A STUDY OF COGNITIVE AND AFFECTIVE OUTCOMES
OF A
CHEMISTRY LEARNING GAME

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ABSTRACT

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A Study of Cognitive and Affective Outcomes of a Chemistry Learning Game

The purpose of this study was to determine the effect of playing a chemistry education game on the cognitive and affective processes of English-speaking secondary school students at Wagar High School in Cote St. Luc, Quebec.

Two classes were used in this study. These students had chosen "three-period" chemistry, a course recommended for those students whose past academic record indicated that they had had previous difficulties in math and science subjects.

The game consists of a number of cards and boards. Players will attempt to a) teach chemistry to their fellow players b) to match, buy and sell cards so profitably as to become the wealthiest player at the conclusion of the game. This is done by correctly matching cards to a board and by correctly challenging incorrect matches.

The game is played for and replaces one-third of the classroom time.

The effects measured were changes both in performance on chemistry exams, and in study habits, as well as in the overall desire to attend chemistry classes.

The results of the study show that the experimental group, as compared with the control group, kept up with their studies, attended class regularly and averaged five percent higher scores in the final matriculation examination.

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DEDICATION

To my wife Rhoda and to my children Charisse Joy and Bradley Evan who spent many weekends without the author who was at the library preparing this dissertation.

CHAPTER I

INTRODUCTION

Background of the Study

The inspiration to develop a didactic game in the area of high school chemistry grew from observing sixteen to eighteen year old chemistry students (at Wagar High School in Cote St. Luc., Quebec) who seldom scored above sixty percent in mathematics and science courses. These same students were often reluctant to do work in class; they would choose the option of a "goof-off" period in lieu of chemistry (six such "goof-off" periods, where the student is free to skip a class, are permitted per month). These students of mixed abilities, mixed backgrounds, and mixed--but basically low--motivation and interests are appropriate subjects for testing the notion that the use of academic gaming can help the unsuccessful student to achieve academic goals.

Boocock and Schild (1968) view the use of academic gaming as one means of helping the unsuccessful student. Their categories of unsuccessful students include the under-achiever, the non-motivated, and the culturally deprived. Boocock and Schild point out that although most innovations in teaching have primarily helped the able student pull further ahead of his peers; academic gaming can produce a breakthrough by stimulating the previously withdrawn, unresponsive non-achiever to come alive and to close the gap between himself and his successful peers.

Objectives of the Study

The aim of this thesis is to prepare and evaluate a didactic game that will be an effective teaching device in chemistry at the high school level.

This thesis is composed of three inter-related parts:

1) A rationale for using academic gaming in science teaching.
2) A rationale for, and description of, the didactic game designed to help alleviate a specified pedagogical problem.
3) An investigation of the utility of this game in achieving its objective.

The Evolution of Play and Games

Play becomes a game when formal rules or constraints are added and a system of rewards and payoffs is present. Play, according to Piaget, is an imaginary imitative activity that serves as a primary socializing influence on children. He believes that play and the aquisition of knowledge are closely related through action:

> "Knowledge is not a copy of reality. To know an object is to act upon it . . . to modify it, to transform the object, and to understand the process of this transformation . . . Intelligence is born of action".
> (Piaget, 1967, p. 47).

Learning games have evolved from play and this natural process can be used to motivate students and help them both to acquire and retain information and learn how to learn. In Piaget's terms formalized play, or games, provide a medium whereby the student can become actively involved with the material and thereby reinvent it for himself.

Eric Berne (1964), developed the idea of play as a means to manipulate self and others with the overall objective of escaping the "matter of fact" situations of life. It may well be that for some students who detest school, educational gaming can be an escape that leads to success in their studies.

War Games

The first elaborate games were war games. By the end of the nineteenth century, most countries throughout Europe and America employed war games as a means of training soldiers in the overall strategy of war. The oldest form of war game was chess; the modern war games are elaborate productions which make use of natural settings and realistic situations. The evolution of war games followed a pattern of logical sevelopment. "Rigid" war games, which employed an elaborate code of rules, began to share their importance with games that had an ingredient of realism whereby umpires could bring the subjective element into the games.

Management Games

War games were employed for hundreds of years before games began to serve a useful place in business and industry. Expanding, diversified corporations (characteristic of the second half of the twentieth century) created the need for the industrial trainer.

Often the industrial trainer was a management consultant in the areas of training, re-training and mental hygiene. The first major task of the management trainers was to find a training technique that would incorporate the teaching of management theory with that of practical experience. In 1956 the adaption of war games to business was attempted as an answer to that problem. The American Management Association developed a business game for general management personnel, they named it <u>Top Management Decision Simulation</u>.

This game was structured as a mathematical model of the business world. A number of formulae were developed in order to show the interaction of the decisions made by each player. All inputs were fed into a computer which would function as the scorekeeper.

The basis of the management simulation game was to divide the participants into five teams representing five companies selling identical products. Each phase of the game lasted forty-five minutes and represented the overall functioning of management over a three month period. During subsequent phases the participants had the opportunity to analyse points where errors of judgement, or mismanagement occured. At the conclusion of the game a leader was chosen to promote discussion among the various group participants.

The American Management Association had provided the spark. Computers and the elements of game theory had already begun to saturate industry, catalyzing reactions in favor of a change in management training techniques--the logical result was that the simulation game as a mode of industrial training spread like wildfire.

Other Educational Games

Hemphill et all. (1962) published a paper on the Jefferson Township School District Study on Simulation. This study was an attempt to study the "on the job" behaviour of a sample of two hundred thirty-two elementary school principals. The game provided a sociological and quantitative description of the simulated school. The participants were involved in the activity of a simulated school.

They dealt with major and minor problems--all of them real. At the end of the simulation decisions and reactions were discussed. This simulation proved useful as a method of training administrators in education. The participants provided the experimenter not merely with normative behaviour patterns of decisions but also with a basis for the analysis of syndromes of fears, satisfactions and frustrations that were experienced on the part of the administrators.

Researchers had already discovered that: "A simulation cannot be effective if the participant is detached from the activity and is coolly academic in his outlook". (Tansey and Unwin, 1969, p. 9). The Jefferson Township School District Study had made allowances for this simulation axiom, and met with success.

