Chemistry, Grade 12

College Preparation SCH4C

This course enables students to develop an understanding of chemistry through the study of matter and qualitative analysis, organic chemistry, electrochemistry, chemical calculations, and chemistry as it relates to the quality of the environment. Students will use a variety of laboratory techniques, develop skills in data collection and scientific analysis, and communicate scientific information using appropriate terminology. Emphasis will be placed on the role of chemistry in daily life and the effects of technological applications and processes on society and the environment.

Prerequisite: Science, Grade 10, Academic or Applied

Big Ideas

Matter and Qualitative Analysis

- The properties of matter can be predicted and analysed qualitatively.
- Substances can be identified based on their distinct properties.
- Qualitative analysis of matter is used in many different fields of endeavour.

Organic Chemistry

- Organic compounds have predictable chemical and physical properties determined by their respective structures.
- Organic compounds can be synthesized by living things or through artificial processes.
- Organic chemical reactions and their applications have significant implications for society, human health, and the environment.

Electrochemistry

- Oxidation and reduction are paired chemical reactions in which electrons are transferred from one substance to another in a predictable way.
- The control and applications of oxidation and reduction reactions have significant implications for society and the environment.

Chemical Calculations

- Relationships in chemical reactions can be described quantitatively.
- Quantitative relationships of chemical reactions have applications in the home, workplace, and the environment.

Chemistry in the Environment

- Air and water quality can be affected by both natural processes and human activities.
- Quantitative relationships of chemical reactions can be used to assess air and water quality.

Fundamental Concepts Covered in This Course (see also page 5)

Fundamental Concepts	Matter and Qualitative Analysis	Organic Chemistry	Electrochemistry	Chemical Calculations	Chemistry in the Environment
Matter	✓	✓	✓	✓	✓
Energy	✓		✓		✓
Systems and Interactions		✓		✓	
Structure and Function		✓	✓		✓
Sustainability and Stewardship	✓	✓	✓	✓	✓
Change and Continuity	✓				

A. SCIENTIFIC INVESTIGATION SKILLS AND CAREER EXPLORATION

OVERALL EXPECTATIONS

Throughout this course, students will:

A1. demonstrate scientific investigation skills (related to both inquiry and research) in the four areas of skills (initiating and planning, performing and recording, analysing and interpreting, and communicating);

A2. identify and describe careers related to the fields of science under study, and describe the contributions of scientists, including Canadians, to those fields.

SPECIFIC EXPECTATIONS

A1. Scientific Investigation Skills

Throughout this course, students will:

Initiating and Planning [IP]*

A1.1 formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research

A1.2 select appropriate instruments (e.g., spectroscope, centrifuge, burettes, meters) and materials (e.g., acid/base indicators, solubility tables, galvanic cells), and identify appropriate methods, techniques, and procedures, for each inquiry

A1.3 identify and locate a variety of print and electronic sources that enable them to address research topics fully and appropriately

A1.4 apply knowledge and understanding of safe laboratory practices and procedures when planning investigations by correctly interpreting Workplace Hazardous Materials Information System (WHMIS) symbols; by using appropriate techniques for handling and storing laboratory equipment and materials and disposing of laboratory materials (e.g., safely disposing of organic solutions); and by using appropriate personal protection (e.g., wearing safety goggles)

Performing and Recording [PR]*

A1.5 conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data

A1.6 compile accurate data from laboratory and other sources, and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams

A1.7 select, organize, and record relevant information on research topics from a variety of appropriate sources, including electronic, print, and/or human sources, using suitable formats and an accepted form of academic documentation

Analysing and Interpreting [AI]*

A1.8 synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data; solve problems involving quantitative data; determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error

A1.9 analyse the information gathered from research sources for logic, accuracy, reliability, adequacy, and bias

* The abbreviation(s) for the broad area(s) of investigation skills – IP, PR, AI, and/or C – are provided in square brackets at the end of the expectations in strands B–F to which the particular area(s) relate (see pp. 20–22 for information on scientific investigation skills).

