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ABSTRACT

GRADES OR AGES: Grade 13. SUBJECT MATTER: Chemistry. ORGANIZATION AND PHYSICAL APPEARANCE: The guide is divided into 15 units, each of which is in list form. It is offset printed and staple-bound with a paper cover. OBJECTIVES AND ACTIVITIES: No objectives are mentioned. Topics to be covered are listed in each unit. Most units also list several experiments to be performed, although no details are given. Suggestions are made for timing of units. INSTRUCTIONAL MATERIALS: One textbook is mentioned in the preface. STUDENT ASSESSMENT: No mention. (RT)

ONTARIO DEPARTMENT OF EDUCATION

CURRICULUM S-17E

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CHEMISTRY, GRADE 13

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CONTENTS

PREFACE

This course is a considerable departure from the one used till now for Grade 13 students. This evolution is made possible in part by the considerable revision of the course for Grade 12 (Curriculum S-17D). It also reflects the substantial efforts made to upgrade and update Chemistry curricula in other parts of the world, especially by the CHEM Study and CBA projects in the United States. The revision of the courses in Chemistry for Ontario students comes at a time when all aspects of chemical education, including university courses, are under intensive study.

The inevitable consequence of the continuous increase in the body of chemical knowledge is that the part of Chemistry which can reasonably be taught in an introductory course must from time to time be reconsidered in the light of its relevance and importance to the whole subject. The result of this review is that some topics that have in the past been regarded as important have had to be removed or given lesser significance, and others brought into prominence.

This course gives much greater attention to the structure of atoms, the energy associated with atomic and molecular events, the nature of bonding in molecules and crystals, the interpretation of redox reactions in terms of electrochemical cells, a quantitative consideration of equilibrium, and the interpretation of reaction kinetics in terms of collision theory. Besides making these changes in content, the new course places some stress on the nature of scientific activity and scientific explanation and the use of models to explain and describe structure and reactions in Chemistry.

The course given here is based on the Chemical Education Material Study (CHEM Study) project in the United States. The textbook issued by this group, *Chemistry—An Experimental Science (1963)*, emphasizes in its title as well as its content the importance attached to laboratory work. From experimental work the student discovers for himself the origin of chemical principles and the limitations and the interpretation of scientific measurements. The nature and number of the experiments will require, for their performance, laboratory facilities and the provision of adequate time. Wherever possible, two double periods per week should be allowed for laboratory experiments.

COURSE OUTLINE

Unit 1:
INTRODUCTION

(3 weeks)

Reference to Curriculum S-17D will show that Chapters 1 to 6, 13, 19, and 21 of *Chemistry—An Experimental Science (1963)* have been largely covered in the Grade 12 course. There are some significant differences in approach, however, between the two courses. Many teachers may wish to use material from these chapters, though not specifically listed in the following outline, as a review of Grade 12 work and as an introduction to the more inductive and deductive approach that characterizes the CHEM Study program. Perhaps this could be made clearer by some specific illustrations.

Chapter 1 of *Chemistry—An Experimental Science (1963)* (The Activities of Science) contains very little scientific information that will be unfamiliar to a Grade 13 student. It has, however, a discussion, very simply illustrated, of inductive reasoning; of the nature of scientific explanation in terms of "models"; of significant figures; of the uncertainty of scientific observations; of the graphical portrayal of experimental data. None of these is specifically treated in Curriculum S-17D.

Chapter 2 (A Scientific Model: The Atomic Theory) includes some interesting examples of deduction, e.g. of the relative weights of molecules, or of the number of atoms in a molecule. Exercises of this kind are not specifically suggested in Curriculum S-17D.

Although material of this sort is not, as such, included in the following Units, it embodies the philosophy of the whole course. The above-mentioned chapters therefore should be adequately presented to the students as background material.

NOTE:
Generally speaking, about three weeks should be given to Unit 1, whether the time is distributed throughout the year or spent at the beginning of the course.

