A REVISED CHEMISTRY COURSE FOR SECONDARY SCHOOLS IN NOVA SCOTIA

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INTRODUCTION

This project is an attempt to explore and identify the irreducible minimum of basic fundamentals that could and should be taught in the Nova Scotia high school chemistry course, and on which the college course would then be built. A review of the chemistry course presently available in Nova Scotia will be presented. Next, several suggested approaches to a "new" study of chemistry will be analyzed. In this connection, the main emphasis is on the examination of recent studies in the United States, Canada and Western Europe. Finally, a revised course of chemistry for secondary schools in Nova Scotia will be outlined.

High schools in Nova Scotia offer a course in chemistry which is poor in quality and out of touch with the science as it is known to the professional. The course follows a traditional syllabus and educational authorities have stubborn reluctance to disregard any material presently on the course. Many important modern chemical concepts are missing from it. Furthermore, there has been a movement away from laboratory experience for the student. The present high school chemistry course in the schools of Nova Scotia on the other hand certainly does not lack quantity. The curriculum seems designed to provide plenty of material, so that little time may be spent on supplementary topics of correlation of class and laboratory work.

One need not go into all the reasons for the shortcomings of high school chemical instruction in Nova Scotia except to exphasize one, for which most chemistry teachers carry the blame. There is a surprising and persistent general lack of interest in high school chemistry and a lack of communication among high school teachers and administrators and college professors of chemistry and professional chemists. This situation has gone on for decades, and high school chemistry courses of the recent past are a monument to it.

Chapter I of this thesis gives an outline of the present chemistry course for secondary schools in Nova Scotia. Chapter II reviews several contemporary approaches to the teaching of chemistry in the United States. Among these are two studies sponsored by the National Science Foundation: (1) "The Chemical Education Materials Study",[1] frequently designated as the CHEM Study, and (2) "The Chemical Bond Approach Project",[2] frequently designated as the CBA Project. The latter is discussed at length in the third chapter. Finally, the fourth chapter contains

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[1]Lawrence E. Strong and M. Kent Wilson, "Chemical Bonds: A Central Theme", Journal of Chemical Education, Vol. XXXV (February, 1958), pp. 56-58.

[2]J. A. Campbell, "The Chemical Education Materials Study", Journal of Chemical Education, Vol. XXXVIII (January, 1961), pp. 2-5.

an outline for a "revised" chemistry course for the secondary schools of Nova Scotia.

Of necessity, one must rely heavily on reports of recent developments in high school chemistry teaching in the United States for information on the most recent trends in this field. There is very little material available on Canadian developments in high school chemistry, although the McGraw-Hill Book Company has recently presented a laboratory manual in chemistry, entitled "Semi-Micro Experiments in High School Chemistry".[3] This text outlines the "semi-micro" laboratory technique developed recently in the United States. The Department of Education of the Province of Saskatchewan has adopted the CHEM Study course in Chemistry on an experimental basis for the school term 1963-64.[4]

European countries are also striving toward better courses for secondary school chemistry and better teaching methods. The organization for European Economic Cooperation with headquarters in Paris, sponsored a seminar on "New Programs in Chemistry for Secondary Schools". This seminar was held at Greystones, Eire, in March 1960, and a second

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[3]G. Hall, S. Madras and R. Holcomb, Semi-Micro Experiments in High School Chemistry, Toronto: McGraw-Hill Co., 1961.

[4]A. B. Van Cleave, "New Ideas in Science Teaching", Quest, (Toronto: The Canadian Home and School and Parent Teacher Federation, Volume I, No. 1, September, 1963), pp. 14-30.

was held at the same place in March 1961.[5] The reports on the seminars contain significant ideas concerning the CBA and CHEM study projects which will be referred to in this thesis. These developments in North America and parts of Europe provide a basis for the suggestions for the revision of the high school chemistry curriculum outlined in the final chapter of this thesis.

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[5]Organization for European Economic Cooperation, New Thinking in School Chemistry, A Report on the OEEC Seminar on the status and development of the teaching of school chemistry (Paris: Organization for European Economic Cooperation, July, 1961).

CHAPTER I

PRESENT CHEMISTRY COURSE IN SECONDARY SCHOOLS IN NOVA SCOTIA

It is the prerogative of the Curriculum and Research Division of the Department of Education to plan and organize the chemistry course for secondary schools in Nova Scotia. The Chief Supervisor of Curriculum and Research solicits co-operation in formulating policy as to any revision of the curriculum by the Science Committee, a continuing committee of teachers, and/or administrators. This chapter contains an outline of the content and laboratory experiments for the present chemistry course, as suggested by the Department of Education.[1]

Presently there are three text books introduced in 1960 recommended by the Department of Education for use in the Grade XI and XII Chemistry courses. The teacher may use discretion as to the choice of:

1) Charles E. Dull, William O. Brooks and H. Clarke Metcalfe, Modern Chemistry (Toronto: Clarke, Erwin and Company Limited, 1950).

2) Raymond B. Brownlee and Others, Elements of

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[1]See Handbook to the Course of Study (Truro: Nova Scotia Department of Education, 1935).

Chemistry (New York: Allyn and Bacon, Inc., 1958).

3) A. G. Croal, J. H. Couke and A. H. Louden, Chemistry for Secondary Schools (Toronto: The Coop Clark Publishing Company Limited, 1958).[2]

These books replace a text by Harold E. Bigelow and Fred G. Morehouse, Dominion High School Chemistry, (Toronto: The MacMillan Company of Canada, at Saint Martin's House, 1935). The Bigelow and Morehouse book was the prescribed text for twenty-seven years.

The Teaching Guide for Chemistry published by the Department of Education of the Province of Nova Scotia in 1960, the document outlining the Grade XI and Grade XII Chemistry Course for Secondary Schools in Nova Scotia, contains the following outline:

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[2]See Education Office Gazette (Halifax: Nova Scotia Department of Education, Vol. XLX, No. 2, March 1960).

CHEMISTRY: GRADE XI

INTRODUCTION (1 period)

1. What is chemistry?
2. Brief history: Greek, Alexandrian and Arabian schools
3. Alchemy. Iatro-Chemistry
4. Decline of alchemy
5. Chemistry as an exact science
6. Lavoisier
7. Scientific method

MATTER (4 periods)

1. The three states of matter
2. Identification of matter
3. Properties or characteristics of matter
4. Study mechanical mixtures, such as iron and sulphur

ENERGY (2 periods)

1. The various forms of energy
2. Special attention to the different forms of energy which bring about chemical reactions: heat, light, electricity
3. Exothermic and endothermic reactions
4. The Law of Conservation of Matter and the Law of Conservation of Energy
5. Discuss the relationship between matter and energy
6. Nuclear energy. Reactions in this field are not ordinary chemical reactions

CLASSIFICATION OF MATERIALS (4 periods)

1. The meaning of a pure substance, element, compound, solution, mixture, metal, non-metal, oxide, acid, base, salt. The terms "homogeneous", "heterogeneous"

2. The distinction between physical and chemical change

3. Study (a) the heating of mercuric oxide, (b) electrolysis of water as simple chemical changes

4. Law of Conversation of Mass as applied to chemical change

5. Law of definite proportions. This should be illustrated by such experiments as (a) decomposition of mercuric oxide; (b) combination of magnesium and oxygen.

NATURE OF MATTER (3 periods)

1. Molecules

2. Kinetic Molecular Theory

3. Atoms, Atomic Hypothesis as devised by John Dalton

4. Symbols - a system for representing atoms of the elements. Review and learn the symbols for the more common elements

5. Formulae. Represent molecules of elements and compounds

6. What do chemical formulae signify?

7. Radicals

8. Discuss the nomenclature of chemistry briefly at this point

9. Chemical equations

THE ATMOSPHERE: A MIXTURE (3 periods)

1. Composition of air

2. Air is a mixture

3. Liquid air and its uses

4. The inert gases

WATER: A COMPOUND (5 periods)

1. Occurrence

2. Physical properties

3. Chemical properties:

   a) Reaction with metals

   b) Reactions with metallic oxides

   c) Reactions with non-metallix oxides

   d) Hydrates. Water of crystallization
      Anhydrous compound

   e) Using anhydrous copper sulphate as a test
      for the presence of water

4. Composition of water. By volume:

   a) Analysis. Electrolysis of water. Two
      volumes of hydrogen to one volume of oxygen

   b) Synthesis

5. Composition of water by weight
   Reduction of copper oxide by hydrogen

6. The purification of water:

   a) Impurities

   b) Purification

      1) Sedimentary of settling
      2) Chemical treatment
      3) Filtration

   c) Distillation

7. Hydrogen peroxide:

   a) Outline the methods of preparation of this
      compound

   b) Properties of hydrogen peroxide

8. The Law of Multiple proportions
   Use the illustrations: Water and hydrogen peroxide
   Carbon monoxide and carbon dioxide
   Sulphur dioxide and sulphur trioxide

SOLUTIONS (4 periods)

1. Properties: variable composition, homogeneous non-settling
   Solvent, solute, soluble and insoluble

2. Types of solutions

3. Rates of solutions:

   a) Nature of both solvent and solute

   b) Temperature

   c) Area of surface

   d) Agitation

4. Henry's Law: the weight of gas dissolved in a solvent is proportional to the pressure
   Manufacture of soft drinks

5. Terms: miscible, immiscible, emulsion, unsaturated, saturated, supersaturated

6. Solubility is defined as the weight of solute that will dissolve in a given amount of solvent to form a saturated solution at a given temperature

7. Crystallization:

   a) Formation of crystals

   b) Water of hydration or water of crystallization

   c) Efflorescence

   d) Deliquescence

   e) Hygroscopic

ATOMIC THEORY (4 periods)

1. Hypothesis, theory, law

2. Main points of the Atomic Theory

3. Law of Gay Lussac and Avogadro's Hypothesis or Law

4. Atomic Weights

5. Determination of atomic weights

6. The contribution of the discovery of radio activity to the modern concept of atomic structure

7. The concept of the nuclear atom (Rutherford) in terms of the fundamental particles, electrons, protons, neutrons. Significance of the terms mass number and atomic number

8. The arrangement of the electrons in the atom

9. Isotopes

10. Heavy water

ATOMS FORM MOLECULES (4 periods)

1. Valence - an indication of the combining power of the atom of an element

2. Types of chemical bonding. Electrovalence, covalence and coordinate convalence

3. Formation of ions. Electro-positive and electro-negative elements. Electrolytes

4. Use of valence. Writing of chemical formulas

5. Valence of elements and the position of the element in the Periodic Table

NOMENCLATURE IN CHEMISTRY (4 periods)

