Chemistry, Grade 11

University Preparation SCH3U

This course enables students to deepen their understanding of chemistry through the study of the properties of chemicals and chemical bonds; chemical reactions and quantitative relationships in those reactions; solutions and solubility; and atmospheric chemistry and the behaviour of gases. Students will further develop their analytical skills and investigate the qualitative and quantitative properties of matter, as well as the impact of some common chemical reactions on society and the environment.

Prerequisite: Science, Grade 10, Academic

Big Ideas

Matter, Chemical Trends, and Chemical Bonding

- Every element has predictable chemical and physical properties determined by its structure.
- The type of chemical bond in a compound determines the physical and chemical properties of that compound.
- It is important to use chemicals properly to minimize the risks to human health and the environment.

Chemical Reactions

- Chemicals react in predictable ways.
- Chemical reactions and their applications have significant implications for society and the environment.

Quantities in Chemical Reactions

- Relationships in chemical reactions can be described quantitatively.
- The efficiency of chemical reactions can be determined and optimized by applying an understanding of quantitative relationships in such reactions.

Solutions and Solubility

- Properties of solutions can be described qualitatively and quantitatively, and can be predicted.
- Living things depend for their survival on the unique physical and chemical properties of water.
- People have a responsibility to protect the integrity of Earth's water resources.

Gases and Atmospheric Chemistry

- Properties of gases can be described qualitatively and quantitatively, and can be predicted.
- Air quality can be affected by human activities and technology.
- People have a responsibility to protect the integrity of Earth's atmosphere.

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

Fundamental Concepts	Matter, Chemical Trends, and Chemical Bonding	Chemical Reactions	Quantities in Chemical Reactions	Solutions and Solubility	Gases and Atmospheric Chemistry
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., a balance, glassware, titration instruments) and materials (e.g., molecular model kits, solutions), 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; 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 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 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

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

* 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).

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, 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., pharmacist, forensic scientist, chemical engineer, food scientist, environmental chemist, occupational health and safety officer, water quality analyst, atmospheric scientist) and the education and training necessary for these careers

A2.2 describe the contributions of scientists, including Canadians (e.g., Carol Ann Budd, Edgar Steacie, Raymond Lemieux, Louis Taillefer, F. Kenneth Hare), to the fields under study

B. MATTER, CHEMICAL TRENDS, AND CHEMICAL BONDING

OVERALL EXPECTATIONS

By the end of this course, students will:

B1. analyse the properties of commonly used chemical substances and their effects on human health and the environment, and propose ways to lessen their impact;

B2. investigate physical and chemical properties of elements and compounds, and use various methods to visually represent them;

B3. demonstrate an understanding of periodic trends in the periodic table and how elements combine to form chemical bonds.

SPECIFIC EXPECTATIONS

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

By the end of this course, students will:

B1.1 analyse, on the basis of research, the properties of a commonly used but potentially harmful chemical substance (e.g., fertilizer, pesticide, a household cleaning product, materials used in electronics and batteries) and how that substance affects the environment, and propose ways to lessen the harmfulness of the substance (e.g., by reducing the amount used, by modifying one of its chemical components) or identify alternative substances that could be used for the same purpose [IP, PR, AI, C]

Sample issue: Many commercial household cleaning products contain corrosive substances that can accumulate in the environment. There are now many "green" cleaners that do not contain these substances, although some of these products may not be as environmentally friendly as claimed.

Sample questions: Why is it more environmentally friendly to use latex rather than oil-based paint? Why should paint never be poured down a drain? What properties of some common pharmaceuticals allow them to stay in water systems and influence the growth and development of organisms? What are some ways in which this impact can be reduced?

B1.2 evaluate the risks and benefits to human health of some commonly used chemical substances (e.g., chemical additives in foods; pharmaceuticals; cosmetics and perfumes; household cleaning products) [AI, C]

Sample issue: Artificial sweeteners, such as aspartame, are used as sugar substitutes to reduce calories in processed foods and beverages. Although such sweeteners may benefit people who are watching their weight, or those with diabetes, some experts say that their harmful effects on human health may outweigh their benefits.

Sample questions: How can the use of non-stick cookware help reduce the amount of fat in our diet? What risks are associated with the use of such cookware? What are the risks and benefits of using sunscreens that contain PABA? What are the risks and benefits of using insect repellents that contain DEET?