A1.10 draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge

Communicating [C]*

A1.11 communicate ideas, plans, procedures, results, and conclusions orally, in writing, and/or in electronic presentations, using appropriate language and a variety of formats (e.g., data tables, laboratory reports, presentations, debates, simulations, models)

A1.12 use appropriate numeric, symbolic, and graphic modes of representation (e.g., represent ionic and molecular compounds by their accepted formulae and names), and appropriate units of measurement (e.g., SI and imperial units)

A1.13 express the results of any calculations involving data accurately and precisely, to the appropriate number of decimal places or significant figures

A2. Career Exploration

Throughout this course, students will:

A2.1 identify and describe a variety of careers related to the fields of science under study (e.g., environmental technologist, pharmacy technician, electroplating technician, green building or renewable energy technician, veterinary technician, biochemical technologist) and the education and training necessary for these careers

A2.2 describe the contributions of scientists, including Canadians (e.g., Jed Harrison, Louis Slotin, Paul Kebarle, James Robert Bolton, Brian Evans Conway, Lee Wilson), to the fields under study

B. MATTER AND QUALITATIVE ANALYSIS

OVERALL EXPECTATIONS

By the end of this course, students will:

B1. evaluate the effects of chemical substances on the environment, and analyse practical applications of qualitative analysis of matter;

B2. investigate matter, using various methods of qualitative analysis;

B3. demonstrate an understanding of the basic principles of qualitative analysis of matter.

SPECIFIC EXPECTATIONS

B1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

B1.1 evaluate the risks and benefits to the environment of some commonly used chemical substances (e.g., substances used in fireworks, fire extinguishers, "green" cleaning products) [AI, C]

Sample issue: Numerous synthetic fertilizers are available for residential lawns and gardens, all of which claim good results based on their chemical composition. Although these fertilizers provide nutrients that are essential for healthy plants and soil, they may also contain harmful chemicals that can pose risks to the environment.

Sample questions: What chemical substances can be removed from drinking water by household water purification systems? What impact do chemical substances used in drive-through car washes have on the local environment? Why are packing chips that are made from cornstarch better for the environment than those made from polystyrene?

B1.2 analyse, on the basis of research, applications of qualitative analysis of matter in various fields of endeavour (e.g., in law enforcement to detect drugs or identify counterfeit money; in the manufacture of food products) [IP, PR, AI, C]

Sample issue: Forensic chemists use many qualitative analysis techniques in their work, including spectroscopy to identify controlled substances such as chemicals, drugs, and explosives. Spectroscopy can detect minute traces of substances, so care must be taken in handling samples to ensure that they are not contaminated during transport, storage, or analysis.

Sample questions: What substances do environmental chemists test for in the soil of industrial sites that have been rezoned for residential use? What different chemical compounds are used to create some of the desired effects in fireworks? What types of particulate matter do air quality testers measure when there is the potential for a smog alert?

B2. Developing Skills of Investigation and Communication

By the end of this course, students will:

B2.1 use appropriate terminology related to qualitative analysis of matter, including, but not limited to: *double displacement*, *precipitate*, and *energy level* [C]

B2.2 use a table of solubility rules to write chemical equations for double displacement reactions and to write balanced net ionic equations for chemical reactions [AI, C]

B2.3 investigate precipitation reactions and flame tests, using qualitative analysis instruments, equipment, and techniques (e.g., gas discharge tubes, high-voltage electrical sources, spectroscope, centrifuge) [PR, AI]

B2.4 conduct qualitative analyses of an unknown sample (e.g., a household or workplace chemical), using a flow chart and experimental procedures, including flame tests and precipitation reactions, to determine the presence of metal ions [PR, AI]