1. Binary compounds

2. Naming of oxides. Distinguish between dioxides and peroxides

3. Oxygen acids

4. Salts, normal salts, acid salts

5. Elements with more than one valence

CALCULATING CHEMICAL FORMULAS (6 periods)

1. Meaning of a formula. Formula weight. Molecular weights, mole, a molal solution
2. Gram-molecular-volume
3. Percentage composition
4. Calculation of simplest formula
5. Calculation of the molecular formula
6. Calculation of molecular weights experimentally

CHEMICAL EQUATIONS (3 periods)

OXYGEN - REVIEW (5 periods)

HYDROGEN (6 periods)

CHEMICAL CALCULATIONS (6 periods)

CARBON (3 periods)

OXIDES OF CARBON (5 periods)

IONIZATION (5 periods)

ACIDS, BASES AND SALTS (5 periods)

CHEMICAL REACTIONS (3 periods)

NITROGEN (3 periods)

COMPOUNDS OF NITROGEN

(A) Ammonia (3 periods)

(B) Nitric Acid (3 periods)

(C) Oxides of Nitrogen (3 periods)

SUGGESTED LABORATORY EXPERIMENTS - GRADE XI

1. Laboratory procedures:
    - a) The Bunsen burner
    - b) Class manipulations
        - (1) Glass cutting
        - (2) Fire - polishing
        - (3) Bending glass tubing
        - (4) Drawing out glass tubing
    - c) How to make weighings
    - d) How to handle solids
    - e) How to measure liquids
    - f) Filtration
2. Physical and chemical change
3. The Law of Conservation of Mass
4. Mixtures and compounds
5. Preparation and properties of oxygen
6. The Law of Definite Proportions
7. Preparation and properties of hydrogen
8. *Reduction of copper oxides with hydrogen
9. Decomposition of water with sodium and calcium
10. *Electrolysis of water
11. Distillation of water
12. Solutions:
    - a) Suspensions
    - b) Properties of true solutions

c) Solubility of solids, liquids and gases in water

d) Crystallization

*13. Properties of carbon

14. Preparation and properties of carbon dioxide

*15. Preparation and properties of carbon monoxide

16. Acids and bases

17. Preparations of salts:

a) Soluble salts

b) Insoluble salts

18. Preparation and properties of nitrogen:

a) Chemical nitrogen

b) Atmospheric nitrogen

19. Preparation and properties of ammonia

20. Preparation and properties of nitric acid

*21. Preparation and properties of nitrous oxide

22. Preparation and properties of nitric oxide and nitrogen dioxide

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Experiments marked with an asterisk may be done as demonstrations.

CHEMISTRY: GRADE XII

THE GAS LAWS (5 periods)

SULPHUR - Group 6A (3 periods)

COMPOUNDS OF SULPHUR (12 periods)

A. Hydrogen Sulphide (4 periods)

B. Oxides of Sulphur (2 periods)

C. Sulphuric Triocide (2 periods)

D. Sulphuric Acid (4 periods)

HALOGENS - Group 7A (11 periods)

A. Fluorine (2 periods)

B. Chlorine (3 periods)

C. Bromine (2 periods)

D. Iodine (2 periods)

E. Action of concentrated sulphuric acid on sodium and potassium halides (1 period)

F. Preparation of hydrogen bromide and hydrogen iodide (1 period)

THE PERIODIC LAW (5 periods)

NITROGEN FAMILY - Group 5A (6 periods)

A. Phosphorus (3 periods)

B. Arsenic, Antimony, Bismuth (2 periods)

C. Other Non-Metals (1 period)

METALS - Methods of metallurgy (4 periods)

LIGHT METALS (18 periods)

A. Group 1A - The alkali metals (4 periods)

B. Group 2A - Magnesium and calcium (5 periods)

C. Group 2B - Zinc (4 periods)

D. Group 3A - Aluminum (4 periods)

COMMON HEAVY METALS (13 periods)

A. Group 8 - Iron, Cobalt, Nickel and Platinum (5 periods)

B. Group 1B - Copper, Silver and Gold (2 periods)

C. Mercury (2 periods)

D. Group 4A - Tin and Lead (2 periods)

E. Chromium and Manganese (2 periods)

NECLEAR CHEMISTRY (8 periods)

A. General (5 periods)

B. Colloids (3 periods)

ORGANIC CHEMISTRY (29 periods)

A. General (4 periods)

B. Hydrocarbons (4 periods)

C. Alcohols (3 periods)

D. Ethers (1 period)

E. Aldehydes (½ period)

F. Ketons (½ period)

G. Acids (2 periods)

H. Esters (2 periods)

I. Fats and Oils (3 periods)

J. Aromatic Hydrocarbons (1 period)

K. Carbonhydrates (4 periods)

L. Other Important Organic Compounds (2 periods)

M. Rubber and Plastics (2 periods)

CHEMISTRY AND AGRICULTURE (3 periods)

SUGGESTED LABORATORY EXPERIMENTS - GRADE XII

1. Preparation of the different forms of sulphur

   Properties of sulphur

   Test for sulphur

2. Preparation and properties of hydrogen sulphide

   Preparation of hydrosulphuric acid

   Test for the sulphide ion

3. Preparation and properties of sulphur dioxide

   Preparation of sulphurous acid

4. Preparation and properties of sulphuric acid

   Test for the sulphate ion

5. Preparation and properties of chlorine

6. Preparation and properties of hydrogen chloride

   Preparation of hydrochloric acid

   Test for the chloride ion

7. Preparation and properties of bromine of iodine

   Test for the bromine ion or iodide ion

8. Properties and compounds of phosphorus, antimony and bismuth

9. Preparation and properties of typical hydrocarbons

   Methane

   Acetylene

10. Preparation and properties of certain alcohols

    Methyl alcohol

    Ethyl alcohol

11. Preparation and properties of acetic acid

12. Preparation of esters

13. Preparation of soap

14. Tests for carbohydrates

15. Tests for proteins

16. Preparation and properties of colloids

17. Reactions involving certain alkali metals

    Sodium compounds

    Potassium compounds

18. Important compounds of calcium

    "Temporary" hardness in water

    "Permanent" hardness in water

19. Flame tests for metals, such as sodium, barium, strontium, potassium and cobalt

20. Aluminum and its compounds

    Amalgam

    Thermite reaction

    Aluminum hydroxide

21. Oxidation and reduction of iron salts

    Tests for ferrous ion

    Tests for ferric ion

22. Reactions of copper compounds

    Electroplating

23. Silver salts used in photography

24. Qualitative Tests for lead, silver and mercury

25. Properties of chromates and dichromates (optional)[3]

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[3]See <u>Chemistry (Grade 11 and 12) - A Teaching Guide</u> (Halifax: Nova Scotia Dept. of Education Bulletin, No. 3, 1960-61).

The above chemistry course outline, approved in 1960, represents the basic chemistry program introduced into Nova Scotia high schools in 1935 and as brought up to date in 1960. The 1935 course was strengthened at that time with regard to laboratory work, class time and clarification of Dalton's atomic theory over the pre-1935 course; and the sections on ionization and standard solutions were expanded.[4] While there can be no question but that the 1935 chemistry course was superior to its pre-1935 predecessor, and that its 1960 edition contains needed revisions, the fact remains that the basic structure of the Nova Scotia course in high school chemistry is nearly thirty years old, and that its 1960 outline is inadequate. The 1960 course outline continues to present chemistry as a collection of rather loosely related topics, and it is largely left to the teacher to organize these topics into a more structured and meaningful whole. And the task of making a transition between the multiplicity of topics and giving thematic unity to the whole course, as well as correlating class work and lab experiments, is a very difficult one. A curriculum outline itself organized

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[4]For information on the pre-1935 Nova Scotia Chemistry Course, see Province of Nova Scotia, Journal of Education (Halifax, 1934). This source recommends the use of Evan's Elementary Chemistry (revised edition), for the Grade XI and Grade XII Chemistry courses. This, then, was the chemistry text used in the province before the Bigelow and Morehouse text, Dominion High School Chemistry, was adopted in 1935.

around a central theme, thus imitating in a way the chemical structure of matter and energy, would surely provide teachers with a more meaningful method of approach. This leads us to a discussion in the next two chapters of several approaches to the teaching of chemistry which illustrate this thematic method.

CHAPTER II

GENERAL TRENDS IN TEACHING HIGH SCHOOL CHEMISTRY IN THE UNITED STATES

Many changes in the nature of teaching chemistry in high school are already widely accepted in the United States. A general outline of several such trends relating to changes in theory and methodology is given here, along with a summary of examples of the most significant trends.

A. Changes in Theory

The following items represent elements of theoretical novelty widely incorporated into new approaches to the teaching of high school chemistry in the United States developed in recent years:

1. The objective of chemistry can now be stated as a method of interpreting the physical universe.

2. Chemistry should be presented as an evolving, dynamic method of exploring the universe having many new problems yet to be solved.

3. In the area of structure:

   (a) The importance of the octet (or rule of eight) should be minimized and emphasis should be given to orbitals or pairs of electrons (rule of two). If the atomic orbital theory is used, it should be taught as a method of explaining chemical bonding but not as the only method.

(b) The concept of polar covalent bonds and hydrogen bonding should be taught.

(c) The concept of subshells and use of the concept of unfilled subshells should be introduced to explain the properties of the transition elements.

(d) Data on ionization potentials should be used to teach the relative electron attracting power (or electronegativity) of atoms and hence predict whether they will form ionic or covalent bonds.

(e) The structure of compounds and their properties should be taught.

4. In the realm of definitions or new terms:

(a) The term "oxidation number" is now used as a means of bookkeeping for oxidation-reduction changes.

(b) The term "mole" has general usage as an abbreviation for a gram molecular weight, a gram formula weight, or an Avogadro number of particles.

(c) The "anode" is now defined as the electrode at which oxidation occurs.

5. The concept of activation energy and distributor of energy of molecules should be used to explain chemical processes.

6. An introduction to graphic relationships is suggested as a means of developing visualization and stimulating imagination.

7. The concepts of chemical equilibrium and the driving force of chemical reactions should be introduced.

8. The concept of "simplification by classification" for the elements in the periodic table grouped in eighteen families and for the organic compounds grouped in the nine common families should be taught; this is an extrapolation of the concept that "elements whose atoms have similar electron configuration, have similar properties."

9. An introduction to areas of future research should be given.

10. A discussion of topics not included in the text is suggested where local industries can supply lecturers or materials.