Simulations can provide not only a simulated type of problem to be solved, but can also specify the circumstances surrounding the problem. Kersh applied simulation learning games to pre-service teacher training. He concluded that four basic elements are necessary in providing a valid simulation:

1. Suitable background information be provided to the learner.

2. The material should be real and believable.

3. Responses of the participant be made while he is under supervision.

4. The feedback routine be part of the simulation.
(Kersh, 1961, p. 110)

Kersh pointed out that simulations which provide these four essential elements should prove invaluable in both the pre-service, and inservice training of teachers.

Kersh's work paved the way for the use of simulation in teacher-training by showing that simulation was indeed effective as a teaching device in this area.

Clark Abt identified four fundamental types of games.

a. Games of Skill in which the outcome of the game depends on those playing the game, e.g. golf, business game

b. Games of Chance in which the outcome is independent of player abilities, e.g. dice or roulette.

c. Reality and Fantasy Games. e.g. singing and acting.

d. Skill and Chance Games with elements of competition.

e. Model Reality e.g. drama and war games. (Abt, 1967, p.141).

Abt summarizes these four classes of games as an activity among two or more independent decision makers seeking to achieve their objectives in some limiting context.

Among the types of games, there are some which Abt calls "serious games", in the sense that these games have an explicit and carefully thought out educational purpose and are not intended to be played primarily for amusement--although amusement is a great advantage to a "serious game". Abt asserts that these "serious games" offer us a rich field for risk-free, active exploration of serious intellectual and social problems.

Educational Implications

The educational implications of each of Abt's four fundamental game types may be described as follows:

Games of Skill: Most skills require a good deal of effort and practice. In order to succeed the student will have to work hard, but at his own individual pace and thus to exercise self control and responsibility. The student is encouraged to become self-reliant in planning and attaining instructional goals.

The disadvantage of games of skill may become pronounced among heterogenic groups, as games of skill can discourage the backward, dramatize natural inequalities and perhaps feed the conceit of the skillful player.

Games of Chance: Games of pure chance are best used with heterogeneous groups. The laws of nature will encourage underachievers and humble the overachievers. The disadvantages of such games are mainly that they encourage passivity, erase personal responsibility, deny meaningful relationships among phenomena and encourage magical thinking. Games of chance can be useful in order to develop a respect for uncertainty, a capacity to deal with failure, and an understanding of probability and risk.

Fantasy Exhilaration: These games can be used to encourage divergent thinking, and to provide recreation or rejuvenation of interest. These must be well supervised so that they are not carried to extremes.

The Model Reality Game: The main advantage of a model reality game is that it can provide for both an understanding of problems and motives and methods of others, while developing co-operative social behaviour. Its main disadvantage lies in the possibility of confusion between the boundaries of the game and the real world. Further it frequently is not necessary to model physical reality but rather the intellectual processes of the participant in the modelled situation (Mitchell, 1973).

An additional advantage of academic gaming, apart from the didactic advantage, is that the game itself can contribute to a person's mental growth. Bruner describes a process by which certain situation ethics are developed through the playing of a game,

> first of all an attitude in which the child learns that the outcomes of various activities are not as extreme as he hoped or feared... In time, the attitude of play is converted into what may best be called a game attitude, in which the child gets a sense of not only that the consequences are limited, but that the limitations come by virture of rules that govern a procedure. . . .
> (Bruner, 1966, p. 134-135).

Research on academic gaming

Academic games are assuming a prominent role in the new technology of education. Gaming in education is quickly becoming a process whereby one can acquire both knowledge and techniques of how to learn. In addition, educational games provide an enjoyable way of practicing what one is required to know. Current educational research shows widespread use of academic games in the classroom. Blumenfeld (1970), Coleman (1970), Harvey (1970), Hubik (1972), Kidder (1971), McCormick (1972), Tansey and Unwin (1954) are but a few of the researchers reporting on academic gaming. Their reports cite games used for educational purposes which create interest, involvement, and motivation, thereby resulting in significantly improved learning in both the affective and cognitive domains. These games tend to focus on the interrelation of concepts and their understanding rather than on minute detail. However, the only conclusion completely accepted is that "they are useful devices for getting and holding student attention" (Avedon and Smith, 1971, p. 32).

Didactic Science Games

A survey of the literature supports the conclusion that reports on academic gaming in science teaching at this time are woefully deficient. Of the many games described by Abt (1968) and in Boocock and Schild (1968) none are clearly examples of games for science subjects. The games for use in biological education at the tertiary level (for undergraduates in an introductory biology course) as reported on by Tribe and Peacock (1973) focused on small group learning and resulted in the development of skills such as formulating appropriate questions for problem solving, formulating hypotheses, designing experiments for testing hypotheses, interpreting the results of experiments for significance and implications, and reporting concisely in writing on experimental results. Such skill development need not be the results of a science game *per se*, but will more likely result from the structural design of the game. For example, in the

Ecological Research Game reported on by Tribe and Peacock, the players were given a real problem and specific objectives for the playing sessions; they were divided into research groups to decide on possible solutions to the problem; they were allocated research time at the first game session with subsequent time allocation based on player reports and papers; they were given general requirements of reports and papers; a Science Research Council (two faculty members) was provided which gave feedback to the players on the progress of the groups, acted as referee and editor for submitted papers, decided on time allocation, and served as a consulting service paid for in research time; finally, they were allowed access to problem related references. The comments of student-players indicated that the skills were developed in "a stimulating and enjoyable way".

The chronological procedure followed in the process of designing the games reported on by Tribe and Peacock is not clear, but it did include an outline of the game form adapted from Boocock and Schild (1968), the development of game objectives, and the planning of instructional units.

Despite the paucity of research on science games, research in other areas of teaching suggests that the didactic game is a useful education tool irrespective of the subject areas that it covers. Kidder (1964) and Abt (1970) show that positive attitudes toward the academic subject are enhanced by an educational game. Although chemistry was not one of the subjects investigated, Abt's conclusion is reassuring:

> Games encourage imaginative freedom to experiment with alternative solutions, while at the same time offering a realistic set of constraints on less practical responses to problems. The students can learn not only by observing the results of games, but also by playing and indeed by designing them (Abt, 1970, p. 28).

Rationale for academic gaming in science teaching

The reasons for using gaming in arts subjects seem fairly clear to current researchers into academic gaming. Science subjects, however, seem not to have as much potential for benefit from academic gaming, at least according to McCormick's assessment:

> In the whole process of transference of knowledge the pupil has been only partially involved. By contrast, in Science subjects the pupil is involved in the solution of the problems put before him. The laboratory is both workshop and place of learning. . . . It is no coincidence that Science subjects are popular with pupils in secondary schools since they are subjects where the learner actually does something. . . .
>
> Simulation is to Arts subjects what experiments are to Science subjects (McCormick, 1972, p. 199).

