Technology Software Products Inc., P.O. Box 60406, Oklahoma City, OK 73146.

S-35 **P S L.** (Data Processor) MS/DOS, IBM, PS/2. IBM Canada Ltd., 140 Grande Allée East, Québec, QC, G1R 5N6.

S-36 **Self Help Chemistry: Disk #6, Kinetic-Equilibrium-Spontaneous.** (Tutorial, Exerciser) MS/DOS, Mactintosh, Tandy, Apple. ScienceSoft & MathSoft, Personalized Programming Service Inc., Op. cit.

S-37 **SuperChamp.** (Interface, Data Processor) MS/DOS, IBM PS/2, Apple II, C64/128. Merland Scientifc Ltd., 247 Armstrong Avenue, Georgetown, ONT.

S-38 **Dynamic Equilibrium.** (Tutorial, Simulation) Apple. Prentice-Hall, School Division of Simon & Schuster, Op. cit.

S-39 **Exploring Chemistry: Rates and Equilibrium.** (Simulation) MS/DOS, XT, AJ, PS/2, Videodisk. IBM Canada Ltd., Op. cit.

S-40 **Duration of Flame.** (Simulation) ICON. Dr. John Olson, Faculty of Education, Queen's University, Kingston, ONT, K7L 3N6.

S-41 **Kinetics.** (Tutorial) Apple. J & S Software, Op. cit.

S-42 **Reaction Rates and Equilibrium.** Apple II. Chemistry according to ROF, P.O. Box 216, Keyesport, IL 92253.

S-43 **The Great Chemistry Knowledge Race.** Apple II +. Boreal, Op. cit.

S-44 **IBM Biology Series: Chemicals of Life III.** (Tutorial) MS/DOS). IBM Canada Ltd., Op. cit.

S-45 **Equilibrium.** (Tutorial) Apple. J & S Software, Op. cit.

S-46 **Acid Base Salt 1.** Apple II. Chemistry according to ROF, Op. cit.

S-47 **The Haber Process.** (Simulation) Apple. Programs for Learning Inc., P.O. Box 954 New Milford, CT 06776 USA.

S-48 **Hot House Planet.** (Tutorial) Apple II, IBM, Macintosh. EME, Op. cit.

S-49 **Air Pollution.** (Tutorial) Apple II, IBM, Macintosh. EME, Op. cit.

S-50 **Water Pollution.** (Tutorial) Apple II, IBM, Macintosh. EME, Op. cit.

S-51 **Titration Lab: The Titration of An Acid with a Base.** (Interactive Lab Simulation) Apple II. EME, Op. cit.

S-52 **Buret.** (Interactive Lab Simulation) Apple II, Macintosh. EME, Op. cit.

S-53 **Acid Base Salt 2.** Apple II. Chemistry according to ROF, Op. cit.

S-54 **The Acid-Base Package.** (Interactive Lab Simulation) IBM. Journal of Chemical Education Software, Department of Chemistry, University of Wisconsin, Op. cit.

S-55 **Introduction to Chemistry: pH, Acids and Bases in Water.** Apple II. Boreal, Op. cit.

S-56 **Titrations.** (Simulation) Apple. High Technology Software Products Inc., Op. cit.

S-57 **Acid Base Problems.** (Computer Assisted Instruction) Apple II, DOS, C64/TRS 80. J & S Software, Op. cit.

S-58 **Oxidation-Reduction.** (Computer Assisted Instruction) Apple. J & S Software, Op. cit.

S-59 **Electrochemical Cells.** (Tutorial) Apple. J & S Software, Op. cit.

S-60 **Electrochemical Cells.** (Tutorial) Apple. Snowbird Software, 71A Leland, Hamilton ONT, L8S 3A1.

S-61 **Stella High Performance Systems.** Apple II. Op. cit.

S-62 **Insights into Science Data.** (Data Bank) MS/DOS, IBM PS/2, Tandy, Apple II. Sunburst Communications, Op. cit.

PERIODICALS

P-1 TEACHWORTH, D.M. "Surviving a Science Project," **The Science Teacher**, 54:1 (1987), P. 34-36

P-2 SHURR, S.H. "Energy," **Scientific American**, (September 1983).

P-3 HUNT, A. "Soot Power," **Discover**, 4:3 (March 1983).

P-4 ROSENTHAL, D. "Warming Up to STS," **The Science Teacher**, 57:3 (September 1990)

P-5 MARTIN, W. "Soda Bottle Boating," **The Science Teacher**, 58:3 (May 1991).