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Unit 2:
ENERGY EFFECTS IN CHEMICAL REACTIONS

(2 weeks)

1. Heat and Chemical Reactions
   a) The water-gas reaction
   b) The heat content of a substance
   c) Additivity of reaction heats
   d) The measurement of reaction heat: calorimetry
   e) Calculation of heat of reaction, ΔH
2. The Law of Conservation of Energy
   a) Conservation of kinetic and potential energy
   b) Conservation of energy in a chemical reaction
3. The Energy Stored in a Molecule
   a) The energy of a molecule: molar heat content
   b) Energy changes on warming
4. The Energy Stored in a Nucleus

Experiment: The heat of reaction

Unit 3:
THE RATES OF CHEMICAL REACTIONS

(2 weeks)

1. Meaning of Rate of Reaction; units for its expression, e.g. moles/litre/second
2. Factors Affecting Rates of Reaction
   a) The nature of the reactants
   b) Effect of concentration: collision theory
   c) Reaction mechanism
   d) The quantitative effect of concentration
   e) Effect of temperature: collision theory
      - Distribution of kinetic energies
      - Threshold energy and rate of reaction
3. The Role of Energy in Rates of Reaction
   a) Activation energy
   b) Heat of reaction
   c) Action of catalysts
   d) Examples of catalysts

Experiments:

a) Reaction of potassium permanganate with (i) iron(II) ion (ii) oxalic and sulphuric acids, to illustrate the effect of reactants, concentration of reactants, temperature, and catalysis on the rate of reaction
b) Reaction to iodate ion and hydrogen sulphite ion in presence of starch to illustrate the effect of concentration changes and temperature changes on the rate of reaction.

Unit 4:
EQUILIBRIUM IN CHEMICAL REACTIONS

(2 weeks)

1. Meaning of the Equilibrium State
2. Qualitative Aspects of Equilibrium
   a) Recognition of equilibrium
   b) The dynamic nature of equilibrium
      - Solubility
      - Vapour pressure
      - Chemical reactions
   c) The state of equilibrium
   d) Altering the state of equilibrium
      - Concentration
      - Temperature
      - Catalysts
   e) Attainment of equilibrium
   f) Predicting new equilibrium concentrations: Le Chatelier's Principle
      Effect of changes in
      - Concentration
      - Pressure
      - Temperature
   g) Application of equilibrium principles: the Haber process
3. Quantitative Aspects of Equilibrium
   a) The equilibrium constant
   b) The law of chemical equilibrium
   c) The law of chemical equilibrium derived from rates of opposing reactions
   d) The factors which determine equilibrium
   e) Simple problems

Experiment: Verification of the equilibrium law for the reaction:

$$Fe^{3+}(aq.) + SCN^{-}(aq.) \rightleftharpoons FeSCN^{2+}(aq.)$$

Unit 5:
SOLUBILITY EQUILIBRIA

(1½ weeks)

1. Solubility: A Case of Equilibrium
   a) Solubility of iodine in ethyl alcohol
   b) The dynamic nature of solubility equilibrium
      - Rate of dissolving
      - Rate of precipitation
      - The dynamic nature of equilibrium
   c) The factors that determine the solubility of a solid
      Effect of
      - Randomness
      - Energy
      - Temperature
   d) Solubility of a gas in a liquid
      Effect of
      - Randomness
      - Energy
      - Temperature
2. Aqueous Solutions
   a) Review of meaning of electrolyte and non-electrolyte
   b) Types of compounds that are electrolytes
   c) A qualitative view of aqueous solubilities
   d) The equilibrium law: solubility-product constant (K_{sp})
   e) Calculation of the solubility of copper(I) chloride in water
   f) Prediction of formation of precipitates in chemical reactions
   g) Precipitations used for separations
   h) Simple problems

Experiment: Determination of the solubility-product constant of silver acetate

Unit 6:

AQUEOUS ACIDS AND BASES

(2½ weeks)

1. Electrolytes
   a) Strong and weak electrolytes
   b) Water: a weak electrolyte
   Ion-product constant for water
   c) Special roles of H^+(aq.) and OH^-(aq.) in water
2. Introduction to Acids and Bases (see Curriculum S-17D, Unit IX, 4)
   a) Properties of aqueous solutions of acids
   b) Properties of aqueous solutions of bases and their explanation
   c) The nature of H^+(aq.); some models to explain it
   d) Acid-base titrations
   Calculation of $[H^+]$ and $[OH^-]$ at various points during the neutralization of a strong acid or a strong base
   e) Definition of pH
3. Strengths of Acids
   Weak acids
   a) Equilibrium constants for ionization of weak acids
   Calculations of equilibrium constant for weak acids
   Use of equilibrium constant to calculate $[H^+]$
   b) Competition for protons among weak acids
   Hydronium ion in the proton-transfer theory of acids
   c) Contrast of acid-base definitions

Experiments:

a) Determination of the approximate hydrogen-ion concentration of solutions using indicators
b) Application of Le Chatelier's Principle to a reversible chemical reaction; the influence of $[H^+]$ on the chromate ion-dichromate ion equilibrium
c) Quantitative acid-base titrations
Standardization of a base using a standard acid
Titration of an unknown acid