B2. Developing Skills of Investigation and Communication

By the end of this course, students will:

B2.1 use appropriate terminology related to chemical trends and chemical bonding, including, but not limited to: *atomic radius, effective nuclear charge, electronegativity, ionization energy,* and *electron affinity* [C]

B2.2 analyse data related to the properties of elements within a period (e.g., ionization energy, atomic radius) to identify general trends in the periodic table [AI]

B2.3 use an inquiry process to investigate the chemical reactions of elements (e.g., metals, non-metals) with other substances (e.g., oxygen, acids, water), and produce an activity series using the resulting data [PR, AI]

B2.4 draw Lewis structures to represent the bonds in ionic and molecular compounds [PR, C]

B2.5 predict the nature of a bond (e.g., non-polar covalent, polar covalent, ionic), using electronegativity values of atoms [AI]

B2.6 build molecular models, and write structural formulae, for molecular compounds containing single and multiple bonds (e.g., CO_2, H_2O, C_2H_4), and for ionic crystalline structures (e.g., NaCl) [PR, AI, C]

B2.7 write chemical formulae of binary and polyatomic compounds, including those with multiple valences, and name the compounds using the International Union of Pure and Applied Chemistry (IUPAC) nomenclature system [AI, C]

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 explain the relationship between isotopic abundance of an element's isotopes and the relative atomic mass of the element

B3.3 state the periodic law, and explain how patterns in the electron arrangement and forces in atoms result in periodic trends (e.g., in atomic radius, ionization energy, electron affinity, electronegativity) in the periodic table

B3.4 explain the differences between the formation of ionic bonds and the formation of covalent bonds

B3.5 compare and contrast the physical properties of ionic and molecular compounds (e.g., NaCl and CH_4; NaOH and H_2O)

C. CHEMICAL REACTIONS

OVERALL EXPECTATIONS

By the end of this course, students will:

C1. analyse chemical reactions used in a variety of applications, and assess their impact on society and the environment;

C2. investigate different types of chemical reactions;

C3. demonstrate an understanding of the different types of chemical reactions.

SPECIFIC EXPECTATIONS

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

By the end of this course, students will:

C1.1 analyse, on the basis of research, chemical reactions used in various industrial processes (e.g., pulp and paper production, mining, chemical manufacturing) that can have an impact on the health and safety of local populations [IP, PR, AI, C]

Sample issue: Base metal smelting produces useful metals such as zinc, lead, copper, and nickel directly from their ores. However, during smelting, harmful compounds can be released into the environment, including cadmium, arsenic, sulfur dioxide, and mercury, all of which can endanger the health and safety of local populations.

Sample questions: What are some chemical reactions used in the manufacture of paper? How might the reactants or products of the pulp and paper production process affect the health of people living near the plant? In what ways might the leaching of chemicals from tailing ponds affect the water quality in a local community? In what ways do toxic chemical fires affect local communities?

C1.2 assess the effectiveness of some applications of chemical reactions that are used to address social and environmental needs and problems [AI, C]

Sample issue: Scrubber systems are a group of air pollution control devices used by industry to remove or neutralize acid exhaust gases before they reach the atmosphere. Scrubber technologies help to reduce acid precipitation, but there are many different scrubbing techniques with varying levels of effectiveness in controlling acid gas emissions.

Sample questions: How are chemical reactions used to remediate environments affected by chemical spills? How can tailing ponds be rehabilitated to lessen the effects of hazardous chemicals on plant populations? What types of chemical reactions can change a toxic chemical into one that is less toxic or non-toxic?