P-6 GOLDEN, R., C. SNEIDER. "The Green House Effect in a Vial," **The Science Teacher**, 56:5 (1989) P. 57-59

P-7 CLICHE, J.M. "Industrie Chimique Québécoise," **Spectre**, 18:4 (Mars 1989)

P-8 OVERHEIM, D. "Ideal Gas Law," (Analogy: Get off my toes), **The Science Teacher**, 40:9 (December 1973).

P-9 CROPP, D. "Boyle's Law Experiment," **The Science Teacher**, 45:5 (May 1978).

P-10 TALESNICK, I. "Protractors for Boyle's Law Experiments," **The Crucible**, IX:5 (June 1978).

P-11 COURNEGA, D., H. McDonald. "Combining Volumes," **The Crucible**, III:1 (September 1971)

P-12 LAIDLERS, K. "The Story of the Gas Laws," **Chem 13 News**, (September 1989).

P-13 LAIDLERS, K. "Robert Boyle's - Canadian Connections," **Chem 13 News**, (December 1991).

P-14 SESHADRI, V. "Molar Volume of a Gas," **The Crucible**, IV:2 (October 1972).

P-15 JANKE, L. "Molar Volume of a Gas," **The Science Teacher**, 41:5 (May 1974).

P-16 CANHAM, R.G. "The New Pressure Standard in Chemistry," **Chem 13 News**, (February 1990).

P-17 SCHAMP, H. "Lavoisier and the Theory of Combustion," **The Science Teacher**, 55:6 (September 1998).

P-18 SCOTT, D. "Solar Chemistry," **Chem Matters**, 9:1 (February 1991).

P-19 ANONYMOUS. "Gases Slow Food Spoilage," **Chem 13 News**, (January 1992).

P-20 SATYENDRA, D. "Diffusion of Gases," **The Crucible**, X:6 (September 1979).

P-21 SIVAN, Y. "Diffusion of Gases," **The Science Teacher**, 50:4 (April 1983).

P-22 DREIKORN, C. "Brownian Motion," **The Crucible**, XIV:1 (1982).

P-23 COLLINS, B.L. "Graham's Law of Diffusion," **Chem 13 News**, (April 1991).

P-24 PERKINS, R. "Stability - What's the Problem?" **Chem 13 News**, (December 1991).

P-25 BOATNER, B.E. "The Ancient Art of Chemical Fire," **SciQuest**, 52:6 (1979).

P-26 VIGNEAULT, C. "Storing Winter Cold," A research of Agriculture Canada at Saint-Jean-sur-Richelieu in Québec, **Chem 13 News**, (January 1992).

P-27 HOUGHTON, R., G. WOODWELL. "Global Climate Change," **Scientific American**, 260:4, P. 36-44.

P-28 LAMB, W. "Flame Tests," **The Science Teacher**, 50:4 (April 1983).

P-29 ANONYMOUS. "Crying Wolf Over Chemical Risks in the Laboratory," **Chem Ecology**, (September 1991).

P-30 ISOM, S., C. LAIL. "A Gas of a Class," **The Science Teacher**, 56:3 (March 1989) P. 45-47.

P-31 LAMBERT, W. "Big Bang-Acetylene Gas," **The Science Teacher**, XIV:2 (1983).

P-32 CAPINDALE, B.J. "Is Chemistry a Dirty Word?" **Chem 13 News**, (January 1992).

P-33 BUNKER, D.L. "Computer Experiments in Chemistry," **Scientific American**, (July 1964).

P-34 SLATER, A. "Microchemistry: Rates of Reaction," **Chem 13 News**, (September 1991).

P-35 McCHESNEY, M. "Shock Waves and High Temperature," **Scientific American**, (February 1963).

P-36 SCHURR, S. "Energy," **Scientific American**, (September 1963).

P-37 SHAPIRO, S. "Equilibrium Demonstration," **The Science Teacher**, 45:2 (February 1978).

P-38 DURELL, S.W. "The Industrial Chemist of the '90s," **Chem Tech**, (June 1991).

P-39 LICATA, P.K. "Chemistry is like a ..." **The Science Teacher**, 55:8 (1988).

P-40 SCHARLIN, P., J.J. FORTMAN and R. BATTINO. "The Human Saltbridge," **Journal of Chemical Education**, (February 1990).

P-41 CONHAM, G. "Determining Oxidation Numbers by Deduction," **Chem 13 News**, (November 1991).

P-42 DOLEMAN, R. "Displaying Oxidation Number Changes Using the Ticker-Tape Method," **Chem 13 News**, (December 1991).

P-43 KUBITSCHEK, E.H. "Fusion, Firsthand," **The Science Teacher**, 57:1 (January 1990).