11. Historical items should be included as they are of value in illustrating the method of science, or the evolving character of science, or may serve as interest stimulators.

B. Changes in Methods of Teaching

Some suggestions for more effective teaching included in new American approaches to Chemistry are:

1. Use the required text as a reference text, and use several graded texts to supplement this material.

2. Develop better demonstration problems and laboratory problems with emphasis on the "problem" feature and interpolation of experimental data.

3. Develop a better type of quiz and examination question by greater planning and evaluation.

SOME OUTSTANDING TRENDS IN TEACHING HIGH SCHOOL CHEMISTRY IN THE UNITED STATES

Along with the above mentioned trends towards general changes in the theory and method of teaching chemistry, several specific courses have been developed and put into use in some of the more educationally advanced States in the U.S. A number of these courses is discussed in this section.

New chemistry courses for those high school students of greater than average interest and ability far outnumber other new chemistry courses. For purposes of description, these have been divided into seven headings:

A. The Advanced Placement Program

B. Other First Year Courses

C. Other Second Year Chemistry Courses

D. American Chemical Society Film Series Course

E. Semi-Micro Laboratory Programs

F. The Chemical Bond Approach Project (CBA)

G. Chemical Education Material Study (CHEM)[1]

Several trends appear generally in all these types of new advanced chemistry courses. First, a greater amount

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[1]National Science Teachers Association, New Developments in High School Science Teaching (Washington: National Science Teachers Association, 1960).

of time is spent either in hours per week or in the number of semesters devoted to the subject. Secondly, there is a pruning away of descriptive materials. Thirdly, there is increased dependence on higher mathematics. Fourthly, quantitative measurement is stressed and "open ended" experiments are preferred in the laboratory program.[2]

A. Advanced Placement Program Courses.

The Advanced Placement idea, according to its advocates, is based on the assumption that some twelfth grade students can do college work, and that achievement no matter where or when it occurs should be recognized and rewarded. The proper execution of this plan for able and ambitious students tends to eliminate waste of time and duplication of effort. It encourages schools and colleges to work together and stimulates students and teachers to higher achievement.[3]

Students are selected for these and other types of chemistry courses for the above average student on many bases, with I.Q. and aptitude test scores, scholastic record, and teacher recommendation being the most frequent. A common administrative feature is the provision of longer laboratory periods than usual in the high school science

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[2]Ibid., p. 65.

[3]Advanced Placement Program Committee, Advanced Placement Program Syllabus (New York: Advanced Placement Program, College Entrance Examination Board, 1963).

program. Quantitative and partially structured or "open ended" experiments are also characteristic of many of these courses.[4] College textbooks and laboratory manuals, rather than high school ones, are normally used. Most students in advanced placement courses take the Advanced Standing Program chemistry examinations, while other examinations taken include the College Entrance Examination Board and Merit Scholarship examinations in chemistry.

In general, the chemistry course recommended by the Sub-committee on Chemistry of the School and College Study of Admission with Advanced Standing differs from the traditional chemistry course in that it stresses theory rather than descriptive material and the quantitative as well as the qualitative aspects of chemistry, that it includes much modern chemistry, such as nucleonics, and that it has considerably more mathematical rigor.

Without exception, the advanced placement program chemistry courses described in the present study are taught in the twelfth grade. About half of those described are first year high school chemistry courses and the other half second year.

At Oak Park and River Forest High School, Oak Park, Illinois, three years of high school mathematics and one of

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[4]Manufacturing Chemists Association, Scientific Experiments in Chemistry (Washington: Manufacturing Chemists Association, 1958), p. 16.

high school physics are required for advanced chemistry. When the latter has become a second year course, these requirements will be raised to include a year each of high school biology, chemistry and physics. More than four hours a week are devoted to laboratory work and two and a half hours to discussion and lecture. An average of four hours of preparation per week is required of the student. A college textbook and laboratory manual are used and the topics listed in the Advanced Placement Program Report are covered.[5]

Prerequisites for College Chemistry, the advanced placement course at Forest Hills, New York, High School, are a year each of biology and physics. Students in this course spend three uninterrupted hours a week on college level laboratory experiments. The instructor reports that the class is restricted to fifteen, and meets four to five times a week for a lecture-recitation period and once a week for a laboratory period three hours or more in length. A college chemistry textbook of average difficulty is used.

Selection of the instructor is one of the critical determinants of success or failure for any Advanced Placement course. He obviously must be well trained in the field. The number of graduate degrees is in itself no complete indication of his ability to teach this course, and the

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[5]National Science Teachers Assoc., op.cit., p. 65.

instructor must be willing to put in additional time, much beyond what will be allotted to him. Further, it is a common opinion there must be at least ten teaching periods assigned to the course.

His own experience with the advanced placement chemistry course is the basis for several recommendations made by the Forest Hill High School Chemistry instructor:

1. The college level course should be preceded by a high school chemistry course.

2. Early planning in the student's career will allow his program to be so adjusted that he can successfully pursue this course.

3. The normal year's course in high school chemistry can be compressed to a one semester course to be followed by two semesters of college chemistry.

4. Students who have completed a year of high school physics will experience less difficulty in the course than those who have not.

There must be a minimum of five periods each week for recitation, discussion (lecture), and a complete afternoon set aside for laboratory work.[6]

At Hamden, Connecticut, High School, two years of algebra and one of plane geometry are a prerequisite for the advanced placement chemistry course. The class is scheduled for the last two periods of the school day. A

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[6]National Science Teachers Assoc., op.cit., p. 66.

three hour laboratory period typical of college science programs can be provided by extending the period after school.

The instructor for this course recommends classes of less than fifteen, careful selection of students, and special scheduling of classes for longer laboratory periods. The "open ended" experiments of the Manufacturing Chemists Association are used.[7]

At the Atlantic City, New Jersey, High School, the prerequisite requirements are not rigid, but "a student would hardly be considered without having at least three years of mathematics and two years of science (preferably one of them in physics)". The instructor adds:

> "A good library of reference books in all fields of the sciences is necessary for these students. They should have available a place where they may extend work on the usual laboratory requirements and may work undisturbed on projects of their choice. Careful selection of students in these classes is vital, with strong personal drive for science being weighed as strongly as ability and past performance. The teacher must be adequately prepared and given sufficient time to handle these classes. Such classes are found to require about twice the amount of time as regular sections of chemistry. In addition, considerably more home preparation is needed. Laboratory assistant help is very desirable, although many times members of the class can serve."[8]

A full one hour lecture is scheduled for each day plus a four hour laboratory once a week. Further time for

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[7]Manufacturing Chemists Assoc., op.cit., p. 16.

[8]National Science Teachers Assoc., op.cit., p. 66.

the course will be provided in 1963 by the extension of one of the lecture periods into an eighty minute period to be used for working on research projects.

Second year advanced placement chemistry courses are also common. Chemistry III at Thomas Carr Howe High School, Indianapolis, Indiana, covers topics of chemistry usually given insufficient time in high school chemistry - the Cannizarro reaction and the laws of Du Long, Pettit, Van der Waal and Le Chantelier. Nearly all the experiments followed in this program, are quantitative in nature. When the number of students selecting the course does not warrant a class, those enrolling are taken into a regular class and given individual help after school.[9]

Prerequisites for Advanced Chemistry at Thomas Jefferson High School, Richmond, Virginia, include one year each of high school chemistry and physics and three years of high school mathematics. Some of the experiments in this programme were taken from a well known college laboratory manual; the rest were prepared specifically for the course by the instructor and a research chemist. A large number of both stress the quantitative aspects of chemistry. In order to have two long laboratory periods for the programme, the chemistry class begins at 8 o'clock rather than 9, two days a week. The research chemist who assisted in designing experiments for the course also

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[9]Ibid., p. 67.

presents some of the lectures.[10]

Regents Chemistry, Physics, and Trigonometry are prerequisites for College Chemistry at Midwood High School, Brooklyn, New York. Students are selected for this course on the basis of I.Q. (130 or better), aptitude test scores, and a scholastic average of 90 per cent or better in Regents chemistry and mathematics courses. College texts are used and one original quantitative experiment per year is required of those enrolled.[11]

B. Other First Year Courses.

The principle of "block scheduling" at Lincoln High School in Philadelphia, Pennsylvania, makes it possible for students to progress as a group throughout high school. The advanced chemistry course is made up of members of this group. There are no prerequisites beyond general science and biology, both strong academic courses. The approach in this course is quantitative rather than descriptive, and contains much material on the wave mechanic structure of the atom and chemical bonding. A college text is used.[12]

The second course in the Student Developmental Program in the St. Paul, Minnesota, schools, designated Science 10-D, covers the following broad topics: theoretical chemistry, inorganic chemistry, organic chemistry, and the

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[10] Ibid.

[11] Ibid., p. 68.

[12] Ibid.

chemistry of nuclear energy. The unit on theoretical chemistry is twelve weeks in duration and covers acids, bases, salts, solutions, electro-chemistry, types of reactions, and weight and volume problems. The unit on inorganic chemistry, also twelve weeks in length, covers representative metals and non-metals. The organic chemistry unit, of six weeks' duration, takes up the hydrocarbons, esters, cyclic compounds, carbohydrates, foods, medicines, textiles, dyes and plastics. A final unit devotes two weeks to nuclear energy.[13]

Chemistry AX at the Pleasant Hill, California, High School, is an advanced mathematics-centered accelerated chemistry course which is to become part of an integrated science program beginning in the junior high school. Units in this course based on college chemistry and mathematics texts include: introduction to chemistry, mathematics review (covering proportions, exponent notation, significant figures, graphs, and the use of the slide rule), use of equipment, measurement (metric and English systems), atomic and molecular relationships, valence and chemical equations, acids and bases, water, the periodic table, qualitative analysis, organic chemistry, nuclear chemistry, and mineralogy. Unusual stress is thus given to physical chemistry, organic chemistry, and mathematics.[14]

Honors Chemistry at Coral Gables, Florida, Senior

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[13] Ibid.

[14] Ibid., pp. 68-69.