C2. Developing Skills of Investigation and Communication

By the end of this course, students will:

C2.1 use appropriate terminology related to chemical reactions, including, but not limited to: *neutralization*, *precipitate*, *acidic*, and *basic* [C]

C2.2 write balanced chemical equations to represent synthesis, decomposition, single displacement, double displacement, and combustion reactions, using the IUPAC nomenclature system [PR, AI, C]

C2.3 investigate synthesis, decomposition, single displacement, and double displacement reactions, by testing the products of each reaction (e.g., test for products such as gases, the presence of an acid, or the presence of a base) [PR, AI]

C2.4 predict the products of different types of synthesis and decomposition reactions (e.g., synthesis reactions in which simple compounds are formed; synthesis reactions of metallic or non-metallic oxides with water; decomposition reactions, in which a chemical compound is separated into several compounds) [AI]

C2.5 predict the products of single displacement reactions, using the metal activity series and the halogen series [AI]

C2.6 predict the products of double displacement reactions (e.g., the formation of precipitates or gases; neutralization) [AI]

C2.7 design an inquiry to demonstrate the difference between a complete and an incomplete combustion reaction [IP, C]

C2.8 plan and conduct an inquiry to compare the properties of non-metal oxide solutions and metal oxide solutions (e.g., carbon dioxide reacts with water to make water acidic; magnesium oxide reacts with water to make water basic) [IP, PR, AI]

C2.9 investigate neutralization reactions (e.g., neutralize a dilute solution of sodium hydroxide with a dilute solution of hydrochloric acid, and isolate the sodium chloride produced) [PR]

C2.10 plan and conduct an inquiry to demonstrate a single displacement reaction, using elements from the metal activity series [IP, PR]

C3. Understanding Basic Concepts

By the end of this course, students will:

C3.1 identify various types of chemical reactions, including synthesis, decomposition, single displacement, double displacement, and combustion

C3.2 explain the difference between a complete combustion reaction and an incomplete combustion reaction (e.g., complete and incomplete combustion of hydrocarbon fuels)

C3.3 explain the chemical reactions that result in the formation of acids and bases from metal oxides and non-metal oxides (e.g., calcium oxide reacts with water to produce a basic solution; carbon dioxide reacts with water to produce an acidic solution)

D. QUANTITIES IN CHEMICAL REACTIONS

OVERALL EXPECTATIONS

By the end of this course, students will:

D1. analyse processes in the home, the workplace, and the environmental sector that use chemical quantities and calculations, and assess the importance of quantitative accuracy in industrial chemical processes;

D2. investigate quantitative relationships in chemical reactions, and solve related problems;

D3. demonstrate an understanding of the mole concept and its significance to the quantitative analysis of chemical reactions.

SPECIFIC EXPECTATIONS

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

By the end of this course, students will:

D1.1 analyse processes in the home, the workplace, and the environmental sector that involve the use of chemical quantities and calculations (e.g., mixing household cleaning solutions, calculating chemotherapy doses, monitoring pollen counts) [AI, C]

Sample issue: Health care professionals are expected to calculate dosages of prescription drugs accurately and safely. This requires precision in applying fractions, decimals, ratios, percentages, and metric conversions. Despite the care taken by health care professionals, improper medication use by patients accounts for about 30% of hospital emergency department visits.

Sample questions: Why is baking powder used in cake batter? What happens when too much or too little of that ingredient is used? Why might two people on the same drug regimen not necessarily take the same dosage to treat the same illness? How are carbon dioxide emissions calculated and why are they monitored?

D1.2 assess, on the basis of research, the importance of quantitative accuracy in industrial chemical processes and the potential impact on the environment if quantitative accuracy is not observed [IP, PR, AI, C]

Sample issue: Errors in quantitative accuracy have played a role in many industrial chemical disasters worldwide. Failing to adjust the quantities of chemicals needed to produce different batch sizes of a product have created runaway reactions, resulting in huge explosions. Such industrial accidents can have devastating short- and long-term effects on the environment.

Sample questions: Why is it important to use the correct salt-sand mix on highways during winter storms? Why is it important to correctly measure the chemicals used in water treatment plants? How might incorrect measurements affect the environment? How and why are environmental contaminants monitored in soil, water, and air around a chemical manufacturing plant?