B2.5 identify an unknown gas sample (e.g., hydrogen, helium, neon) by observing its emission spectrum and comparing it to the spectra of known gases [PR, AI]

B2.6 use a table of solubility rules to predict if a precipitate will form in a given chemical reaction, and identify the precipitate formed [AI]

B3. Understanding Basic Concepts

By the end of this course, students will:

B3.1 explain the relationship between the atomic number and the mass number of an element, and the difference between isotopes and radioisotopes of an element

B3.2 describe various types of chemical reactions, including synthesis, decomposition, single displacement, and double displacement reactions

B3.3 explain basic procedures used in qualitative analysis of elements and compounds, including flame tests, precipitation reactions, and the observation of emission spectra

B3.4 relate observations from investigations using flame tests and emission spectra to the concept of quanta of energy proposed by Neils Bohr

C. ORGANIC CHEMISTRY

OVERALL EXPECTATIONS

By the end of this course, students will:

C1. evaluate the impact on society, human health, and the environment of products made using organic compounds;

C2. investigate the physical and chemical properties of organic compounds, and analyse some common organic chemical reactions;

C3. demonstrate an understanding of the structure and the physical and chemical properties of organic compounds.

SPECIFIC EXPECTATIONS

C1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

C1.1 identify various materials and products used in everyday life that are made from organic compounds (e.g., synthetic fabrics, drugs, pesticides, cosmetics, organic solvents, car parts, artificial hearts), and assess the benefits of those products for society, as well as the health hazards they pose [AI, C]

Sample issue: Organic compounds are present in a wide variety of pharmaceuticals and natural health products that can contribute to people's health. However, some of the organic chemicals in these products may not be as natural or healthy as advertised, and they can have adverse affects on some people.

Sample questions: Why are organic compounds often added to food products? What are the benefits, and potential health risks, to farmers of spraying pesticides on their crops? What are the health risks of eating food that has been heated in plastic containers in the microwave? What are the benefits and risks to our health of taking some common pain relief medications?

C1.2 research a useful product made from one or more organic substances (e.g., CDs, made from crude oil), and assess the environmental impact of the production, use, and disposal of the product [IP, PR, AI, C]

Sample issue: We depend on plastics in every area of our lives, from food packaging to construction materials to DVDs. However, the manufacture of plastics involves the release of chemical pollutants and greenhouse gases into the environment, and huge quantities of plastic trash are now being found in our oceans.

Sample questions: What is the environmental impact of the production, use, and disposal of plastic water bottles? What impact does the vulcanization of rubber have on the environment? What are the risks and benefits to the environment of the production of synthetic fibres for the textile industry?

C2. Developing Skills of Investigation and Communication

By the end of this course, students will:

C2.1 use appropriate terminology related to organic chemistry, including, but not limited to: *electronegativity*, *covalent bond*, and *functional group* [C]

C2.2 draw Lewis structures to represent the covalent bonds in some simple organic molecules (e.g., CH_4) [AI, C]

C2.3 build molecular models of, and create structural formulae for, some simple organic molecules (e.g., methane, butane, ethyne) [PR, AI, C]

C2.4 conduct an inquiry to determine the physical and chemical properties of some common organic compounds (e.g., solubility [in polar and non-polar solvents], conductivity, odour, combustibility) [PR, AI]

C2.5 conduct an inquiry to demonstrate separation of a mixture of liquids by distillation [PR]

C2.6 conduct an inquiry to identify some of the products of the combustion of a hydrocarbon and an alcohol [PR, AI]

C2.7 conduct an inquiry to synthesize a common organic compound (e.g., produce an ester, make soap) [PR]

C2.8 predict the nature of a bond (e.g., non-polar covalent or polar covalent), using the electronegativity values of atoms (e.g., H_2, Cl_2, O_2, H_2O, CH_4, CH_3OH) [AI]

C3. Understanding Basic Concepts

By the end of this course, students will:

C3.1 describe the unique characteristics of the carbon atom in terms of covalent bonding