Although science subjects do normally involve laboratories and workshops, the equipment of such facilities may range from inadequate to luxurious. Clearly, games can usefully supplement instructional methods in the case of inadequate or non-existent laboratory and workshop equipment. But even in the case of luxuriously equipped laboratories, and workshops, games may usefully supplement the non-laboratory learning; e.g. theories on which some scientific experiments are based could be learned during game playing. Actually, it seems easy for a student to be introduced to such theories or just to simple sets of facts; the problem is the forgetting which often follows such instruction. Games can serve as a palatable, even enjoyable, method for review.

Harvey (1966) used a science game that he called "Challenge" to review the concepts involved in an elementary school science course. Harvey used two groups: one was a group of Black Teachers who played the game: a control group used the conventional lecture-discussion format. The role-playing design was used to give students practice in expressing scientific concepts in their own words. The results of an analysis of variance indicated that the experimental gaming group had statistically significant superior post-test results in achievement in science, attitude towards science, confidence in science, and learning the specific concepts that were taught in the game. It was also concluded that low achievers benefitted most from the game. Their achievement post-test scores nearly matched those of the high achievement group. These results strongly support the thesis of Boocock and Schild (1968), that educational games can close the learning gap between the unsuccessful student and his more successful peers. But it remains to be seen whether a secondary school science game will prove beneficial.

In the case of the less successful students of science, the limitations of conventional educational methods may be overwhelming. How can didactic games help? Tribe and Peacock (1973) point out that for both successful and unsuccessful students, academic games can provide:

1) structured situations which encourage scientific discovery and problem solving.

2) motivation and stimulation for students to learn about a subject in which they had previously little or no knowledge.

3) motivation for learning factual information when it is related to a specific problem or task (Tribe and Peacock, 1973, p.21).

In addition, educational gaming can provide the teacher with spare time in which to provide individual and small group instruction, thus facilitating truly individualized instruction.

Pedagogical Problems in the Teaching of High School Chemistry

As indicated by the research literature, there is a definite need for more research into the effects of games in varied instructional settings. Most researchers agree that interaction of random characteristics, specific student populations, and quantity and quality of content, play a significant role in the effectiveness of an academic game.

One area that has not been investigated is that of the learning and problem-solving difficulties of high school chemistry students, especially those who are less successful science students than the majority of their peers.

High school chemistry classes are usually heterogeneous, containing students who may take the subject: out of interest, as a necessary pre-requisite, or as a matriculation course elective that fits into an open slot in their time-table. The teacher must therefore cope with many students who have negative attitudes towards his subject.

The chemistry course of study is cumulative; students of chemistry must know previous material in order to comprehend new work. Generally, however, students do not take it upon themselves to "keep-up" with the previously taught work and this hinders their comprehension of the later parts of the course.

Many studies have reported positive attitude changes in different subject areas as a result of playing academic games related to the respective subject matter. In this study, the student population, known to the author, has (at least some) negative attitudes toward the high school chemistry course. Some students complain they are bored and others claim that they shy away from asking questions for fear of being mocked by fellow students. On the other hand, some teachers complain that many of their students study only for "passing Grades" while other students are reluctant to learn any amount of descriptive chemistry.

One of the goals of this research was, therefore, to examine what effects, if any, a chemistry learning game had in producing any attitude change in students' attitude toward the chemistry course.

Intention of this Investigation

The purpose of the study was threefold:

1. To construct a didactic game to be used in teaching the Quebec High School Chemistry Course 12-15-05.
2. To evaluate that game's success in meeting the objectives it is designed to achieve.

3. To examine what effect, if any, a chemistry learning game has in affecting student attitude toward the chemistry course.

The game presented in this thesis is intended to partially replace the conventional "lecture-discussion" method by replacing it for 100 minutes out of the 300 minutes that the course is scheduled for each week.

CHAPTER II

DESIGN AND PROCEDURES

Academic Content and Game Plan

The Quebec Department of Education implicitly provides the academic goals of the chemistry learning game. The exact goals of the Chemistry 12-15-05 course are listed in appendix G. An evaluation of this chemistry course was prepared by the author in order to determine the goal achievement expected to be demonstrated by the students taking the Chemistry 12-15-05 course (cf. appendix E). Previous matriculation exams were analyzed to determine the goal achievement expected to be demonstrated by the students on such exams. These goals were then written out in behavioral terms as modeled from Mager (1961). Analysis of the objectives, using Bloom's (1956) taxonomy of educational objectives as a framework, indicated that the objectives of past examinations did not extend beyond the first three levels of knowledge, comprehension, and application. These three levels were therefore established as objectives to be achieved by the game. In addition, the fourth cognitive level, analysis, was included. The overall organization of the game was prepared in two parts: the first part for the first three cognitive levels; the second, for the fourth level. The primary goals of the didactic game were to teach self-management problem-solving relevant to chemistry and, in the process, to alleviate widespread motivational and attitudinal inhibitions among these potentially poor chemistry students. A secondary goal was to involve the students in the construction of a chemistry learning game.

The general design of the game operation, in keeping with the nature of the student population, incorporated a small degree of the element of chance in order to encourage the under-achiever. It also included a relatively large mixture of both elements of skill and modeled or simulated reality. This was intended to encourage both achievement (specialized competence) and some understanding not only of problems but also of methods of others in a group context. This general design constraint proved to be a teaching device not only for varying the pace of instruction within the whole chemistry course, but within the game itself so as not to dull the novelty of the device.

Given the student-players, the academic goals, and the general game design, other criteria for construction of game materials and rules were then considered. These criteria include simple score-keeping, minimum refereeing or umpiring, simple strategies for part one of the game, and low cost.

Game Objectives

The intent of the designer of the game was to create a chemistry learning game that would:

(1) include a mechanism whereby the teacher could be informed of the areas of the course that give most students difficulties;

(2) motivate students to review the descriptive chemistry that they are reluctant to memorize or forget rapidly;

(3) give students direct feedback about which areas of the course they are weak in;

(4) provide a milieu wherein students could learn not simply from the game and teacher, but from each other;

(5) allow superior students to advance to a level of study beyond that of the curriculum via a supplementary section of the game;

(6) be inexpensive to construct and duplicate, thus enabling the entire class to play simultaneously;

(7) teach the student by giving him an opportunity to organize material of the course into logical units;

(8) free the teacher from lecture-recitation duties so he can help individuals with problems.