Unit 7:

OXIDATION-REDUCTION REACTIONS

(2½ weeks)

1. Electrochemical Cells
   a) The chemistry of an electrochemical cell
   b) Oxidation-reduction reactions without electrodes; competition for electrons (see Curriculum S-17D, Unit IX, 3)
   c) The nomenclature of an electrochemical cell
2. Electron Transfer and Prediction of Reactions
   a) Electron-losing tendency
   Demonstration of voltages of electrochemical cells
   Half-cell potentials; the hydrogen half-cell as a standard; table of half-cell potentials
   b) Prediction of reactions from table of half-cell potentials; effect of concentration on such predictions; validity of predictions
   c) Oxidation numbers
   Oxidation and reduction in terms of changes in oxidation numbers
3. Balancing of Oxidation-Reduction Reactions
   a) Use of half-reactions (electron balancing)
   b) Use of oxidation numbers
4. Electrolysis
   a) Review of Unit IX, 2 of Curriculum S-17D
   b) Electrolysis as a reverse reaction to that occurring in an electrochemical cell

Experiments:

a) An introduction to oxidation-reduction
Reactions involving metals such as zinc, copper, and lead, when placed in solutions of each metal's salts (see Unit IX, Experiment (g) of Curriculum S-17D)
Reactions involving displacement of bromine, iodine, from solutions of halides of metals (see Unit XI, 2(b) of Curriculum S-17D)
b) Electrochemical cells using pairs of metals such as zinc-copper, silver-copper
c) Reactions between ions in solution
Reactions involving solutions containing ions which when mixed produce (i) precipitates and (ii) oxidation-reduction reactions

Unit 8:
EXPERIMENTAL BASIS FOR THE ATOMIC THEORY

(1½ weeks)

1. Chemical Evidence for the Atomic Theory
   a) The laws of definite proportions and multiple proportions
   b) The law of combining gas volumes
   c) Faraday's laws of electrolysis (number of coulombs /mole of electrons)
2. Physical Evidence for the Atomic Theory
   a) Electrical conduction in rarefied gases; properties of cathode rays
   b) Deflection of cathode rays by magnetic fields to measure e/m for electrons
   c) Millikan's oil-drop experiment to deduce e for electrons
   d) Production of positive ions in rarefied gases; measurement of e/m; the mass spectrograph
   e) Scattering of α-particles by metallic foils; hypothesis of nuclear atom (the mathematical basis need not be learned)
3. Spectroscopic Information about Atomic and Molecular Dimensions
   a) Light and the frequency spectrum
   b) X-ray diffraction patterns revealing spacings in crystals
   c) Infrared spectroscopy revealing rotation and vibration in molecules

Experiment: The relationship between the moles of copper, moles of silver, and moles of electrons involved during electrolysis

Unit 9:
ELECTRON ARRANGEMENT AND THE PERIODIC TABLE

(1½ weeks)

1. Spectroscopy of the Hydrogen Atom
   a) Energy associated with light; Planck's relationship
   b) The line spectrum of hydrogen atoms; spectral series
   c) Energy levels in hydrogen atoms
   d) The quantum jump in electronic transitions; stationary states in atoms
   e) Quantum numbers: n, principal quantum number
   f) Orbitals: a representation of the distribution of an electron in space about an atomic nucleus. Designation of orbitals s, p, d, f
   g) Description of s and p orbitals
   h) The total number of orbitals for each value of n; the number of s, p, d, and f orbitals within this total
2. Many-Electron Atoms
   a) Energy levels of many-electron atoms. Differentiation in energy levels of s, p, d, and f orbitals having same value of n (cf. hydrogen atom)
   b) Build-up of periodic table. Filling of orbitals in order of ascending energy regulated by the Pauli Principle (maximum of 2 electrons per orbital) and a principle of maximum repulsion (orbitals of equivalent energy are first filled singly before pairing occurs)
3. Ionization Energy and the Periodic Table
   a) Definition of ionization energy
   b) Trends in ionization energies among first 20 elements
   c) Ionization energies (first, second, etc.) and valence electrons
   d) Fourth row of periodic table; significance of ten transition elements

Unit 10:
MOLECULES IN THE GAS PHASE

(2 weeks)