C3.2 identify functional group structures that define common classes of organic compounds (e.g., alkenes, alkanes, alkynes, alcohols, aldehydes, ketones, carboxylic acids, esters, amines)

C3.3 explain the general properties (e.g., polarity, solubility in water) of molecules that contain oxygen or nitrogen

C3.4 use structural formulae to describe some simple organic chemical reactions (e.g., addition, substitution, combustion)

C3.5 explain how the physical properties of a substance affect the processes used to separate organic chemical substances (e.g., distillation of crude oil, distillation of alcohols)

C3.6 identify the first ten hydrocarbons of the alkanes, the alkenes, and the alkynes by their names and structural formulae, using International Union of Pure and Applied Chemistry (IUPAC) nomenclature for alkanes, alkenes, and alkynes

C3.7 explain the dangers associated with the use of organic solvents (e.g., dry-cleaning compounds, paint thinners, glue solvents, nail polish remover), and some general precautions related to their use

D. ELECTROCHEMISTRY

OVERALL EXPECTATIONS

By the end of this course, students will:

D1. analyse technological applications or processes relating to oxidation-reduction reactions, and assess their impact on the environment;

D2. investigate the oxidation-reduction reaction that occurs in a galvanic cell;

D3. demonstrate an understanding of the concepts of oxidation and reduction, and the principles of oxidation-reduction reactions.

SPECIFIC EXPECTATIONS

D1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

D1.1 analyse, on the basis of research, a technological application that is based on the oxidation-reduction (redox) reaction that occurs in galvanic cells (e.g., in cardiac pacemakers, batteries, electroplating) [IP, PR, AI, C]

Sample issue: Hydrogen fuel cells use a redox reaction that produces water, rather than environmentally harmful greenhouse gases, as waste. Although some cars could run on fuel cells, practical problems, such as the storage and cost of producing hydrogen, currently limit the usefulness of this technology in the transportation sector.

Sample questions: What chemical reactions occur in rechargeable and non-rechargeable batteries? How do different technologies use different types of galvanic cells for their energy? How does the redox reaction occur in the electroplating process? Why is this reaction necessary?

D1.2 analyse, on the basis of research, the causes of metal corrosion, and assess the environmental impact of some techniques used to protect metals from corrosion (e.g., rustproofing, painting, cathodic protection, galvanization) [IP, PR, AI, C]

Sample issue: The maintenance of large span-bridges over salt water has always been challenging, because the salt water spray causes corrosion. Newer bridges use support structures that have been protected from corrosion, but long-term studies have not been done on the impact of these methods on the environment.

Sample questions: What are some of the techniques used to protect metals from corrosion? What are the benefits and risks to the environment of the electroplating of metals? Why do metal orthodontic braces not corrode?

D2. Developing Skills of Investigation and Communication

By the end of this course, students will:

D2.1 use appropriate terminology related to electrochemistry, including, but not limited to: *oxidation*, *anode*, and *electrolyte* [C]

D2.2 build a galvanic cell and measure its voltage [PR, AI]

D2.3 analyse the processes in galvanic cells, and draw labelled diagrams of these cells to show the oxidation or reduction reaction that occurs in each of the half-cells, the direction of electron flow, the location of the electrodes, and the direction of ion movement [AI, C]

D2.4 design and conduct an inquiry to determine the factors that affect rate of corrosion of a metal (e.g., stress on the metal, contact between two metals, surface oxide, the nature of the electrolyte, the nature of the metal) [IP, PR, AI]

D3. Understanding Basic Concepts

By the end of this course, students will:

D3.1 explain the concepts of oxidation and reduction in terms of the chemical changes that occur during redox reactions

D3.2 describe the components of a galvanic cell, and explain how each component functions in a redox reaction

D3.3 describe the chemical reaction that results in the corrosion of metal

E. CHEMICAL CALCULATIONS

OVERALL EXPECTATIONS

By the end of this course, students will:

E1. analyse processes in the home, the workplace, or the environmental sector that use chemical quantities and calculations, and assess the importance of accuracy in chemical calculations;

E2. investigate chemical compounds and chemical reactions using appropriate techniques of quantitative analysis, and solve related problems;

E3. demonstrate an understanding of the mole concept and its quantitative relationships in chemical reactions.