Student Involvement

The justification for involving students in game design, building and teaching (the second objective) grew out of reports (previously cited) by educational researchers such as Kidder and Abt which indicated that positive attitudes are enhanced by an academic game. Recall that: "The students can learn not only by observing the results of games, but also by playing and indeed by designing them" (Abt, 1970, p. 28). Hence, although formal rules were provided with the game, the players began with a simple knowledge of the basic operation of the game and made their own rules. After experience with the self-made constraints and with the constraints set forth in the official rules for part one of the game the more advanced students were introduced to part two. Part two focuses upon assessment and selection of alternative solutions for problems.

Content

Part one of the game reviewed the descriptive parts of the chemistry course, included token rewards for correct responses and presented material in small units. In this way the learning of formulae, for example, became more a joy and less a chore.

Part two of the game served as an added challenge to the superior chemistry students. In this sequel, good players were expected to choose a logical and rigorous set of laws and theories whose application to a given problem yields a viable solution. Several solutions are possible.

Regular Classes

For both parts of the game, the lecture material was compacted so that the coverage was not reduced. Lectures continued on a regular basis for two hundred of a possible three hundred minutes of class time per week; the game was played for one hundred minutes per week.

Number of Players

The game was designed to be played in groups of four or five, but students often preferred to play the game in groups of two (they seemed to feel freer to ask each other for explanations without the fear of holding up a third player). A system of rotation among players was encouraged during the regular playing of the game.

Students often called upon the teacher or referred to their notebooks when expanding on a specific problem that arose from playing the game.

Scoring

Originally, there was only one system of tabulating scores: a player earned token 'money' from the 'bank' according to how many cards he matched within the two minute period of time alotted per play. A player could also earn money by detecting a mistake made by an opposing player and calling a 'challenge' (Appendix A). The person with the largest amount of money at the end of the game was declared the winner.

The advent of a shorter version of the game, in which teams of two and three players competed against each other as to which team could match the most cards within a specified time period, gave rise to a simplified version of scoring. In this abbreviated version of the game, the team received one point for each correctly matched card. The opposing teams verified all answers from an answer sheet at the end of the gaming period.

Monitoring Performance

In order to provide feedback to both teacher and student of the player's competence in a specific area, without subjecting the student to a formal examination, duplicate 'error' or 'challenge report' (cards on which the student reports which areas of the game cost him points) were filled out -- one for the student and one for the teacher. (This card will be illustrated in Chapter Three). These cards permitted the teacher to know which parts of the game were troublesome for various students. The player, by filling out a challenge report card, was given the opportunity to recognize his or her weaknesses. Having been given the opportunity to recognize the areas in which remedial help may be needed, the players could:

1. Ask another player to solve the specific game problem;
2. Review the area of the game that gave him trouble;
3. Seek help from the teacher while other students are playing the game.

Experimental Subjects

The study was conducted to investigate the effect which playing an educational chemical science game has on the cognitive and affective processes of male and female English-speaking Quebec students (these subjects were the ones previously described as 'Three Period' chemistry elective students whose records indicate that they have had difficulty scoring above sixty percent in mathematics and science) who are registered in the Quebec High School Chemistry course 12-15-05. The students are expected to be familiar with the approach and content of the textbook: Boyland, Elements of Chemistry (Canada, McMillan, 1964). A concurrent treatment group using only a 'lecture-discussion' format served as the control

Sample

Two classes of twenty students each were used in this study. The students attended full-time day classes at Wagar High School (in Cote St. Luc, Quebec). These students have chosen 'three period' chemistry as an elective after having been told that 'three-period' chemistry is recommended for those students whose academic record indicates that they have had trouble scoring above sixty percent in mathematics and science. The experimental and control groups were selected and assigned to classes by a computer from a list of students who have chosen 'three period' chemistry. It is assumed that a random selection is made by the computer. The two classes were taught by different instructors who collaborated closely.

The subjects were pre-tested to insure that there was no significant difference in their previous knowledge of the chemistry course. The final examination was set and graded by the province. A post-test examination set by the instructor preceeded the Final exam by approximately one month.

Research Design

Both experimental and control subjects performed the same laboratory experiments. All students were shown the same films, wrote the same examinations and were required to do the identical homework. The vast majority of class time consisted of lectures being given by the teacher, and discussions of the material that is being lectured to the class hereafter referred to as "lecture-discussion time".

Theoretical Hypothesises

TH_1: If students with potentially low aptitude for chemistry play a didactic game, the content of which covers the goal achievement expected of a high school senior chemistry course, and if this didactic game be part of the overall teaching strategy of that course (replacing one-third of regular classes for one-term), then these students' achievements on the Provincial matriculation exam will be as good as, or better, than, that of control students taught with regular classroom teaching.

TH_2: If students play the didactic game then they will demonstrate a more positive attitude toward the chemistry course.

Operational Hypothesises

OH_1: If Secondary school chemistry students with a record of below average maths and science grades play a didactic game every third period during the final four months of the chemistry course (as part of the overall teaching strategy), the arithmetic means of their final matriculation examination scores will be as high as, or higher than the arithmetic mean of control subjects from the same population who do not play that didactic game.

OH_2: If students play the didactic game then: (1) they will opt for fewer "goof-off" periods than the control group; (2) they will do voluntary homework assignments; and (3) they will help other students in solving chemistry problems.

Measuring Instruments

Description of tests to be given

COGNITIVE DOMAIN TESTS:

Pre-test: sixty multiple choice questions on the first nine chapters of the chemistry text "Elements of Chemistry" by Boyland.

Diagnostic Test: 50 multiple choice questions covering nine subsequent chapters of the same text, compiled by science consultant P.S.B.G.M.

Post-test: The matriculation examination 12-15-05 set by the Quebec Department of Education.

The test will be of two hours duration.

Assumptions Concerning Data

In order to test the hypothesis several assumptions are made.

a. Since the students from each group are randomly chosen (by a computer), randomization within this socioeconomic group occured;

b. Errors in measurement will be randomly distributed around the mean scores of each tested group, hence it is possible to consider the mean as a true estimate of gain for each group, and

c. The intervals of the scale will be equal so that gains starting from any initial score are comparable if allowance is made for the errors in measurement.

Factors Affecting Study Results

Some of the more important and uncontrolled factors which can affect the study are: learning rates of students, the class size, and attitudes of students towards teachers. It is not within the scope of this research to deal with all of these factors, but they shall be considered in the discussion of results.