High School, another first year chemistry course, is divided into six, six week parts. The first deals with atomic theory, periodic classification, and chemical bonding. Part II treats the mathematics of chemistry, Part III the water solvent system, Part IV periodic families V-VII, Part V the chemistry of carbon compounds, and Part VI chemical families I-III, the transition elements and nuclear chemistry.[15]

C. Other Second Year Chemistry Courses.

Yuba City, California, Union High School offers a course called Advanced Chemistry. Second year algebra and a grade of "A" in beginning chemistry are required. The only grade given in Advanced Chemistry is "A". If a student fails to achieve the level expected, he is asked to drop the course. This evaluation is based on excellence of laboratory work, level of discussion, and the results of comprehensive tests.[16]

In this course, the college textbook used is supplemented by extensive reference reading, particularly with respect to the structure of the atom, bonding, stoichiometry, and crystalline structure. Laboratory explorations have included titrations and stoichiometric calculations, pH determinations, construction of crystal models, and the growth of macrocrystals, as well as selected

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[15] Ibid., p. 69. [16] Ibid., pp. 69-70.

"open ended" experiments. A large selection of equipment is available including a high vacuum system, glass blowing equipment, and a muffle furnace (2000 degree F capacity). The instructor reports that:

> "The typical curious and questioning attitude of these students is revealed in dissatisfaction with available explanations for several basic assumptions including the following: (1) the nature of molecular orbits, (2) the nature of electron spin when the spin occurs at a 90 degree angle to the suggested two directional spin, and (3) explanations given for the two-fold increase in size of the chlorine atom after receiving an electron and assuming the ionic configuration."[17]

Second year chemistry in Tulsa, Oklahoma, schools has been divided into two independent semesters of organic chemistry and advanced inorganic chemistry. There is a prerequisite of one year of chemistry and one year of physics for both. There has been considerable interest from students, parents and local members of the American Chemical Society in both of these courses, and it was suggested that the Tulsa school system will probably offer a college freshman type course for second year chemistry with advanced college placement for students in mind.[18]

The course at Bayside, New York City, High School has one year of college preparatory chemistry with mathematics through intermediate algebra and physics as prerequisites. A thread of historical approach runs through the course. The Phase Rule is used to explain allotropy

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[17] *Ibid.*, p. 70.

[18] *Ibid.*

and fractional distillation.[19]

Stuyvesant High School in New York City offers a year's chemistry elective in qualitative analysis. This is not a new course at Stuyvesant, but it may be of interest to those in other places who are rethinking their science programs. General chemistry is a prerequisite for this course and, since Stuyvesant is one of New York's three academic high schools, the course standards are high. Laboratory work is on an individual basis. After the material has been presented, each student receives his own sample to analyze. He proceeds at his own rate using semi-micro techniques. His grade depends upon accuracy as well as speed. The instructor attempts to inculcate a sense of responsibility and independence in the laboratory and the ability to recognize and pursue clues through research. The course of study consists of a systematic analysis of the metallic ions during the fall semester and of the negative ions, alloys, minerals, and salts during the spring semester.[20]

D. American Chemical Society Film Series Course.

The American Chemical Society's film series has one hundred and sixty titles, among which treatment of the mole concept, ionic and covalent bonding, the Bronsted-Lowry theory, biochemistry, and the packing of spheres

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[19] Ibid.

[20] Ibid., pp. 70-71.

might be considered unusual elements for a high school chemistry course.

In spite of the hardships incurred by its introduction into a high school curriculum before the final films in the series were finished, several school systems decided to use the American Chemical Society's chemistry course. One interesting example of this is the project undertaken by the Extension Division of the University of Nebraska which combined a TV presentation of the films with a correspondence course in order to make a chemistry course available to students in smaller schools within range of the University television station.

The correspondence instructor recommended that students should have completed at least a good course in algebra, a suggestion, however, which was not always followed. All students applying for the course were high school juniors or seniors, but their actual selection was made by the superintendent or principal of their local high schools. Since most of the schools involved did not have a laboratory, the Extension Division supplied laboratory kits at cost for schools requesting them. Certain standard experiments were performed, but for the most part the Manufacturing Chemists Association's "open ended" experiments were used. In all, twelve experiments were scheduled. Classes ranged in size from three to eighteen students. Local schools were expected to provide a viewing room and a faculty member to serve as liaison between students and the correspondence instructor. One hundred and thirty films were presented on a five day per week basis, except for days scheduled for tests, laboratory work, and special TV programs. Class periods in the different schools ranged from forty-five to fifty-five minutes, during which the thirty minute TV presentations were correlated with the correspondence course syllabus. This syllabus included a film guide, sets of self-test questions with keys, text references, work sheets, and laboratory activities developed by the Extension Division. Quizzes and unit tests were prepared and evaluated by the Extension Division, although keys were generally supplied for class review after a test. Consultation sheets were supplied so each pupil could request help on any principle, problem, or equation giving him trouble.[21]

The University of Nebraska Extension Division has conducted this program as an experimental study involving TV groups and control groups taught by conventional methods. Measurement is based on the Cooperative Chemistry Test. Unfortunately, results were not available at the time of preparation of this thesis.[22]

E. Semi-Micro Laboratory Programs.

Semi-micro laboratory techniques are by no means

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[21] *Ibid.*, p. 71.

[22] *Ibid.*, p. 72.

new, even at the high school level. In spite of the apparent advantages (smaller quantities of reagents, smaller storage space, less expensive replacements, greater safety, and greater precision in techniques), however, this method has not had widespread adoption.

Qualitative Analysis, a senior year course at Baltimore Polytechnic Institute, Maryland, uses semi-micro methods in its laboratory program. A year of general chemistry and advanced algebra are prerequisites for the course.[23] Semi-Micro Qualitative Analysis by Evans, Garrett, and Sisler[24] is the basic textbook for this course, and each student also has a copy of a college textbook for reference purposes. Topics covered include the ion-electron method of balancing equations, molarity and normality, determination of equilibrium ionization, and hydrolysis constants.

The unique feature of the class work required for the course is that students solve problems including equation constants, ion constants, and solubility product constants, topics which are not usually taught in high school chemistry.

Rich Township, Park Forest, Illinois, High School also offers a regular chemistry course using the semi-micro

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[23] Manufacturing Chemists Association, op.cit., pp. 16-18.

[24] The publisher, place and date of publication of this text, by Evans, Garrett and Sisler was not available in the National Science Teachers Association publication; New Developments in High School Science Teaching.

approach in the laboratory program. Laboratory assignments are made as problems to be worked out by the student. These problems are discussed in class; methods of solution are suggested by members of the class; and several of these methods are studied carefully. Each student then chooses a method, writes up the procedure, and performs the experiment. Upon completion, he adds the calculations and observations to his report. Students in this program are encouraged to do more than the usual amount of work required for a chemistry course. The chemistry laboratory is open before and after school every day and two evenings a week with a chemistry teacher in charge. In addition, it is customary for local scientists to be present to help and advise interested students.[25]

F. The Chemical Bond Approach Project.

A group of high school and college chemistry teachers discussed the content of high school chemistry courses at a conference held at Reed College, Portland, Oregon, in June 1957. Those attending the conference, sponsored by the Division of Chemical Education of the American Chemical Society and the Crown-Zellerbach Foundation, agreed that chemical bonding was a logical theme for a high school chemistry course.

It was suggested that three bond types be included

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[25]National Science Teachers Association, op.cit., p. 73.

in such a course - ionic, covalent and metallic. Descriptions of these three types of bonds in high school courses are not new, but using them to explain and bring order to such a wide variety of phenomena is unusual. A course of study to achieve this purpose was outlined at this conference.

In the summer of 1958, a second conference, sponsored by Wesleyan University, Middletown, Connecticut, and the Committee on Institutes and Conferences of the Division of Chemical Education of the American Chemical Society, was underwritten by the National Science Foundation. It carried the objectives of the original conference still further.

During the summer of 1959, nine high school teachers and nine college teachers of chemistry worked together at Reed College to prepare the first draft of a textbook and laboratory manual for a course in chemistry with the theme of chemical bonding treated throughout. The course was tried in the classrooms of nine selected high schools during the 1959-1960 school years. Plans are to revise the text and laboratory manual in the light of this trial run before putting them into wider classroom use. Tentative plans for the course are suggestive of the final form the textbook will take.[26]

One teacher participating in the trial run of the course reports:

"The course now has continuity, challenge, and depth.

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[26] Ibid., p. 74.

> The laboratory sequences are so planned that they are an integral part of the course and one is unable to distinguish the customary separation of laboratory and text prevalent in course studies without a theme."[27]

The laboratory guide for student use in the Reed College program is guided by a research type philosophy which enables and causes students to seek answers in a logical manner and apply their observations to extended knowledge of the chemical bond. Techniques are not taught as ends in themselves, but are developed within. Students are given considerable freedom to develop their own procedures, provided they obtain permission to proceed in problem areas. Experiment reports are done during the laboratory period. Students are provided a blank notebook constructed with carbon inserts, and one copy of the report is given to the teacher upon completion of the experiment. All experiments are so designed that students may continue every investigation; thus at no time is an experiment considered final.[28]

G. Chemical Education Material Study.

The CHEM Study, supported by the National Science Foundation, is investigating means of making the high school chemistry course as effective as possible. This particular project was begun in 1959 under the aegis of the National

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[27]Strong and Wilson, op.cit., pp. 56-58.

[28]National Science Teachers Association, op.cit., p. 75.

Science Foundation of the United States. The materials developed so far have a strong laboratory emphasis, and approach chemistry from the standpoint of the important concepts a chemist uses, rather than with an emphasis on the isolated bits of information which can be acquired from studying purely descriptive chemistry. These two bases can serve as a firm foundation for a course suited for the general or terminal student, and also provide a more than adequate background for those going on to further study.

The course treats chemistry from the standpoint of dynamic chemical reactions. Energy, mechanisms of reactions, rates, and equilibrium are emphasized to a degree unusual in a beginning chemistry course. These ideas are then applied to the understanding of such more general concepts as acid-base and oxidation-reduction reactions, and to general descriptive chemistry. The material from the CHEM Study is now in its fourth year of experimental use, and is being studied in at least one hundred and thirty high schools by some 13,000 students. All the teachers who used the material in 1960-61 continued in 1961-62, and as of 1963-64 are still enrolled in the CHEM Study Experiment.

The Study has also designed a series of tests to be given in cooperation with the Educational Testing Service. The evidence from testing so far is that students have no more difficulty with CHEM study materials than with a conventional course, and there is some evidence that their overall knowledge of chemistry is appreciably greater. However, no definite results on this will be available at least until the end of the 1963-64 school term. Further, the Study has so far produced a text, teacher's guide, laboratory manual, and some special equipment for use in lecture experiments. It has also produced seventeen motion pictures designed to cover those aspects of chemistry which cannot adequately be covered by the student in the laboratory or by the teacher in the classroom.[29] This material is available from "Modern Learning Aids", New York, 22, New York. In Canada the films may be purchased from "Modern Learning Aids", 140 Merton Street, Toronto 7, Ontario.[30]

Some of the new courses in chemistry, as well as in other high school science areas, have caused administrative problems. In order to put greater depth into them, it has frequently been necessary to increase the number of hours per week or the number of semesters. A number of the questionnaires for advanced placement courses indicate a change from first year to second year or third semester courses.