P-44 ZOLLER, U. "Relevance is Primary in Secondary School Chemistry," **The Science Teacher**, 52:9 (December 1985) P. 32-35.

P-45 NAIR, I. "Chernobyl, Asking the Right Question," **The Science Teacher**, 54:8 (November 1987).

P-46 FENSTER, A., D.N. HARP and J.A. SCHWARCS. "A Useful Balloon Demonstration: Pressure Difference Behavior," **Journal of Chemical Education**, 63:629 (1986).

P-47 SEARS, A.J., C.J. GRIEVE. "Five Fun Phase Changes," **The Science Teacher**, 57:2 (February 1990).

P-48 RAMAN, V.V. "The Gas Laws," **The Physics Teacher**, II:419-424 (October 1973).

P-50 BARR, E.S. "James Prescott Joule and the Quiet Revolution," **The Physics Teacher**, 7:199-208 (April 1969).

P-51 WINTER, P. "A Forest in the Hand," **Science Dimension**, 17:6 (1985).

P-52 GENNARO, G., B. MUNSON. "The Iodine Clock Reaction and Hypothermia," **The Science Teacher**, 55:9 (December 1988).

P-53 ALLEN, M. "Diffusion of Gases," **The Science Teacher**, 50:4 (April 1983).

P-54 NERO, V.A. "The Indoor Radon Story," **Technology Review**, 89:1 (January 1986).

P-55 CONKLIN, H. "Demo a Day - A Series of Demonstrations for Use in Thermodynamics," **Chem 13 News** (December 1991).

BOOKS

B-1 BELLER, J. **So You Want to Do a Science Project**. Prentice-Hall Canada Inc., Toronto, 1982.

B-2 SCHULMAN, E., et al. **Science Projects with Computers**. Prentice-Hall Canada Inc., Toronto, n.d.

B-3 Ministère de l'énergie et des ressources. **Energy: The Driving Force for Economic Development and Political energy for the 1990**, Québec, 1990.

B-4 Ministère de l'énergie et des ressources. **L'énergie du Québec**. Québec, 1989.

B-5 Ministère de l'énergie et des ressources. **Atlas énergétique du Québec.** Québec, 1989.

B-6 CARPENTIER, Jean-Marc. **Our Energy Heritage, Oil and Gas.** Meridian and SoQuip, Montréal, 1989.

B-7 WOLFE, E., T.J. ELGIN et al. **Physics Today I**. Prentice-Hall Canada Inc., Toronto, 1989.

B-8 SUMMERLINE, Lee et al. **A Source Book for Teachers**. Volume I, 2nd edition. American Chemical Society, Washington, 1988.

B-9 SUMMERLINE, Lee et al. **A Source Book for Teachers**. Volume 2, 2nd edition. American Chemical Society, Washington, 1988.

B-10 GIANCOLI, C.D. **The Ideas of Physics**. Academic Press Canada, Toronto, 1981.

B-11 IN COLLABORATION, STSC. **Chemistry 30: Teacher's Edition**. Karitann Publishers Inc., Edmonton, 1988.

B-12 LEWIS, L.J. **Physics**. Longman Science 11-13 Series. Copp Clark Pitman Ltd., Mississauga, 1977.

B-13 ORD. D. **Exploring Chemistry**. McGraw-Hill Ryerson Ltd., Toronto, 1986.

B-14 GERLOVICH, J., et al. **School Science Safety**. Flinn Scientific, New York, 1985.

B-15 NEARING, M. **Lab Safety Handbook**. The Chemical Institute of Canada, Ottawa, n.d.

B-16 LEICESTER, H.M.and H.S. KLICKSTEIN. **A Source Book in Chemistry**. Harvard University Press, Cambridge, Massachussets, 1956.

B-17 LEICESTER, H.M. **The Historical Background of Chemistry**. John Wiley & Sons Canada Ltd., Toronto, 1956.

B-18 LUCRETIUS, S. **The Nature of the Universe**. (Paperback) Penguin Books, London, 1959.

B-19 BRONOWSKI, J. **Science and the Human Values**. (Paperback) Harper, New York, 1959.

B-20 HUMPHREYS, A.D. **Demonstrating Chemistry**. Chemistry Department, McMaster University, Hamilton, Ontario, 1983.

B-21 ANONYMOUS. **Teachers' Guide for Chemistry--An Experimental Science**. (Chem Study) W.H. Freeman and Company, San Francisco, 1963.

B-22 **HANDBOOK OF CHEMISTRY**. McGraw-Hill Book Company, New Jersey, 1987.