CHAPTER III

THE GAME: "DECISION"

Materials of the Game

For financial reasons, the entire game consists of cardboard and paper. Each area of the game is on a separate sheet of cardboard, the parts of the game are easily replaceable. The student is required to have with him only a pencil or pen in order to complete the "Challenge Report Cards". A small pad of paper is useful in solving game problems.

Materials of the game used in the experiment were prepared on a spirit master, and run off on a spirit duplicating machine. The resulting materials were then attached to a cardboard backing to reduce wear and tear of the game's components.

Desk tops were used as playing surfaces. The game did not require a student to do much talking, thus permitting several small groups to play the game simultaneously within a single classroom.

Instructions

The following information was presented to each student.

Rules

The rules of the game are:

a. to teach chemistry to your fellow students
b. to match, buy and sell cards so

profitably as to become the wealthiest player at the conclusion of the game. This is done by correctly matching cards to a board and, by correctly challenging incorrect matches.

Equipment:

Periodic table, game money, boards, cards, player's stands for cards, answer sheet, timer, challenge report cards.

Preparation:

Each player must roll the dice to see who plays first. Each player is given a specified sum of money and selects the number of boards to be played from the total pile. After mixing the deck (112 cards), eight cards are dealt to each player, and the remainder are placed face down in a pile. One of the players is elected as banker.

To start

Each player in turn is given two minutes to: match a card(s) to the board and earn money from the bank; OR trade a card with the deck and to give his trader to the banker who removes that card from the deck; OR use his two minutes to auction a card for another and perhaps money. The player may trade one card per turn.

Challenge

Players are given one minute after a completed play in which to call a challenge. The banker then verifies the answer from the answer card. The successful challenger earns money from the bank that would normally go to the player having made the initial play.

Incorrect plays and false challenges are to be reported on the challenge report card. (Figure 1).

Insult

An incorrect challenge results in an insult fine to be paid by the challenger to the insulted player. All insults are reported on the challenge report card.

Explanation

A game may be delayed if half of the players call "EXPLANATION" and a player wished to explain the thinking behind a particular play. No penalities or rewards are associated with EXPLANATION, but $2.00 payment is customary.

Bluff

An undetected false answer is acknowledged as a correct play.

Bank

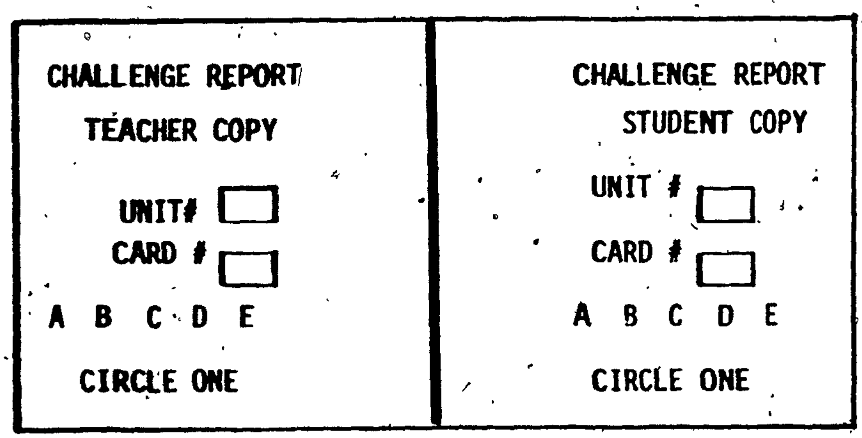
A participant who verifies all CHALLENGES with the answer sheet, pays all token monies for correct board answers, collects time fines and 'played' cards.

End of Game

The point in a game when a player has used up all of his cards, or one round of play after the deck has been used up.

FIGURE 1

CHALLENGE REPORT CARD



Winner

The player with the most money at the end of the game is declared the winner.

Playing Board

Each board represents one unit or classification of material. There are twelve such boards:

Unit #1: classification of matter

Unit #2: Kinetic Molecular Theory

Unit #3: Electronic Configurations

Unit #4: The Periodic Table

Unit #5: Chemical Bonds

Unit #6: Formulae

Unit #7: Equations: Acids, Bases, and Salts

Unit #8: Ionization and Dissociation

Unit #9: Boyles Law

Unit #10: Charles Law

Unit #11: Density, Specific Gravity, G.M.W.

Unit #12: Weight and Volume Problems

Playing the Game

Part One

A player who is about to have his turn has already arranged his eight playing cards in a definite pattern. He has grouped together those cards that he believes are common to a specific board.

As this player's turn comes up, he must study the boards that contain the material pertinent to the cards he is about to play. In order to illustrate specifically a particular player's turn, let us use Figure 2 to illustrate the eight cards of a player who is about to have his turn. This player has placed cards number 44 and 63, one below the other, at the extreme left of the stand that holds his cards. By so doing he asserts his belief that cards 44 and 63 both illustrate a particular property of a family of metals within the periodic table. The information on one card matches the information on the other card bioconditionally. The player hopes to successfully match both cards to a square on a particular board entitled "Unit 4: The Periodic Table" (Fig.3). He decides that "Elements that have equal numbers of valence electrons", unit 4 -b (the 4 refers to the unit number and the b to the position on the unit card) is a statement that explains the information on both cards 44 and 63. The player then uses his playing time to place both cards on top of Unit 4-b. Should he be correct in this play, he would receive four token dollars from the bank. At this point, however, another player calls "challenge". This player has read card 63 incorrectly and used the term 'family' to denote 'period'. As a result, he challenges the play. The 'banker' verifies the answer and announces that both cards, numbers 44 and 63 are indeed to be placed on Unit 4-b. The challenger, in an attempt to earn the four dollars of the original player, now must pay that player an insult fine of five dollars. In addition, he completes a challenge report card. While he fills out the challenge report card, he is hopefully reminded of the difference between a family and a group. The banker now places cards 44 and 63 in the 'played' pile and pays the successful

FIGURE 2

PLAYER'S STAND

44 Elements A, B, C, D, E all have a common oxidation number of +X. It is likely that elements A, B, C, D, E are . . .	88 1. H_2S 2. H_2O	96 calcium hydroxide , Ca	49 Fluid molecules begin to roll over each other
63 Members of any Particular "A" family (group)	51 $V_i T_f = V_f T_i$ $\frac{V_i}{T_i} = \frac{V_f}{T_f}$ f = final i = initial	41 Density (g./l) X 22.4	31  Describe this bond