D2. Developing Skills of Investigation and Communication

By the end of this course, students will:

D2.1 use appropriate terminology related to quantities in chemical reactions, including, but not limited to: *stoichiometry*, *percentage yield*, *limiting reagent*, *mole*, and *atomic mass* [C]

D2.2 conduct an inquiry to calculate the percentage composition of a compound (e.g., a hydrate) [PR, AI]

D2.3 solve problems related to quantities in chemical reactions by performing calculations involving quantities in moles, number of particles, and atomic mass [AI]

D2.4 determine the empirical formulae and molecular formulae of various chemical compounds, given molar masses and percentage composition or mass data [AI]

D2.5 calculate the corresponding mass, or quantity in moles or molecules, for any given reactant or product in a balanced chemical equation as well as for any other reactant or product in the chemical reaction [AI]

D2.6 solve problems related to quantities in chemical reactions by performing calculations involving percentage yield and limiting reagents [AI]

D2.7 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]

D3. Understanding Basic Concepts

By the end of this course, students will:

D3.1 explain the law of definite proportions

D3.2 describe the relationships between Avogadro's number, the mole concept, and the molar mass of any given substance

D3.3 explain the relationship between the empirical formula and the molecular formula of a chemical compound

D3.4 explain the quantitative relationships expressed in a balanced chemical equation, using appropriate units of measure (e.g., moles, grams, atoms, ions, molecules)

E. SOLUTIONS AND SOLUBILITY

OVERALL EXPECTATIONS

By the end of this course, students will:

E1. analyse the origins and effects of water pollution, and a variety of economic, social, and environmental issues related to drinking water;

E2. investigate qualitative and quantitative properties of solutions, and solve related problems;

E3. demonstrate an understanding of qualitative and quantitative properties of solutions.

SPECIFIC EXPECTATIONS

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

By the end of this course, students will:

E1.1 analyse the origins and cumulative effects of pollutants that enter our water systems (e.g., landfill leachates, agricultural run-off, industrial effluents, chemical spills), and explain how these pollutants affect water quality [AI, C]

Sample issue: Golf courses use fertilizer and irrigation systems to sustain the vegetation. However, chemical substances, when combined with water, may run off and pollute local water systems.

Sample questions: What pollutants might be found in untreated wastewater from a chicken farm or a poultry-processing plant? How do leachates from old landfill sites enter our water system? How might they affect the water quality of local streams? What are some of the sources and effects of mercury in water systems? What impact might this contaminant have on Aboriginal communities that depend on fishing as a source of food?

E1.2 analyse economic, social, and environmental issues related to the distribution, purification, or use of drinking water (e.g., the impact on the environment of the use of bottled water) [AI, C]

Sample issue: In developing countries, thousands of people, many of them children, die every year from drinking contaminated water. Many of these countries cannot afford to build water treatment plants. In North America, where safe water is generally available, we spend millions of dollars on bottled water, draining sources of fresh water and challenging waste-disposal systems.

Sample questions: What are the economic costs of building, maintaining, and monitoring water-purification plants? What are the social and environmental costs if these plants are not properly maintained and monitored? How effective are municipal wastewater treatment processes at removing pharmaceuticals such as hormones and antibiotics from our drinking water? What public health concerns are associated with the consumption of water bottled in plastic containers?

E2. Developing Skills of Investigation and Communication

By the end of this course, students will:

E2.1 use appropriate terminology related to aqueous solutions and solubility, including, but not limited to: *concentration, solubility, precipitate, ionization, dissociation, pH, dilute, solute,* and *solvent* [C]

E2.2 solve problems related to the concentration of solutions by performing calculations involving moles, and express the results in various units (e.g., moles per litre, grams per 100 mL, parts per million or parts per billion, mass, volume per cent) [AI, C]

E2.3 prepare solutions of a given concentration by dissolving a solid solute in a solvent or by diluting a concentrated solution [PR]

E2.4 conduct an investigation to analyse qualitative and quantitative properties of solutions (e.g., perform a qualitative analysis of ions in a solution) [PR, AI]

E2.5 write balanced net ionic equations to represent precipitation and neutralization reactions [AI, C]

E2.6 use stoichiometry to solve problems involving solutions and solubility [AI]

E2.7 determine the concentration of an acid or a base in a solution (e.g., the concentration of acetic acid in vinegar), using the acid–base titration technique [PR, AI]

E2.8 conduct an investigation to determine the concentrations of pollutants in their local treated drinking water, and compare the results to commonly used guidelines and standards (e.g., provincial and federal standards) [PR, AI]

E3. Understanding Basic Concepts

By the end of this course, students will:

E3.1 describe the properties of water (e.g., polarity, hydrogen bonding), and explain why these properties make water such a good solvent