B-23 KOTZ, C.J.and K.F. PURCELL. **Chemistry and Chemical Reactivity**. Saunders College Publishing, New York, 1987.

B-24 STONE, H. Jody et al. **Spice Chemistry.** Kendall/Hunt Publishing Company, Iowa, 1987.

B-25 DORIN, H. **Chemistry: The Study of Matter.** Cebco Standard Publishing, New Jersey, 1982.

B-26 TOON, R.E. et al. **Foundation of Chemistry.** 2nd edition. HBJ-Holt Canada, Toronto, 1990.

B-27 METCALFE, H.C. et al. **Modern Chemistry.** Holt, Rinehart and Winston, Canada, 1986.

B-28 SHAKHASHIRI, Z.B. **Chemical Demonstrations.** A Handbook for Teachers of Chemistry, Volume I. The University of Wisconsin Press, Madison, 1983.

B-29 ROSMORDUC, J. **De Thalés à Einstein: Histoire de la Physique et de la Chimie.** Études vivant, Paris/Montréal, 1979.

B-30 GILLISPIE, C.C. (Ed). **Dictionary of Scientific Biography.** 8 volumes. Scribner, New York, 1970-1980.

B-31 MADDISON, W.E. **The Life of the Honourable Robert Boyle.** n.p., London, 1969.

B-32 O'CONNOR, R.P. et al. **Chemistry: Experiments and Principles.** (Teachers' Lab Guide) D.C. Heath and Company, Toronto, 1982.

B-33 TALENSNICK. I. **Idea Bank Collation--A Handbook for Science Teachers.** Volume I. Science Supplies and Services Co. Ltd., Kingston, Ontario, 1986.

B-34 KOZMAN, N. et al. **Physical Science: Discovering Matter and Energy.** Copp Clark Pitman Ltd., Mississauga, 1991.

B-35 NAKON, R. **Chemical Problem-solving Using Dimensional Analysis**. 2nd edition. Prentice-Hall Canada Inc., Toronto, 1988.

B-36 ILPAC. **Independent Learning Project for Advanced Chemistry**. John Murray Ltd., London, 1987.

B-37 PARTINGTON, J.R. **A Short History of Chemistry**. (Paperback) Harper, New York, 1960.

B-38 STILLMAN, M.J. **The Story of Alchemy and Early Chemists**. (Paperback) Dover Publication, New York, 1960.

B-38 HALL, B.M. **Dictionary of Scientific Biography**. University of Indiana Press, Indiana, 1970.

B-40 HALLIDAY, D. and R. RESNICK. **Fundamentals of Physics**. 3rd edition. John Wiley & Sons, Toronto, 1988.

B-41 BOURGOUIN, Louis. **Histoire des sciences et de leurs applications**. Volume I. Éditions de l'Arbre, Paris, 1945.

B-42 OLDS, D. **Chemical Demonstrations**. Department of Chemistry, York University, Toronto, n.d.

B-43 BRENNER, M. **Fireworks Tonight**. Hastings House Publishers Inc., New York, 1974.

B-44 NASH, L.K. **Elements of Chemical Thermodynamic.** (Paperback) Addison-Wesley Publishing Co, Don Mills, 1962.

B-45 WRIGHT, H. **The Energy of Chemistry**. John Wiley & Sons Canada Ltd., Toronto, 1977.

B-46 FARADAY, M. **Chemical History of a Candle**. Chicago Review Press, Chicago, 1988.

B-47 POSTEL, S. **Altering the Earth's Chemistry**. World Watch Institute, Washington DC, 1986.

B-48 ASIMOV. I. **The Physical Sciences.** Volume 1, Basic Books, USA, 1961.

B-49 **Les CFF: Des émissions mortelles**. 3 rapports du Comité permanent de l'environnement, Information: TD 886C47C425/1990, Ministère de l'Environnement, Gouvernement du Québec.
See also: **Deadly Releases: CFFs.** Idem.

B-50 JAFFE, B. **Men of Science in America**. Simon and Schuster, USA, 1958.

B-51 JAFFE, B. **Crucibles - The Story of Chemistry**. (Paperback) Fawcett, New York, 1963.

B-52 CANBY, C. (ed). **History of Chemistry**. Hawthorne, Dallas, 1964.

B-53 STRONG, L.E. and W.J. STRATTON. **Chemical Energy.** (Paperback) Reinhold, Toronto, 1964.

B-54 HILL, G. **Chemistry Counts**. Dominie Press Ltd., Agincourt, Ontario, 1986.

B-55 BENARDE, A.M. **Our Precarious Habitat - Fifteen Years Later**. John Wiley & Sons Canada Ltd., Toronto, 1989.