FIGURE 3

PLAYER'S BOARD

UNIT 4: THE PERIODIC TABLE	
An atom with an electronic configuration of $1s^2$ $2s^2$ $2p^6$ $3s^2$	Elements that have equal numbers of Valence Electrons
a b c d e	A trend from top to bottom in any particular "A" family
A class of elements that are high in electronegativity	The trend from left to right in any particular "A" family

FIGURE 5

SAMPLE SOLUTION CARDS FOR ADVANCED PLAYER

1 Test with blue litmus	2 Test with red litmus	12 Add chlorine water
21 Add a weak base	11 Test with $BaCl_2$ 10%	7 Bubble it through lime water
10 Place it in direct sunlight	8 Add HCl 10% solution	3 Bubble it through potassium permanganate

player from the bank. The successful player now picks up two cards from the deck to replace those which he had played, and places them among the remaining cards. He should now study these new cards until the next player makes his play, at which time he will examine and perhaps challenge the play.

Part Two

The second part of the game has questions, such as those shown in Figure 4, which are matched to particular cards. The object of this game is to select the order of the minimum number of squares of information which are necessary in solving the problem on the 'problem card'. An illustration of the technique can be observed from the study of Figures 4 and 5. One question in Figure 4 is "Determine if a gas is SO_2". The player may decide that card 1 in Figure 5 is sufficient for the test. Another player suggests that a better technique would be to first test the gas with potassium permanganate (card 3). A player would require the agreement of the other players as to the number and order of the tests to be performed in determining if a gas is SO_2. This means that advantages or reasons for selecting a particular card must generally be given. In the particular unit from which this example is taken, there are a total of four basic questions (problems) with twenty-one possible answers (solutions) to choose from. Often, more than one solution is viable. Another section of part two focuses on the use of laws written on game cards such as Boyle's Law, Avogadro's Law, Charles' Law. This section focuses on solving problems presented in the form of questions.

Extensive formal rules do not exist for Part Two; the person whose solution most clearly parallels that of the teacher is usually considered to be the most proficient player.

CHAPTER IV

Results

The results of the analyses performed in this experiment are presented in this chapter under two headings.

Under the first heading, 'pre-measures' the two treatment groups are compared using the following two criteria: chemistry achievement and the desire to opt for "goof-off" periods. T-Tests were computed in order to assess any differences between the groups on these pre-experimental measures.

Under the second heading, 'experimental results', evidence is presented which was used to measure the comparative effectiveness of the experimental and the control treatment (gaming and lecture-discussion). This later section contains three T-Test comparisons.

Pre-Measures

Comparison of Treatment Groups

The two groups used in this study were equal in size (N = 16). These groups were pre-tested in order to determine if there was a significant difference in chemistry achievement between the groups at the start of the experiment. (Recall that they were assigned randomly to the classes and had two prognoses of low grades in science and mathematics courses.)

Pre-test Scores

Table 1 describes the results of a pre-test given to both experimental and control groups in January 1973. The examination (Appendix B) was compiled by a teacher who was not directly involved in the experiment.

TABLE 1

RESULTS OF THE JANUARY 1973 PRE-MEASURE EXAMINATION

Experimental Group			Control Group		
Individual Student Grade (X)	Deviation from the Mean Score $\lvert X-\bar{X}\rvert$	$\lvert X-\bar{X}\rvert^2$	Individual Student Grade (Xi)	Deviation from the Mean Score $\lvert Xi-\bar{X}i\rvert$	$\lvert Xi-\bar{X}i\rvert^2$
62	13	169	75	27	729
60	11	121	65	17	289
58	9	81	65	17	289
57	8	64	65	17	289
56	7	49	62	14	196
55	6	36	60	12	144
54	5	25	55	7	49
52	3	9	50	2	4
51	2	4	50	2	4
50	1	1	45	3	9
43	7	49	41	7	49
40	9	81	35	15	169
35	14	196	29	19	361
27	22	484	22	26	676

Notes: The mean score for the Experimental Group in this table (μ) is 49 percent. The mean score for the Control Group in this experiment (μ) is 48 percent. In addition, $\sigma = 14$, $t = 0.2$ and $p > 0.8$

Let μ and μ_1 denote population mean scores attained by students of each group in the January 1973 examination. On the basis of a two-tailed test (with alpha = 0.05) and using thirty degrees of freedom, H_0 would be rejected if "t" were outside the range -2.04 to 2.04. The above results ("t" = 0.2) show that we cannot reject H_0 and we must conclude that there is no significant difference between μ and μ_1. These pre-test results, in conjunction with the random class selection which was done by computer, support the conclusion that there was no initial difference between the two groups in the area of chemistry achievement.

"Goof-Off" Periods

Table 2 describes the results of compiling the number of "goof-off" periods taken from chemistry classes per student during each class during November and December, 1972, the two months preceeding the start of the experiment.

TABLE 2

RESULTS OF THE NOVEMBER AND DECEMBER COUNT OF "GOOF-OFF" OPTIONS TAKEN

Experimental Group			Control Group		
"Goof-Offs" per Student (X)	Deviation from the Mean Score lX-Xl	lX-Xl^2	"Goof-Offs" per Student (Xi)	Deviation from the Mean Score lXi - Xil	lXi-Xil^2
12	5.6	31.4	12	5.1	26.0
12	5.6	31.4	10	3.1	9.6
12	5.6	31.4	9	2.1	4.4
10	3.6	13.0	9	2.1	4.4
10	3.6	13.0	9	2.1	4.4
7	0.6	0.3	9	2.1	4.4
7	0.6	0.3	8	1.1	1.0
6	0.4	0.3	7	0.1	-
5	1.4	2.0	7	0.1	-
5	1.4	2.0	7	0.1	-
5	1.4	2.0	7	0.1	-
3	3.4	11.6	6	0.9	0.8
3	3.4	11.6	5	1.9	3.6
2	4.4	19.0	5	1.9	3.6
2	4.4	19.0	0	6.9	47.6
1	5.4	29.0	0	6.9	47.6

Notes: The mean score for the Experimental Group in this table (μ) is 6.4 periods. The mean score for the Control Group in this experiment (μ_1) is 6.9 periods. In addition, $\sigma = 1.9$, $t = 0.7$, $P > 0.5$

Let μ and μ_1 denote population mean "goof-off" periods taken by the students of the two groups, as per Table 2. On the basis of a two-tailed test (with alpha = 0.05) and using thirty degrees of freedom, H_0 would be rejected if "t" were outside the range - 2.04 to 2.04. The results of Table 2 ("t" = 0.7) show that we cannot reject H_0 and we must conclude that there is no difference between μ and μ_1.