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[29]American Association of the Advancement of Science, Report on Broad Improvement in Science Education (Washington: American Association of the Advancement of Science, December 1961), p. 5.

[30]Chemical Education Material Study, CHEM Study Chemistry Films (Circular attached to Newsletter) March, 1962.

The increased emphasis on "open ended" experiments and other forms of original laboratory work presents a need for longer laboratory periods in an already overcrowded school day. Several of the schools reporting have chemistry laboratory periods comparable in length to the traditional college laboratory period. In some schools, the time has been obtained by overlapping out of school hours at either the beginning or end of the regular school day. In addition, the emphasis on original laboratory work and higher standards of student performance makes smaller classes imperative, and places an additional burden on school schedules and finances.

Neither teachers nor administrators today can successfully "go it alone" in working out new science programs. Each must cooperate with the efforts of the other in the common problem of curriculum planning.

CHAPTER III

THE TWO MOST OUTSTANDING APPROACHES TO THE TEACHING OF CHEMISTRY IN THE UNITED STATES

Much has been written in recent years concerning the effective relationship between high school and college chemistry courses. Two of the main comments that recur are: (1) great care should be taken to avoid wasteful repetition between the two courses, and (2) performance in freshman college chemistry appears to be little influenced by whether or not the student has had high school chemistry. This latter statement seems to imply that the standard high school chemistry course is ineffective as a basis for more advanced work. On the other hand, most college chemistry students say they found their original interest in chemistry during their years in high school.[1]

Two of the most prominent approaches to the teaching of chemistry in the United States are: (1) "The Chemical Education Materials Study", and (2) "The Chemical Bond Approach Study". The concern of both these groups is the problem of duplication between chemistry taught in high school and in the first year college course. As a solution

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[1]Strong and Wilson, op.cit., pp. 56-58.

to the problem, they propose that the high school course content be given a central theme. The "Chemical Bond Approach" represents one attempt to provide a central theme. It seems to be a reasonable solution since it is now possible to explain the properties of compounds in terms of the types of bonds present in the compounds. "The Chemical Education Materials Study", taking a different approach to the problem of unifying the content of an introductory course in chemistry, developed a strong emphasis on laboratory work and major chemical concepts, rather than isolated bits of information.[2] The following discussion shall treat these two important studies in more detail than previously outlined.

THE CHEMICAL EDUCATION MATERIALS STUDY

The "Chemical Education Materials Study" (CHEM) is one of two large scale programs being supported by the National Science Foundation to investigate ways of improving the teaching of chemistry in secondary schools. The other is the Chemical Bond Approach (CBA). The reason for the existence of both the CHEM and CBA study groups is that there are many ways to teach high school chemistry. The intent is not to produce a single, "best" chemistry course. The groups wish to try out ideas and make it easy for others to adopt and adapt from them. Chemistry courses should

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[2]Glen T. Seaborg, "New Currents in Chemical Education", Chemical and Engineering News, (October, 1960), pp. 100-102.

continue to differ in details. The main purpose of the present studies is to investigate major concepts and emphasis, to base a high school course upon them, and to determine the feasibility of the resulting material.[3]

The CHEM Study assumes that a student going into high school chemistry believes firmly in the existence of atoms, molecules, nuclei and electrons. If their ideas are hazy, it is all to the good; the best representations of atoms are hazy.[4] The CHEM committee recommended exploration of a project to identify the irreducible minimum of basic fundamentals that could and should be taught in the high school course and on which the college course would then be built. It was proposed that the syllabus for the high school course should be built around these fundamentals. It was also proposed that this study should include the other ancillary features of the course, namely, laboratory problems, demonstration problems, additional reading materials, visual aids and teachers' guides.

The outline for the first CHEM course of study has been obtained from one of the exponents of the CHEM group, Dr. J. Arthur Campbell, through the kind assistance of Mr. Willis Hall, Department of Education, Halifax, Nova Scotia. The outline is as follows:

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[3]Campbell, op.cit., pp. 2-5.

[4]Ibid., p. 2.

Table of Contents of Text for First Course

25. The Transition Elements.

26. Biochemistry - the chemistry of Living Matter.[5]

Table of Contents for Laboratory Experiments

Introduction: Observation and Description.

1. Melting Points.
2. Chemical Reactions of a Burning Candle.
3. Heat Effects.
4. The Reaction of Solid Copper with a Solution of Silver Nitrate.
5. The Empirical Formula of Silver Chloride.
6. Construction of Some Molecular Models.
7. Mass Relations in a Chemical Reaction.
8. Determination of the Formula of a Hydrate.
9. Comparing the Weights of Gases.
10. A comparison of the Boiling Points of a Pure Liquid and a Solution.
11. Some Aspects of Solubility.
12. Quantitative Determination of Solubility and Construction of a Solubility Curve.
13. Reaction between Ions in Solution.
14. The Density of Hydrogen.
15. A Study of Reactions.
16. Heats of Reaction.
17. Study of Reaction Rates.
18. Chemical Equilibrium.

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[5]Chemical Education Material Study, "CHEM Study Materials Revised at Conference", Chemical Education Material Study Newsletter, Vol. I (August, 1961), pp. 1-2.

19. A Study of Indicators.

20. Cells (to accompany a demonstration).

21. Quantitative Titration.

22. Ionic Reactions.

23. The Relation between Moles of Electrons and Moles of Copper Involved during Electrolysis.

24. Investigation of some of the Properties of a Pair of Cis - Trams Isomers.

25. Development of a Scheme of Qualitative Analysis using Reagents Labelled A, B and C.

26. Development of a Scheme for the Analysis of an Unknown containing various Anions of Sulfur.

27. The Packing of Atoms or Ions in Crystals.

28. Some Reactions of Hydrocarbons and Alcohols.

29. The Preparation of some Derivatives of Organic Acids.

30. The Electrolysis of Aqueous Potassium Iodide.

31. Some Chemistry of Iodine.

32. Some Chemistry of the Elements of Row Three.

33. The Separation of some Transition Metal Ions with an Ion-Exchange Resin.

34. Some Investigations into the Corrosion of Iron.

35. Preparation of a Complex Salt and a Double Salt.

36. Preparation of Potassium Dichromate.

37. Preparation of Chrome Alum.[6]

The CHEM Study chemistry course is based on an experimental approach, and to emphasize this the title of the textbook for the course is Chemistry, An Experimental

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[6] Ibid., p. 2.

Science.[7] The course begins in the laboratory; on the first day, the student is asked to light a candle and observe it.

Originally, some of those concerned with developing the CHEM course were worried lest the candle be treated by students as a trivial thing but, for most, it now appears to be a productive source of observation. The student is asked to write in five to ten minutes what he observes in the candle. He is then asked to revise his work that evening and then bring back to school the revised summary of what he has observed about a burning candle. He then receives his text for the first time. In it he finds a three page appendix called "Description of a Burning Candle" written by a professional chemist. The appendix points out fifty-three different observations. Most students list six to twelve. After the description of what a professional chemist sees when he looks at a candle, the appendix states:

> "(a) The description is qualitative and comprehensive. Did you mention appearance, odor, taste, feel and sound? (Note: A chemist is reluctant to taste or smell an unknown chemical. A chemical should be considered poisonous unless it is known not to be.)
>
> (b) Whenever possible, the description is stated quantitatively. The "quantity" is made more meaningful by the expression of how much, "bright but not blinding".

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[7]The Chemical Education Materials Study, Chemistry: An Experimental Science, (San Francisco: W. H. Freeman and Company, July 1963).

(c) The description does not presume the "importance" of an observation. The observation that a burning candle does not emit sound deserves mention just as much as the observation that it does emit light.

(d) The description does not confuse observations with interpretations. It is an observation that the top of a burning enadle is wet with a colorless liquid. It would be an interpretation to state the presumed composition of this liquid."[8]

It seems important to get the student to distinguish between what he can see and what he thinks it means, even at this very early stage. During and after some six days of laboratory work, the class continues to discuss the candle at considerable length, going into the various roles of such things as the wick and the fact that one can in a candle isolate an intermediate in a chemical reaction, the soot. Very little soot comes out the top of the candle, yet you can find a great deal of soot within the flame. In this way and in the second week of the course, are introduced the concepts of mechanisms of reactions, rates of reactions, energy release and activation energies, phase changes and products of reactions. Indeed, the candle introduces in a clear fashion most of the fundamental ideas of chemistry in terms of a system which the student himself can observe and understand. He also finds out that "simple" systems are not necessarily simple, but that they can be comprehended in simple terms.[9]

The laboratory and the textual materials for the

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[8] Ibid., pp. 2-3. [9] Ibid., p. 3.

course stress the importance of the forces acting between atoms and molecules and of the geometric factors affecting their properties. At this point, the course relies heavily on the use of molecular models, primarily space filling models which, in many cases, the student will build. Discussed in some detail is the use of models in science, and their limitations. The student realizes, for example, that atoms are not really made of styrofoam, but it is not necessarily clear that they may not all be of the same hardness or that they are not really red, and white, and orange, and blue.[10]

It is also important to educate students concerning the very large numbers involved in any chemical system, the very large numbers of atoms and molecules, and their minute sizes. The conservation laws become much more vivid and useful when tied to this concept. Here the CHEM Study Group reverses the usual order, and emphasizes that chemists normally think, not in terms of the conservation of mass-energy, but in terms of the conservation of atoms and of electrical charge. These two laws are more directly applicable than the conservation of mass-energy theory the student will meet. Students taught with emphasis placed upon atoms and electrical charge seem to balance chemical equations quickly and intelligently and to approach equilibrium, rate and mechanism ideas more readily.

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[10] Ibid.

The concept of energy and its role in chemical reactions also comes in for extensive treatment. A modified Borh-Haber treatment is used to interpret many reactions, but still to be explored is the extent to which entropy and free energy should be treated. The CBA is vigorously working on entropy and free energy, but there is little material on either subject in the first edition or the revised editions of their texts. The CHEM Group introduces the idea of randomness and the tendency of systems to become random. Whether the CHEM Study committee will explore free energies and entropies in a more thorough fashion still remains to be seen.[11]

It seems unfortunate that most introductory courses treat chemical reactions in terms only of reagents and the products, while completely neglecting the occurrences represented by the arrows or equal signs. Yet the intermediate stages constitute some of the most interesting sections of chemistry. In the future, development through some mechanism, such as that of the hydrogen-oxygen reaction, could point out that hydrogen and oxygen do not react directly to give water. Water eventually forms, but there is little evidence that molecular hydrogen and molecular oxygen give water directly.