SPECIFIC EXPECTATIONS

E1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

E1.1 analyse processes in the home, the workplace, or the environmental sector that require an understanding of accurate chemical calculations (e.g., baking according to a recipe; manufacturing items such as fertilizer, paint, pharmaceuticals; testing water quality in a public pool) [AI, C]

Sample issue: Farmers use fertilizers that contain nitrogen and phosphorus to fertilize their crops. Although these nutrients are needed by the crops for growth, too much fertilizer can harm crops and potentially run off into water systems and contribute to the eutrophication of ponds and lakes.

Sample questions: What are the potential effects of adding too much or too little chlorine to drinking water at a water purification plant or private well? Why is it important to have the correct quantities of each tint when mixing paint colours? How would a slight miscalculation affect the paint colour?

E1.2 assess, on the basis of research, the importance of quantitative accuracy in the concentration of solutions used for medical purposes or personal care (e.g., cough syrup, intravenous solutions, sunscreen) [IP, PR, AI, C]

Sample issue: The components of hair colour products are carefully calculated to achieve a certain outcome within a specific time. However, if these variables are changed by the user, or if the hair has recently been chemically processed, unintended results can occur.

Sample questions: Why is it important to follow the dosage instructions on prescription medication and over-the-counter drugs? Why is it important to understand which type of sunscreen is best to use for your specific skin type? What does the SPF factor indicate about the active ingredients in sunscreen?

E2. Developing Skills of Investigation and Communication

By the end of this course, students will:

E2.1 use appropriate terminology related to stoichiometry, including, but not limited to: *molar mass*, *molar concentration*, *percentage yield*, and *Avogadro's number* [C]

E2.2 calculate the molar mass of simple compounds with the aid of the periodic table [AI]

E2.3 convert the quantity of chemicals in simple chemical reactions from number of particles to number of moles and mass, using the mole concept [AI]

E2.4 solve problems involving relationships between the following variables in a chemical reaction: quantity in moles, number of particles, atomic mass, concentration of solution, and volume of solution [AI]

E2.5 solve problems involving stoichiometric relationships in balanced chemical equations [AI]

E2.6 conduct an inquiry to determine the actual yield, theoretical yield, and percentage yield of the products of a chemical reaction (e.g., a chemical reaction between steel wool and copper(II) sulfate solution), assess the effectiveness of the procedure, and suggest sources of experimental error [PR, AI]

E2.7 use qualitative observations of a chemical reaction to identify the chemical changes, presence of limiting reagents, and the products occurring in a chemical reaction (e.g., aluminum reacting with copper(II) chloride solution, steel wool reacting with oxygen) [PR, AI]

E2.8 prepare aqueous solutions of given concentrations (e.g., concentrations expressed in grams per litre or moles per litre) by dissolving a solid solute in a solvent or by diluting a concentrated solution (e.g., a stock solution) [PR, AI]

E3. Understanding Basic Concepts

By the end of this course, students will:

E3.1 describe the relationships between Avogadro's number, the mole concept, and the molar mass of any given substance

E3.2 describe some possible sources of experimental error in an investigation of a chemical reaction, and explain how the errors would affect the percentage yield of products of the reaction

E3.3 explain the relationships between the mole concept, the values of coefficients, the number of particles, and the mass of substances in balanced chemical equations

E3.4 explain the concept of molar concentration of a solution, using appropriate units of measure

E3.5 explain the concept of a limiting reagent in a chemical reaction, using examples of chemical processes from everyday life (e.g., synthesis of aspirin, synthesis of ammonia)

F. CHEMISTRY IN THE ENVIRONMENT

OVERALL EXPECTATIONS

By the end of this course, students will:

F1. evaluate the importance of government regulations, scientific analyses, and individual actions in improving air and water quality, and propose a personal plan of action to support these efforts;

F2. investigate chemical reactions, using appropriate techniques of quantitative analysis;

F3. demonstrate an understanding of chemical reactions that occur in the environment as a result of both natural processes and human activities.