Conclusion

We conclude that for the major dependent variables of this study--chemistry achievement and "goof-off" periods taken--the two groups did not differ significantly at the beginning of this experiment but were successfully matched.

Post Measures

Academic Performance

Table 3 describes the results obtained by the subjects of the two groups in the June 1973 Matriculation Examination (Appendix D). These are displayed graphically in the histogram of Figure 6.

FIGURE 6

HISTOGRAM OF 1973 MATRICULATION RESULTS

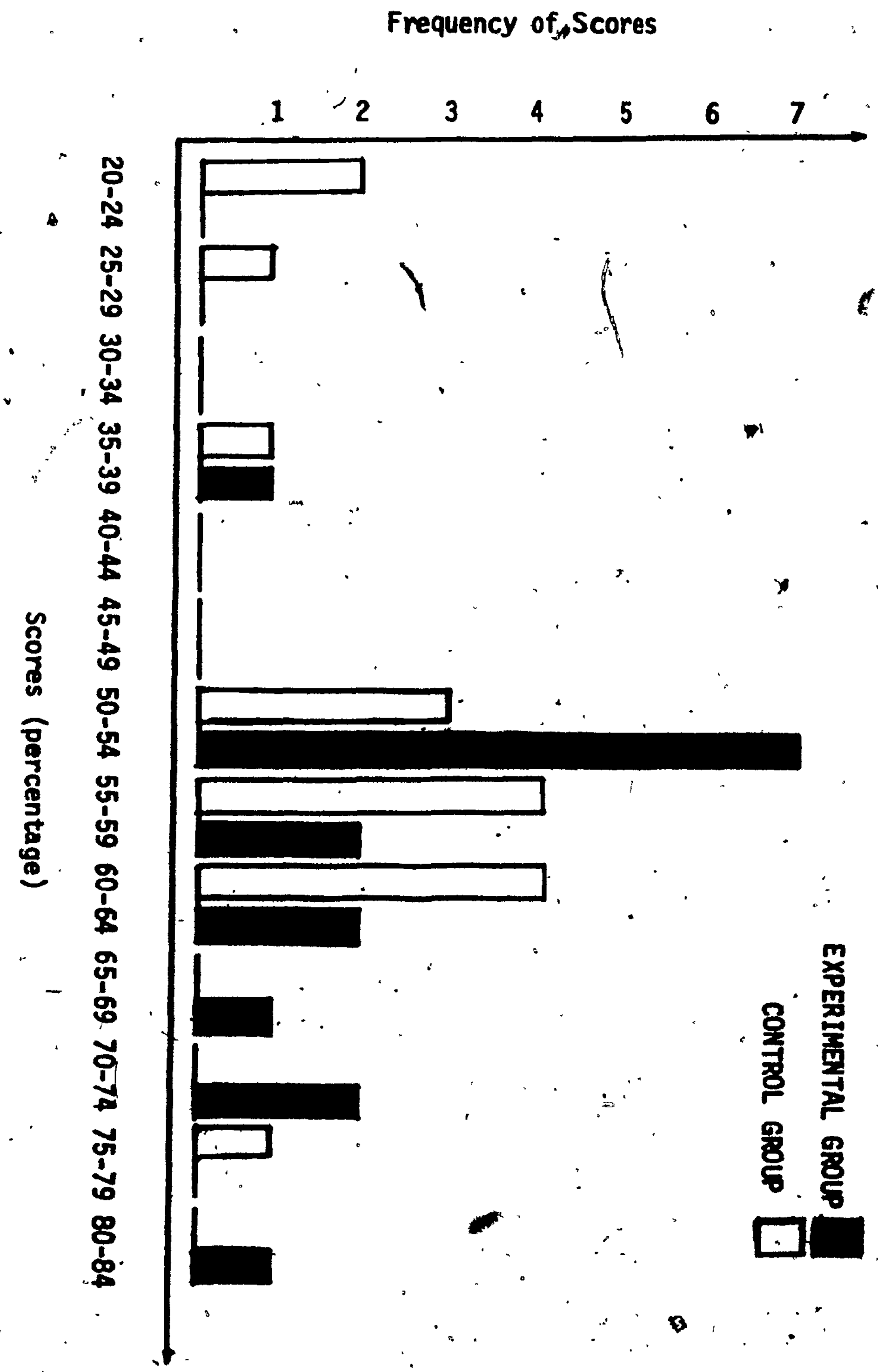


TABLE 3

JUNE 1973 MATRICULATION RESULTS IN CHEMISTRY

Experimental Group			Control Group		
Individual Student Grade (X)	Deviation from the Mean Score $\lvert X - \bar{X} \rvert$	$\lvert X-\bar{X} \rvert^2$	Individual Student Grade (xi)	Deviation from the Mean Score $\lvert Xi - \bar{X}i \rvert$	$\lvert Xi-\bar{X}i \rvert^2$
81	23.7	570	78	26.6	707
71	13.7	188	64	12.4	154
70	12.7	161	63	11.6	135
65	7.7	59	62	10.6	112
60	2.7	7	60	8.6	74
60	2.7	7	58	6.6	44
58	0.7	0.5	58	6.6	44
55	- 2.3	5	56	4.6	21
53	4.3	18	56	4.6	21
53	4.3	18	53	1.6	3
52	5.3	28	50	1.4	2
50	7.3	53	50	1.4	2
50	7.3	53	39	1.4	154
50	7.3	53	39	12.4	154
50	7.3	53	29	22.4	502
50	7.3	53	24	27.4	751
38	19.3	372	22	29.4	846

Notes: The mean score for the Experimental Group in this table (μ) is 57.3 percent. The mean score for the Control Group in this table (μ_1) is 51.4 percent. In addition, $\sigma = 13.2$, $t = 1.26$, $p > 0.1$

Let μ and μ_1 denote population mean scores attained by students of each group in the June 1973 examination. The experimental group obtained a mean of 57.3 percent and the control a mean of 51.4 per cent. (cf. Figure 6). On the basis of a two-tailed test (with alpha = 0.05) and using thirty degrees of freedom, H_0 would be rejected if "t" were outside the range -2.04 to 2.04. The above results ("t" = 1.26) show that we cannot reject H_0 and we must conclude that there is no significant difference between μ and μ_1.