The concept of dynamic equilibria is also treated and serves as an excellent basis for discussing the

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[11]Seaborg, op.cit., pp. 100-102.

competitive factors acting in chemical systems in general. There is always competition between several possible states, with the net change depending on the combination of competitive factors acting. Acid-base and redox systems are dealt with on this basis and eventually a discussion of the energy-entropy competition is offered in some detail.[12]

> So far the quantitative treatment of data has not been mentioned. Quantitative treatment is not emphasized so strongly that students with only a year of algebra will fail to handle it. The principal emphasis is placed on using realistic experimental data (e.g., weight data rather than per cent compositions) in carrying out fundamental calculations involving weights, volumes, concentrations, temperatures and pressures. Equilibrium constants and E^{o}'s are developed and used in a qualitative fashion, but their quantitative applications are treated in "fine print".[13]

In summary, it is hoped that a student when he leaves the course will think of any chemical system with which he comes in contact in terms of the structure of the system. Structure here means not only electron structure, but the geometrical arrangement of the atoms, the relative sizes and shapes of the atoms, the packing together of atoms and molecules, the forces between them, and how these affect their chemistry. He will also think in terms of dynamics; for not only will he have organized a great deal of factual information but, just as important, he will be able to

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[12]The W. M. Welch Scientific Company, "The Chemical Education Materials Study", <u>Welch Physics & Chemistry Digest</u>, Vol. II (1961), p. 7.

[13]<u>Ibid</u>., pp. 5-6.

interpret his own new observations in terms of these concepts of structure and dynamics.[14]

The first third of the CHEM Study course gives a preview of chemistry. The second third investigates the major generalizations which the CHEM Study committee thinks should be covered at the secondary school level, *viz.*, energy and chemical reactions, rates of chemical reactions, equilibrium and chemical reactions, acids and bases, oxidation-reduction, ionic reactions, stoichiometry, atoms and their structure, periodicity of chemical properties, and electronic structure all of which are introduced and developed from an experimental point of view. The last third of the course explores chemistry in more detail, building on these generalizations. Thus, one has the preview first, then the introduction through experiment of the generalizations, and then the use of the generalizations in interpreting larger chemical schemes.

The last section of the course includes some chemical systems of major, long-term interest to a high school student. For example, there is a discussion of hemoglobin and its mechanism of operation under the general topic of complexes. The relationship between chlorophyll and hemoglobin is also developed, and a path is prepared for investigating chemical similarities between plants and animals, such as the porphyrin ring structure occurring in both.[15]

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[14] *Ibid.*, p. 6.

[15] *Ibid.*

This does not mean the student is supposed to memorize the porphyrin ring. In fact, one emphasis is that the student should not be required to memorize very much. Rather, he should tie facts together with concepts, not memorize valences, chemical symbols, or formulas. He is asked to learn facts by using them, rather than by memorizing them for the imminent quiz.[16]

Going back to a more typical nomenclature, the Committee thinks there are some things which can be improved and some changes which should be tried. Apparently many chemists are encouraged that the high schools and teachers have been asked to participate on all levels of the Study, and have shown great interest and enthusiasm.[17]

In August 1958, twenty-four high school teachers were invited to come to Claremont to become familiar with the materials. The teachers were to perform all the laboratory experiments and thoroughly discuss the text. They were to decide whether or not they would use the materials in their classes. It was made clear that their presence in Claremont involved no commitment to use the material, but that if they did use it, they were to adhere closely to it. All twenty-four decided to use the materials. This statistic was cited because it is known that many of these teachers are skeptical as to how well the materials

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[16]Campbell, <u>op.cit.</u>, p. 4.

[17]Chemical Education Material Study, <u>op.cit.</u>, pp. 1-4.

will succeed. The staff of the CHEM Study Group has its doubts too, but criticisms from all concerned are being actively gathered and each summer criticisms are closely reviewed.[18]

The Study is also investigating films (moving, filmstrip, and still), monographs, teacher's guides and lecture experiments and models, with a view to producing additional material to enhance the course. Suggestions are also being actively solicited for staff consideration. The Committee has produced a tested course published in the fall of 1963 which has undergone a fifth revision.[19]

The overall aim, then, is to generate and collect ideas which will not so much outline a course, but set a tone and suggest directions in which the CHEM course can move so that it honestly presents a contemporary view of chemistry and its continual growth.

In Saskatchewan, Canada, where Educational authorities seem keenly interested in advancing a new science curriculum the CHEM study course has been introduced on an experimental basis for the school term 1963-64. Educators in Saskatchewan have already adopted the PSSC (Physical Science Study Committee). The latter, along with the CHEM study is sponsored by the National Science Foundation of the United

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[18] Ibid., p. 4.

[19] Chemical Education Material Study, op.cit., August, 1961, pp. 1-2.

States.[20]

The Teachers' Magazine, a Quebec publication, briefly mentions the use of the CBA chemistry course in one high school in that province, Monklands High School, Montreal. The course is being taught to one class of selected students during the 1963-64 term.[21]

THE CHEMICAL BOND APPROACH PROJECT

This project originated in 1957, when a group of high school and college chemistry teachers met for a two week conference at Reed College, Portland, Oregon.[22] The group concluded that a science could be taught better if the course content had a central theme. A similar conference was held at Wesleyan University, Delaware, Ohio, in the summer of 1958, and several possible themes and sequences for a first chemistry course were explored. At that time a group of high school and university teachers agreed to try out experimentally a course based on the Chemical Bond as a central theme. In 1959, the National Science Foundation began the support of this program and has continued that support ever since. At a writing conference held in the summer of 1959, nine high school

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[20] A. B. Van Cleave, op.cit., pp. 14-30.

[21] The Provincial Association of Protestant Teachers of Quebec, "CBA Chemistry" (a report by Garnett Stephens), The Teachers' Magazine, Vol. XLIV (November 1963), p. 48.

[22] Strong and Wilson, op.cit., pp. 56-58.

and nine college teachers prepared the first text and laboratory guides for the program. The text and laboratory materials have been revised regularly up to 1962 to reflect the experience of the teachers employing them in the classroom.[23]

The nature of the Chemical Bond Approach (CBA) Chemistry is influenced strongly by the belief that chemistry is inherently fascinating, and that students must recognize this early in their exposure to the subject.

> To reveal this fascination, however, it is not enough to have the student memorize the data of chemistry. Rather he must see that chemistry is a powerful process for uncovering and extending natural phenomena, and that the power resides in the combination of ideas and facts, or the interplay of concepts and experiments.[24]

The CBA text emphasizes the development of those ideas which provide organization for the experimental observations of chemistry. Central to these is an understanding of the electrical nature of matter, and the description of chemical bonds in terms of the limiting models referred to as ionic, covalent, and metallic bonds. The models for these limiting types are presented early in the text and thereafter the properties of substances are related to these models.

Closely linked with the structural model is the idea of energy; energy changes accompanying changes in a

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[23]Alfred B. Garrett, "The New Chemistry", The Science Teacher, Vol. XXVIII (April, 1961).

[24]Seaborg, op.cit., pp. 100-102.

chemical system are considered throughout the text. This naturally involves the development of the kinetic molecular theory, and the roles played by temperature and thermal energy in the changes occurring in chemical systems. The model for atomic and molecular structure is intimately related to the periodic system. Trends in the properties of elements and compounds throughout the periodic system are related directly to the structural model. To aid in this relationship, the text discusses atomic size, nuclear charge, ionization potential, electronegativity and atomic orbital assignments.[25]

This course is organized to aid the student in his study of the interaction of conceptual schemes with observation and experiment. Successful laboratory work in the CBA program means that the student collects data in the laboratory and also applies ideas to these data. The laboratory experiments are presented as problems and, insofar as possible, it is left to the student to decide what information he needs to solve each problem. Ideally, some information from the laboratory and some from the literature are fitted into a logical scheme based on a set of assumptions and often some mental pattern. Logical reasoning leads to a reasonable solution to the problem. In most cases, either the solution to the problem or some of the difficulties encountered will suggest still other

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[25] Strong and Wilson, op.cit., pp. 56-58.

paths to be explored. Where time and facilities permit, the student is encouraged to follow up such "extensions" as may intrigue him.[26]

In such a setting, it is important to note that laboratory experiments do not automatically lead to a predetermined result known only to the teacher. It is the ability of the student to follow and to construct a line of argument that is the hallmark of good work. The importance of quantitative and reproducible work is not minimized, but it is not made a goal in itself. Nor is the learning of manipulations treated as an end in itself. A number of experiments, however, are deliberately designed to acquaint the student with important laboratory techniques, but these are handled only as incidental to the solution of a particular problem.

The actual use of atomic structure and chemical bonds in the CBA course is presented in a sample outline of the CBA chemistry course. This follows the proposed outline for the initial CBA course as envisioned by Dr. L. E. Strong, initial director of the CBA Study, and Dr. Kent Wilson, a co-worker of Tufts University, Medford, Massachusetts. Further, the table of contents for the text book is presented, along with the laboratory experiments.[27]

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[26] Ibid.

[27] Ibid., p. 57

PROPOSED OUTLINE FOR HIGH SCHOOL CHEMISTRY COURSE BASED ON CHEMICAL BONDS AS THE CENTRAL THEME[28]

I. Introduction

Metric system

II. Elements and atoms

Laws of chemical combination

Atomic weights and symbols

Atomic structure

Electrons

Electronic forces: coulombic, exchange

Atomic numbers: protons and neutrons

Periodic table

III. Chemical bonds - discontinuity of chemical change

Bond types: ionic, covalent, metallic

Physical properties of substances

Gases: gas laws, kinetic molecular theory

Liquids

Solids: crystals, e.g., diamond, sugar, sodium chloride

Physical transformations and temperature

Gas to liquid

Liquid to solid

Relation of mass to properties

Relation to transformations to bond types

Classification of matter and physical transformations: mixtures, solutions, compounds, elements

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[28] Ibid.