E3.2 explain the process of formation for solutions that are produced by dissolving ionic and molecular compounds (e.g., salt, oxygen) in water, and for solutions that are produced by dissolving non-polar solutes in non-polar solvents (e.g., grease in vegetable oil)

E3.3 explain the effects of changes in temperature and pressure on the solubility of solids, liquids, and gases (e.g., explain how a change in temperature or atmospheric pressure affects the solubility of oxygen in lake water)

E3.4 identify, using a solubility table, the formation of precipitates in aqueous solutions (e.g., the use of iron or aluminum compounds to precipitate and remove phosphorus from wastewater)

E3.5 explain the Arrhenius theory of acids and bases

E3.6 explain the difference between strong and weak acids, and between strong and weak bases, in terms of degree of ionization

F. GASES AND ATMOSPHERIC CHEMISTRY

OVERALL EXPECTATIONS

By the end of this course, students will:

F1. analyse the cumulative effects of human activities and technologies on air quality, and describe some Canadian initiatives to reduce air pollution, including ways to reduce their own carbon footprint;

F2. investigate gas laws that explain the behaviour of gases, and solve related problems;

F3. demonstrate an understanding of the laws that explain the behaviour of gases.

SPECIFIC EXPECTATIONS

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

By the end of this course, students will:

F1.1 analyse the effects on air quality of some technologies and human activities (e.g., smelting; driving gas-powered vehicles), including their own activities, and propose actions to reduce their personal carbon footprint [AI, C]

Sample issue: Gas-powered lawnmowers cut grass quickly and efficiently, but they emit greenhouse gases. However, there are several alternatives, including electric or push mowers or replacing lawn with a naturalized garden.

Sample questions: In what ways does our consumption of products imported from distant countries affect our carbon footprint? How might "eat local–buy local" initiatives help to reduce our carbon footprint? How effectively does the use of digital communications for business reduce our carbon footprint?

F1.2 assess air quality conditions for a given Canadian location, using Environment Canada's Air Quality Health Index, and report on some Canadian initiatives to improve air quality and reduce greenhouse gases (e.g., Ontario's Drive Clean program to control vehicle emissions) [AI, C]

Sample issue: Historically, mining and smelting polluted the air, land, and water around Sudbury, Ontario. More recently, as a result of government regulations, industry has significantly reduced emissions, leading to an improvement in air quality and reversal in the acidification of local waterways.

Sample questions: How effective has Ontario's Drive Clean program been in reducing greenhouse gas emissions in the province? What are some industrial and geographic factors that might make air quality in some communities very different from that in others? What are some municipal governments doing to improve local air quality? How can public transit initiatives help improve air quality? What are the limitations of such initiatives?

F2. Developing Skills of Investigation and Communication

By the end of this course, students will:

F2.1 use appropriate terminology related to gases and atmospheric chemistry, including, but not limited to: *standard temperature*, *standard pressure*, *molar volume*, and *ideal gas* [C]

F2.2 determine, through inquiry, the quantitative and graphical relationships between the pressure, volume, and temperature of a gas [PR, AI]

F2.3 solve quantitative problems by performing calculations based on Boyle's law, Charles's law, Gay-Lussac's law, the combined gas law, Dalton's law of partial pressures, and the ideal gas law [AI]

F2.4 use stoichiometry to solve problems related to chemical reactions involving gases (e.g., problems involving moles, number of atoms, number of molecules, mass, and volume) [AI]

F2.5 determine, through inquiry, the molar volume or molar mass of a gas produced by a chemical reaction (e.g., the molar volume of hydrogen gas from the reaction of magnesium with hydrochloric acid) [PR, AI]

F3. Understanding Basic Concepts

By the end of this course, students will:

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

F3.2 describe the different states of matter, and explain their differences in terms of the forces between atoms, molecules, and ions

F3.3 use the kinetic molecular theory to explain the properties and behaviour of gases in terms of types and degrees of molecular motion

F3.4 describe, for an ideal gas, the quantitative relationships that exist between the variables of pressure, volume, temperature, and amount of substance

F3.5 explain Dalton's law of partial pressures, Boyle's law, Charles's law, Gay-Lussac's law, the combined gas law, and the ideal gas law

F3.6 explain Avogadro's hypothesis and how his contribution to the gas laws has increased our understanding of the chemical reactions of gases