B-56 CHARTRAND, L., R.D. DUCHESNE and Y. GINGRAS. **Histoire des Sciences du Québec**. Les Éditions Boréal, Montréal, 1987.

B-57 GINGRAS, Y. **Les origines de la recherche scientifique au Canada: le cas des physiciens**. Les Éditions Boréal, Montréal, 1991.

B-58 PLIMPTON, G. **Fireworks: A History of Celebration.** Doubleday and Company Inc. Toronto, 1984.

B-59 POZOA, R.S. and D.O. BORN. **Hypothermia: Causes, Effects, Preventions.** New Century Publishers, Piscataway, NJ, 1982.

B-60 IHDE, J.A. **The Development of Modern Chemistry**. Harper and Row, New York, 1964.

B-61 PARRY, W.R. et al. **Chemistry: Experimental Foundations.** (Teachers' Lab Guide) Prentice-Hall of Canada Ltd., Toronto, 1970.

B-62 EYRING, H. and M. EDWARD. **Modern Chemical Kinetics** (Paperback) Reinhold, Toronto, 1963.

B-63 HUFF, E.G. **Molecules in Motion: The Rate of Chemical Reactions.** John Wiley & Sons Canada Ltd., Toronto, n.d.

B-64 KING, L.E. **How Chemical Reactions Occur.** (Paperback) W.A. Benjamin, New York, 1963.

B-65 LATHAM, J.L. **Elementary Reaction Kinetics.** (Paperback) Butterworth, Stoneham, 1962.

B-66 PRETTRE, M. **Catalysis and Catalysts.** (Paperback) Dover, New York, 1963.

B-67 ANONYMOUS, **Le monde des sciences, de la technologie.** Éditions du Club France Loisirs (Québec Loisirs), 1990.

B-68 MAHAN, B.H. **Chemical Thermodynamics** (Paperback) W.A. Benjamin, n.p., 1962.

B-69 WILSON, M. and the Editors of Time Life. **Energy.** Time Inc., USA, 1963.

B-70 LIPPINCOTT, T.W. et al. **ChemCom: Chemistry in the Community**. The American Chemical Society, Kendall/Hunt Publishing Company, Iowa, 1988.

B-71 ROLEY, R.W. **A Matter of Balance: Chemical Equilibrium**. John Wiley & Sons Canada Ltd., Toronto, 1976.

B-72 CARNELL, P.H. and R.N. REUSCH. **Molecular Equilibrium**. (Paperback) A Programmed Manual. W.B. Saunders Co., New York, 1963.

B-73 DENBIGH, K. **The Principles of Chemical Equilibrium**. (Paperback) Cambridge University Press, London, 1961.

B-74 GORDON, G. **The Delicate Balance**. Harper & Row, New York, 1973.

B-75 Ministry of Supply and Services Canada. **A Primer on Water**. Environment Canada, Ottawa, 1990.

B-76 PRYDE, T. Lucy. **Chemistry of the Water Environment**. Cummings Publishing Company Inc., Melno Park, CA, 1973.

B-77 PRYDE, T. Lucy. **Chemistry of the Air Environment**. Cummings Publishing Company Inc., Op. cit., 1973.

B-78 CHRISTENSEN, H.N. **pH and Dissociation**. (Paperback) W. B. Saunders Co., New York, 1963.

B-79 RICHARDSON, A.R. **Proton Chemistry**. John Wiley & Sons Canada Ltd., Toronto, 1976.

B-80 MITSUNAGA, T. T. **Competition for Electrons-Oxidation-Reduction**. John Wiley & Sons Canada Ltd., Toronto, 1976.

B-81 DIBNER, B. **Gavani-Volta**. Bunndy Library, Norwalk, Conn., 1952.

B-82 BOLIN, B. et al. (ed). **The Green House Effect, Climate Change and Ecosystems.** John Wiley & Sons, New York, 1986.

B-83 ASIMOV, I. **A Short History of Chemistry.** Doubleday & Company Canada Ltd., Toronto, 1965.

B-84 ASIMOV, I. **The Chemicals of Life.** The New American Library of Canada Ltd., Toronto, 1967.

B-85 RONAN, A.C. **The Natural History of the Universe.** Doubleday & Company Canada Ltd., Toronto, 1991.

B-86 NEWTON, E.D. **Science and Social Issues.** J. Weston Walch Publisher, New Brunswick, 1992.

B-87 WILLIAMS, I.T. **The History of Invention - From Stone Axes to Silicon Chips.** Les Éditions Boreal, Montréal, 1987.

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