Purification procedures

Discontinuities between elements and compounds

IV. Chemical change and covalent chemical bonds

Reactive systems go to unreactive systems

Inert gases

Reactivity and structure

Methane, hydrogen, chlorine, hydrogen, chloride

Physical properties

Substitution reactions: formulas, equations, calculations

Chloromethanes

Oxygen, water and carbon dioxide

Combustion

Chemical energy

Chemical geometry

V. Chemical change involving metallic and ionic bonds

Atomic structure of metals

Oxidation and reduction (metals plus non-metals yield ions)

$NaCl$, $MgCl_2$, KCl, MgO

Physical properties

Simple chemistry

Electrolysis to produce Na, Cl_2, Mg

Main chemistry of electrolysis

VI. Periodic table

VII. Hydrogen, chlorine, hydrogen chloride

Relative attraction for electrons, e.g., stabilities of NaH, NaCl and HCl

Polar covalent bonds

Properties of HCl

VIII. Properties of H_2O

Physical properties

Reaction with HCl

Reaction with Na

IX. Acids and bases

Stoichiometry

Titration

X. Nitrogen and NH_3 system

Equilibrium

XI. Polyatomic ions

Oxidation of NH_3 to yield NO -

Sulfuric acid

XII. Bonds between like atoms

Carbon chains

Multiple bonds

Functional groups

SAMPLE OUTLINE OF ATOMIC STRUCTURE, CHEMICAL BONDS AND PROPERTIES[29]

1. Types of Bonds
    a. Ionic
    b. Covalent
    c. Polar Covalent
    d. Hydrogen Bond

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[29]Chemistry, L. E. Strong (Ed.), Vol. I & II; 2nd rev. ed., (Portland, Oregon: The Reed Institute, 1962).

e. Metallic

2. Structure of Atoms

   a. Energy levels and electron clouds

   b. Spinning electrons

   c. Orbitals

3. Why Atoms React

   a. To complete main shells

   b. To fill orbitals

4. Types of Atomic Structures that Produce Ionic Bonds

   a. Nearly filled and almost empty orbits

   b. Atoms with much different electron attraction power

5. Types of Atomic Structures that Produce Covalent Bonds

   a. Atoms with similar electron attracting power

6. Coordinate Covalent Bonds

   a. One atom or group supplies both electrons

   b. Leads to modern theory of acids and bases

   c. Leads to understanding of complex ion formation

7. Polar Covalent Bond

   a. Due to unsymmetrical electrical field

   b. Explains some properties of H_2O, such as high boiling point and freezing point, good solvent for ions, change in density of ice and water, etc.

TABLE OF CONTENTS OF CBA TEXT

1. The Science of Chemical Change.

2. Some Typical Chemical Reactions.

3. Electrons, Protons, and Chemicals.

4. Structures from Electrons and Protons.
5. Disrupture Processes.
6. Properties and Chemical Change.
7. The Orbital Model of the Atom.
8. Energy and Chemical Changes.
9. Metals.
10. Ionic Bonds.
11. Periodic Table.
12. Polar Covalent Bonds.
13. Chemical Equilibrium.
14. Acids and Bases.
15. Water.
16. Chemistry of the OH Group: Alcohols.
17. Covalent Holides and Oxyhalides.
18. Chemistry of the OH Group: Acids.[30]

TABLE OF CONTENTS OF THE CBA LABORATORY MANUAL-EXPERIMENTS.

1. Observation.
2. Introduction to the Nature of Chemical Reactions.
3. Some Quantitative Aspects of Chemical Reactions.
4. The Reaction of Methane with Oxygen.
5. A Comparison of Sodium Chloride with Naphthalene.
6. An Aqueous Solution of Sodium Chloride.
7. A Comparison of Carbon Dioxide with Oxygen.

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[30] Ibid., p. vii.

8. The Geometry of Electron Pairs.
9. Diffusion - Effusion.
10. Heat of Vaporization.
11. Heat of Formation of Solid Ammonium Chloride.
12. Other Experiments now in Process of Development.[31]

A seminar on new developments in high school chemistry sponsored by the Organization for European Economic Cooperation, was held at Greystones, Ireland, in March 1960.[32] This meeting was attended by exponents of both the CHEM Study, in the person of Dr. J. Arthur Campbell, and the CBA project, represented by Dr. L. E. Strong. A joint discussion was held on both the CHEM Study and the CBA approach to chemistry by the delegates in attendance. There was a general agreement about their value in teaching. The only objection voiced against these new approaches was directed at the CHEM course use of models; some European representatives felt that care would have to be exercised as to how the models were applied to various concepts in chemistry.[33]

The delegates at the 1960 Greystones seminar also agreed that in order to teach the CBA chemistry course, one had to possess a good mastery of the subject and that

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[31] Ibid.

[32] Organization for European Economic Cooperation, op.cit.

[33] Ibid., p. 189.

generally the course content assumed a level of knowledge beyond that of the average teachers. It was pointed out that chemistry in the United States was an optional subject and that the general level of the text books of the CBA and CHEM Study text books was too high for most European countries.[34]

Some of the comments on the American projects by European delegates to the seminar were as follows:
The various European countries differ enormously in technological development and extent of science instruction. Further, many countries have national syllabuses and/or national examinations with the result that few teachers and few schools are free to adopt an experimental course such as CBA or CHEM Study. Changing the national syllabus requires decisions at university and government levels. And another point that must be kept in mind is that one of the factors influencing the amount of time available for science is the emphasis European educational systems place on language study.

The impact of CBA on Europe is difficult to determine. The course is being taught in Cork Technical College (Eire), Mill Hill School (London), and at a medical school in London. CBA data, tables and concepts are creeping into high school texts. However, a proper European evaluation

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[34] Ibid., pp. 188-189.

of the course is not available.[35]

In 1961 there was a second meeting at Greystones, Ireland. Again interested educators from Europe met with the CBA sponsors and were introduced (and re-introduced) to new developments in the CBA project. In 1962 the CHEM Study Committee of the United States sponsored two seminars, one at Oslo, Norway and another at London, England. J. A. Campbell, Director of the CHEM Study suggests that foreign interest in the CHEM course may foster translation of the course into several languages, the latter may take place in 1964-65.[36]

The rapid changes in science and technology have forced those setting up school curricula, to consider the question of what should be included in a first course in chemistry. These two national American studies (CBA and CHEM Study), will give impetus to the acceptance of new ideas to be included and new methods to be used. Teachers individually and collectively will also make their contributions. Both projects present a fresh and stimulating introduction to the science of chemistry and, if incorporated, should strengthen secondary education in any school system.

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[35]Chemical Bond Approach Project, "The International Aspects of the Chemical Bond Approach Project", <u>CBA Newsletter</u>, (February, 1962), p. 2.

[36]Chemical Education Material Study, "Memorandum: Persons Abroad Interested in the Chemical Education Material Study", <u>Chemical Education Material Study Newsletter</u>, (October, 1961), pp. 2-3.

CHAPTER IV

A REVISED COURSE OF CHEMISTRY FOR SECONDARY SCHOOL IN NOVA SCOTIA

In order to present the study of chemistry in the light of modern theory and to keep the subject matter abreast of the latest developments in the field of chemistry, constant revision is necessary. This fact alone argues strongly for a revision in the present high school chemistry course in Nova Scotia, since the present course was first introduced in 1935. What follows is a specific suggestion for such a revision and in the first place the following general remarks should be made. In general, there should be a fresher approach to the teaching of chemistry. This will require the deletion of certain antiquated concepts and techniques in the present course of study and the addition of more modern ones. Secondly, class time generally must be extended to provide for the advancement of teaching. Thirdly, the Grade XI course should be provided more class time, while the Grade XII course requires a longer laboratory session.

What follows is a completely revised syllabus for the Grade XI and Grade XII chemistry courses in Nova Scotia. It attempts to overcome some of the obstacles to efficient teaching present in the current chemistry syllabus, and to meet the varying needs of a contemporary standard high school chemistry course. First, an outline is presented of a revised Grade XI course, and this outline includes in Unit I an introduction to the metric system and to scientific notation of numbers. The outline also embodies a thematic approach to chemistry, as exemplified by the contents of Unit II. This kind of approach is actually suggested in the Grade XI syllabus for chemistry issued by the Nova Scotia Department of Education in 1960, but the 1960 document neglects to stress the importance of the Periodic Table in relation to Atomic Structure and thus fails adequately to incorporate its own suggestion. The contents of Section 1 and 2 in Unit II of the revised course below attempt to rectify this oversight.

A Revised Course of Chemistry for Grade XI

Unit I - Introduction

1. An introduction to Chemistry
    a) Chemistry as a physical science
    b) Matter and energy
    c) Measurements in chemistry (metric system)
    d) The scientific notation of numbers
2. The composition of matter
    a) The organization of matter
    b) The Law of Definite Composition
3. Matter and its changes
    a) The nature of matter

b) The Kinetic Theory

c) Changes in matter

Unit II - The Structure of the Atom

1. Atomic Structure

   a) The modern atomic theory

   b) Nuclear charge and the arrangement of electrons

2. The Periodic Law

   a) Periodic Law and its relation to atomic structure

   b) Explanation of periodicity in terms of properties of elements

3. Chemical Bonding; the Writing of Chemical Formula and Equations

   a) Chemical Bonds

   b) Formula Writing

Unit III - Water

1. The preparation and properties of Oxygen

2. The preparation and properties of Hydrogen

3. The Gas Laws

   a) Pressure changes: Boyles Law

   b) Temperature changes: Charles Law

4. Water

   a) The nature of water

   b) Hydrogen Peroxide

   c) The Laws of Multiple Proportions

Unit IV - Chemical Calculations

1. Chemical Composition

   a) Molecular and Formula Weight

   b) Percentage composition

   c) Emperical Formula of a Compound

2. Chemical Equations

   a) Writing and balancing of simple equations (by inspection only)

   b) Energy of Reactions

   c) The activity series of metals

3. Stoichiometry

   Solving mass-mass problems by the proportion method, the arithematic method and the mole method

4. Molecular composition of gases

   a) Density and specific gravity problems

   b) Problems on Gas Law

   c) Chemical problems involving gases:

      (1) Volume - volume

      (2) Mass - volume

Unit V - Carbon and Hydrocarbons

1. Properties and forms of carbon

2. The oxides of carbon

   a) Carbon dioxide: preparation and properties

   b) Carbon monoxide: preparation and properties

3. Hydrocarbons

   a) Structural formula

b) The series of hydrocarbons: alkanes, alkenes, alkynes, alkadienes and aromatic hydrocarbons

Unit VI - The Atmosphere

1. Composition of atmosphere
2. Inert Gases
3. Nitrogen and its compounds

Unit VII - Solutions

1. Solutions and crystallization
   a) Methods of expressing concentrations
      (1) Molarity
      (2) Normality
      (3) Molality
   b) An introduction to crystallography
2. The Theory of Ionization
3. Acids, Bases and Salts
   a) Properties of acids
   b) Properties of bases
   c) Standard solutions (use of indicators)

As a glance at the syllabus just outlined will show, Unit I of the Revised Grade XI Chemistry course follows most standard high school chemistry courses. An introduction to some fundamental terms and concepts is given, but in addition the course does contain a detailed explanation of significant figures and scientific notation. The latter may be correlated with the Grade XI Mathematics course. Atomic

Structure, the Periodic Table and Chemical Bonds are outlined in Unit II. Here the use of Chemical Bond Approach materials is advocated, along with selected teaching aids on the presentation of atomic configuration. The concepts of sublevels and sublevel notation is introduced to the Grade XI student for background to the Revised Grade XII Chemistry course. The remainder of the Units contain theoretical and descriptive material based on the relationship between the structure of substances and the properties they exhibit, thus exemplifying the thematic approach to the presentation of the course.