1. The Covalent Bond
   a) The hydrogen molecule
   b) Interaction between helium atoms
   c) Representation of chemical bonding
   d) The bonding of fluorine
2. Bonding Capacity of the Elements Lithium to Oxygen
   The correlation of ordinary bonding capacities with orbital occupancies of the atoms of these elements
3. Trend in Bond Type Among Some Fluorine Compounds
   a) The bonding in gaseous lithium fluoride
   b) Ionic character in bonds to fluorine (lithium to oxygen)
   c) Ionic character in bonds to hydrogen
4. Molecular Architecture
   a) The shapes of some molecules: water, difluorine oxide, ammonia, nitrogen trifluoride, methane, carbon tetrafluoride, boron trifluoride, beryllium difluoride
   b) Molecular shape and electric dipoles
5. Double Bonds
   a) Bonding in the oxygen molecule
   b) Ethylene: a carbon-carbon double bond

Experiment: Investigation of some of the properties of a pair of cis-trans isomers; e.g., maleic and fumaric acids

Unit 11:
THE BONDING IN SOLIDS AND LIQUIDS

(2 weeks)

1. The Elements
   a) van der Waals' forces
   b) Covalent bonds and network solids
   c) Metallic bonding
2. Compounds
   a) van der Waals' forces and molecular substances
   b) Covalent bonds and network solid compounds
   c) Alloys
   d) Ionic solids
   e) Effects due to charge separation
   f) Hydrogen bonds

Experiment: Construction of models to show the packing of atoms or ions in crystals

Unit 12:
THE CHEMISTRY OF CARBON COMPOUNDS

(3 weeks)

1. Sources of Carbon Compounds
2. Molecular Structures of Carbon Compounds
   a) The composition and structure of carbon compounds
   b) Experimental determination of molecular structure
   c) The ethyl group
3. Some Chemistry of Organic Compounds
   a) Chemical behaviour of ethyl and methyl bromide
   b) Oxidation of organic compounds
   c) The functional group
   d) Amines
   e) Acid derivatives: esters and amides
4. Nomenclature
5. Hydrocarbons
   a) Saturated hydrocarbons
   b) Unsaturated hydrocarbons
   c) Benzene and its derivatives
6. Polymers
   a) Types of polymerization
   b) "Nylon," a polymeric amide
   c) Protein, another polymeric amide

Experiments:

a) Some reactions of hydrocarbons and of alcohols
b) The preparation of some derivatives of organic acids

Unit 13:
THE THIRD ROW OF THE PERIODIC TABLE

(1½ weeks)

1. Physical Properties of the Elements
   a) Sodium, magnesium, and aluminium: metallic solids
   b) Silicon: a network solid
   c) Phosphorus, sulphur, and chlorine: molecular solids
2. The Elements as Oxidizing and Reducing Agents
   a) Sodium, magnesium, and aluminium: strong reducing agents
   b) Silicon, phosphorus, and sulphur: oxidizing and reducing agents of intermediate strength
   c) Chlorine: a strong oxidizing agent
3. The Acidic and Basic Properties of the Hydroxides
   a) Sodium and magnesium hydroxides: strong bases
   b) Aluminium hydroxide: an amphoteric hydroxide
   c) Silicon, phosphorus, sulphur, and chlorine oxy-acids
4. Occurrence and Preparation of the Third-row Elements
   a) Occurrence
   b) Preparation of the elements
5. Trends in Some Properties of Second-row and Third-row Elements

Experiment: Comparison of the relative acid-base strength of the hydroxides of the third row of the periodic table

Unit 14: THE FOURTH-ROW TRANSITION ELEMENTS

(2½ weeks)

1. Meaning of Transition Element
   a) Electron configuration
   b) General properties
2. Complex Ions
   a) Nature
   b) Geometry
   c) Bonding
   d) Amphoteric complexes
3. Some Properties of Fourth-row Transition Elements
   a) General properties
   b) Specific properties of chromium, manganese, iron, nickel, copper, zinc

Experiments:

a) Separation of iron, cobalt, and nickel ions by an anion exchange resin
b) Corrosion of iron
c) Preparation of a complex salt and double salt
d) Preparation of potassium dichromate

Unit 15: SOME SIXTH-ROW AND SEVENTH-ROW ELEMENTS

(½ week)

1. The Sixth Row of the Periodic Table
   a) The lanthanides, or rare earths
2. The Seventh Row of the Periodic Table
   a) The occurrence of the seventh-row elements
   b) The elements following actinium
   c) Nuclear stability and radioactivity
   d) Types of radioactivity
   e) Nuclear energy