SPECIFIC EXPECTATIONS

F1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

F1.1 evaluate, on the basis of research, the effectiveness of government initiatives or regulations (e.g., the Great Lakes Action Plan), and the actions of individuals (e.g., use of public transportation), intended to improve air and water quality, and propose a personal action plan to support these efforts [IP, PR, AI, C]

Sample issue: The Yellow Fish Road is a nationwide program in which volunteers paint yellow fish symbols by storm drains to remind people that material poured into the drains flows directly into our local waterways, and that they should not pour hazardous substances down the drains. However, not everyone is aware of the symbolism of the fish, so the program may not be as effective as it could be.

Sample questions: How can your personal actions influence the air or water quality in your local area? Why have government initiatives, such as mass transit in urban areas, not been readily accepted by everyone? What can be done to encourage more people to use mass transit? What plans do local conservation authorities have to improve water quality in lakes, rivers, and streams in your local area? How effective are these plans?

F1.2 evaluate the importance of quantitative chemical analysis in assessing air and water quality (e.g., the use of Environment Canada's Air Quality Index to determine when smog advisories need to be issued; systems to monitor the quality of drinking water), and explain how these analyses contribute to environmental awareness and responsibility [AI, C]

Sample issue: Traditional stationary monitoring stations may not be able to supply sufficient data to reflect the differences in air quality from one location to another. However, researchers in Ontario now use mobile air quality monitors to measure vehicle emissions in high traffic areas and "hot spots" where vehicles idle for long periods of time. These data can be used to develop more precise air quality indices.

Sample questions: How can increased monitoring and reporting of air and water pollution influence the actions of individuals? Why are present chemical analyses not sufficient to detect and quantify all organic and inorganic contaminants in the water supply? How does WHMIS aid in minimizing damage to the environment and ensuring the safety of individuals in a case of an industrial accident?

F2. Developing Skills of Investigation and Communication

By the end of this course, students will:

F2.1 use appropriate terminology related to chemical analysis and chemistry in the environment, including, but not limited to: *ozone*, *hard water*, *titration*, *pH*, *ppm*, and *ppb* [C]

F2.2 write balanced chemical equations to represent the chemical reactions involved in the neutralization of acids and bases [AI, C]

F2.3 conduct an acid–base titration to determine the concentration of an acid or a base (e.g., the concentration of acetic acid in vinegar) [PR, AI]

F2.4 conduct an inquiry, using available technology (e.g., probewear) or chemical tests, to detect the presence of inorganic substances in various samples of water [PR, AI]

F3. Understanding Basic Concepts

By the end of this course, students will:

F3.1 identify major and minor chemical components of Earth's atmosphere

F3.2 identify gases and particulates that are commonly found in the atmosphere, and explain how they affect air quality (e.g., greenhouse gases, tropospheric and stratospheric ozone, carbon monoxide, chlorofluorocarbons, soot)

F3.3 state and explain the Arrhenius definition of acids and bases

F3.4 explain the difference between strong and weak acids, and between strong and weak bases, in terms of degree of ionization

F3.5 identify the gas emissions that are the major contributors to acid precipitation, and explain the steps in the formation of acid rain

F3.6 explain the difference between the concepts of strength and concentration when referring to solutions of acids and bases

F3.7 identify inorganic substances that can be found dissolved in water as a result of natural processes and human activities (e.g., hard water contains metal ions)