In order to correlate the Grade XI and Grade XII Revised Course, Unit I of the Revised Grade XII course begins with Remedial Work in Chemical Equations. Further, oxidation - reduction reactions are introduced in the same unit to build up the foundation of Grade XI equation writing. The thematic approach, introduced in the Grade XI course, is extended by the use of the Periodic Table and Atomic Structure in explaining the significance of elements being placed in a family or group. (e.g., Unit II, Revised Grade XII Course)

Organic chemistry is introduced to the student in Unit XI of the Grade XII course. This contains only a background in writing structural formula, the use of a general formula for a family or group and common organic compounds used in the home and in industry.

Nuclear chemistry, a topic found in the present Nova Scotia Grade XII syllabus, is supplemented in the revised course by introductory material dealing with recent developments in this field (see the suggestions for Unit VII, Grade XII Revised Course).

A Revised Course of Chemistry for Grade XII

Unit I - Dynamic Equilibrium

1. Chemical Equilibrium

2. Oxidation - Reduction Reactions

Unit II. The Active Metals

1. The Sodium Family

2. The Calcium Family

Unit III. The Halogen Family

Unit IV. Sulphur

1. Sulphur and Sulphides

2. The Oxides and Acids of Sulphur

Unit V. The Nitrogen Family

1. Review of nitrogen and its compounds

2. Phosphorus, Arsenic, Antimony and Bismuth; preparation and properties

Unit VI. The Light Metals

1. Beryllium, magnesium, aluminum, titanium; preparation and properties

Unit VII. The Heavy Metals

1. The Iron Family

2. The Copper Family

3. Zinc, cadmium, mercury, tin and lead

Unit VIII. Nuclear Reactions

1. Natural radioactivity
2. Artificial radioactivity

Unit IX. Baron and Silicon

1. Baron and silicon
2. Manufacture of glass

Unit X. Colloids

1. Colloidal suspensions
2. Suspensoids and emulsoids

Unit XI. Common Organic Compounds

1. Review of hydrocarbon series
2. Fuels and petroleum
3. Hydrocarbon substitution; products
4. Textiles and paper
5. Rubber and plastics

Unit XII. Supplementary topics

This may include any or all of the following:

1. Visits to local chemical industries
2. Special speakers
3. Films and other teaching aids

The Revised Grade XII Chemistry Course begins as suggested in Unit I, with a description and explanation of the concept of equilibrium. Various types should be included, such as physical, solubility, and ionic equilibria. Oxidation and Reduction are treated in terms of electron transfer. Any discussion of acidic reactions throughout the Revised Grade XII and XI Chemistry courses is defined in the modern sense using the hydronium ion as well as the hydrogen ion.

Revised Laboratory Experiments
for Grade XI Chemistry

1. Introductory procedures in the laboratory:
    a) Transfer of solids and liquids
    b) Measurement of solids and liquids
    c) Manipulation of a bunsen burner
    d) Filtration
    e) Evaporation
    f) Glass working (1) cutting
    (2) fire-polishing
    (3) bending
    g) Collection of gases
2. The measurement of solid, liquid and gaseous materials:
    a) Standard English and metric equivalents
    b) Analytical balance
    c) Numerical notation; significant figures
3. Use of molecular models (this exercise should be closely correlated with class work)
4. Preparation and properties of Oxygen Gas
5. Preparation and properties of Hydrogen Gas
6. Measurement of pressure and temperature
    a) Barometers
    b) Centigrade, Farenheit and Kelvin temperature scales

7. Water

   a) Electrolysis of water (demonstration)

   b) Distillation of water

   c) Chemical purification of water

8. Preparation and properties of carbon

   a) Reducing activity of charcoal

9. Oxides of Carbon

   a) Carbon dioxide

   b) Fire extinguisher (demonstration)

   c) Carbon monoxide (demonstration)

10. Hydrocarbons

   a) Preparation of methane (alkane series)

   b) Preparation of a representative member of the alkene, alkyne, alkadiene and aromatic hydrocarbons (optional)

11. Nitrogen

   a) Preparation and properties of nitric oxide and nitrogen dioxide

   b) Preparation of nitric oxide

   c) Preparation of nitrous ocide (demonstration)

12. Preparation of Ammonia

13. Preparation of nitric acid (demonstration)

14. Measurement and preparation of standard solutions

   a) Molarity

   b) Normality

   c) Molality

15. Conductivity of water solutions

16. a) Properties of Acids

    b) Indicators for acidic reactions

17. a) Properties of bases

    b) Indicators for alkali reactions

18. a) Titration of an acid with a base

    The Standardization of the Base

If an "open-end" approach is desired, some of the above experiments can be substituted for a group of experiments produced by the Manufacturing Chemists Association. This group has prepared about thirty quantitative and partially structured "open-end" experiments. The latter differ from the conventional laboratory exercise in that the answer, or the expected answer, is not known previously. The student may organize the research in such a way that generally the conclusions are his own.[1]

Revised Laboratory Experiments

for Grade XII Chemistry

1. Oxidation - reduction reactions

2. a) Properties of Sodium Metal

   b) Properties of Calcium Metal

   c) Flame Tests for Metals (sodium, barium, strontium, potassium, cobalt)

3. a) Preparation and properties of Chlorine

   b) The test for the Chloride Ion

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[1]Manufacturing Chemists Association, op.cit.

4. a) Preparation and properties of Bromine and Iodine

   b) The test for the Bromide and Iodide Ions

5. Preparation of the different forms of Sulphur

6. a) Preparation and properties of Hydrogen Sulphide

   b) The test for the Sulphide Ion

7. Preparation and Compounds of Phosphorous, Bismuth and Antimony

8. Aluminum and its compounds; amalgam and thermite reactions

9. a) Oxidation and reduction of iron salts

   b) The test for the Ferrous and Ferric ions

10. a) Reactions of copper compounds

    b) Electroplating

11. The Photographic Process

12. a) Tests for the presence of lead, silver and mercury

    b) The sulphides of copper, silver and zinc

13. a) The use of Radioactive Tracers in Chemistry

    b) Radioactive Measurement (scintillometer and probe-type Geiger counter)

14. Preparations and properties of colloids

15. Preparation and properties of alcohols

    a) Methyl alcohol

    b) Ethyl alcohol

16. Preparation and properties of Acetic Acid

17. Preparation of Esters

18. Preparation of Soap

19. a) The test for Carbohydrates

    b) The test for Proteins

20. Supplementary topics, such as Temporary and Permanent Hardness of water, and the use of the "open-end" type of experiment developed in Grade XI should be extended and expanded upon in Grade XII Chemistry to try and produce a proper foundation for college chemistry.

No specific textbook is recommended for use in this revised chemistry course; although several presently available could be used satisfactorily in such a course. It is felt that considerable freedom ought to be left to an instructor to develop those topics which best meet local needs. This would be of value in a terminal course (general) for those who do not plan to attend university. A pre-university course, closely following the Revised Grade XII Chemistry course designed so as to emphasize the use of materials from the Chemical Bond Approach Project or the Chemical Education Materials Study. However, the exponents of both these groups advise educators that special training for the instructor be a prerequisite of such a course.

An introduction to the Chemical Bond Approach Project was presented at the Nova Scotia Summer School at Dalhousie University in July 1962. This Special Emphasis Course in Chemistry, in which the present writer was enrolled, was sponsored by the Department of Education, Province of Nova Scotia. It was suggested by the class, at the termination of the course, that the Chemical Bond Approach type of chemistry course could only be used with an enriched (educationally accelerated) group.[2] An average group would probably find some of the concepts rather difficult and the present writer considers the CBA Course much too difficult for such a group.

A guidance program is in the process of development in Nova Scotia schools, and until it is provided there can be no chance to promote a chemistry course such as the Chemical Bond Approach. However, the use of many techniques of the latter project can be used in any discussion of Atomic Structure (e.g. Unit II, Grade XI Revised Course).

A recent development in Nova Scotia has been the introduction of Educational Television, with programs in Mathematics (Algebra and Geometry) and Science (Physics and Chemistry) begun during the 1962-63 school year. Since there has been no attempt to measure the value of such a development as an aid to teaching, therefore, no significant correlation can be made between Educational Television and the Revised Course in Chemistry, and for that reason the Revised Course makes no reference to television as an educational technique.

It should be said, in conclusion, that the Revised Course in Chemistry outlined here is not to be considered

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[2]A Recommendation by Special Emphasis Course Group to Mr. Willis Hall, Assistant Supervisor of Curriculum and Research, Mathematics and Science, Department of Education, Province of Nova Scotia, July 1962.

a "cure-all" with respect to the many difficulties facing the teacher of secondary school chemistry. But it is one attempt to promote a fresh outlook to the teaching of chemistry with emphasis being placed on the thematic method. Constant surveillance of curriculum materials is necessary to keep abreast of changes in the field of chemistry. Further, the establishment of a chemistry course with a more meaningful approach should not be left to the Department of Education alone, or to a certain group of teachers. The Science Curriculum should be constructively influenced by teachers at all levels and by those working as professionals in the chemical industry. The high school teacher must undertake serious new study of chemistry from a professional point of view. New developments such as the CBA Project and the CHEM Study are excellent examples of the sort of new study of his subject with which the high school chemistry teacher must be aquainted with, and they give impetus to the acceptance of new ideas to be included and new methods to be used in the field. Teachers, individually and collectively, will also make their contributions. Only in such a way could a Revised Chemistry course or any other such development be effective.

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