Goof-Off Scores

Table 4 describes the results of compiling the number of "goof-off" periods taken by the experimental and control groups during the months of February, March, April and May 1973 (i.e. during the experiments).

TABLE 4

RESULTS OF THE NUMBER OF "GOOF-OFF" OPTIONS TAKEN DURING THE MONTHS OF FEBRUARY, MARCH, APRIL AND MAY 1973

Experimental Group			Control Group		
"Goof-Offs" Per student (X)	$\lvert(X - \bar{X})\rvert$	$\lvert X - \bar{X}\rvert^2$	"Goof-Offs" Per student (X_1)	$\lvert X_1 - \bar{X}_1\rvert$	$\lvert X_1 - \bar{X}_1\rvert^2$
10	8.3	69.0	24	11	121
4	2.3	5.3	20	7	49
4	2.3	5.3	20	7	49
3	1.3	1.7	19	6	36
2	0.3	0.1	17	4	16
1	0.7	0.5	16	3	9
1	0.7	0.5	16	3	9
1	0.7	0.5	15	2	4
1	0.7	0.5	14	1	1
0	1.7	2.9	12	1	1
0	1.7	2.9	10	3	9
0	1.7	2.9	9	4	16
0	1.7	2.9	8	5	25
0	1.7	2.9	7	6	36
0	1.7	2.9	0	13	169
0	1.7	2.9	0	13	169

Notes: The mean score for the Experimental Group in this table (μ) is 1.7 periods. The mean score for the control group in this experiment (μ_1) is 13 periods. In addition, $\sigma = 5.3$ $t = 6.2$, $p < 0.01$.

Let μ and μ_1 denote population mean "goof-off" periods taken by the students of the two groups, as per Table four. On the basis of a two-tailed test (with alpha = 0.01) and using thirty degrees of freedom, H_0 would be rejected if "t" were outside the range -2.75 to 2.75. The results of Table 4 ("t" = 6.2) indicate that we must reject H_0 and we conclude that there is a significant difference between μ and μ_1. The experimental group took off a mean of 1.7 periods and the control group took off a mean of 13 periods each.

Unannounced Test

Table 5 describes the results of a diagnostic "surprise" test compiled by the Science Consultant of the Protestant School Board of Greater Montreal (Appendix C). The test was given to both the experimental and the control groups in May 1973 after the experiment had been two-thirds complete. These results are displayed graphically in the histogram of Figure 7.

FIGURE 7

HISTOGRAM OF THE MAY 1973 SURPRISE TEST

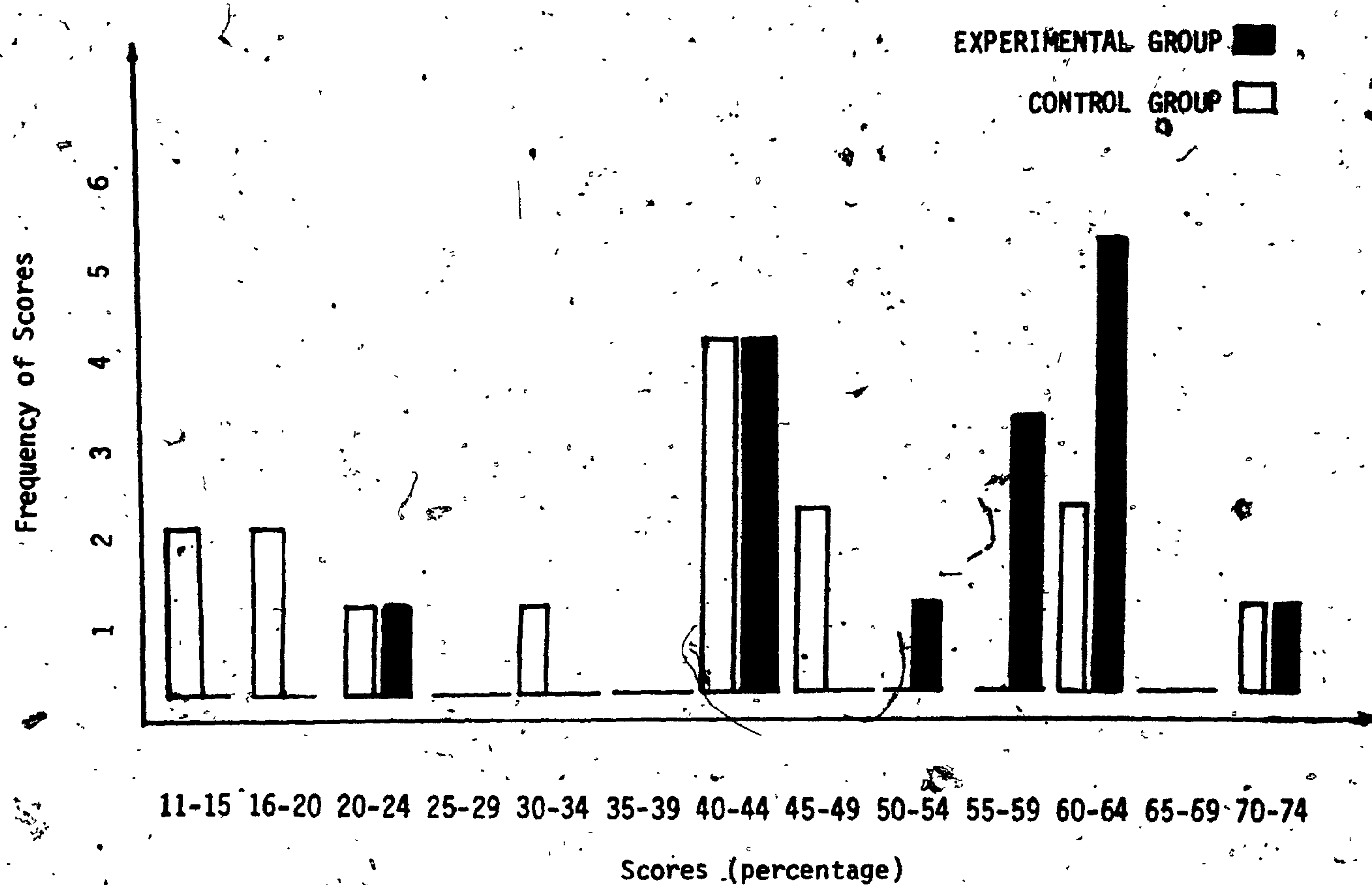


TABLE 5

RESULTS OF THE MAY 1973 SURPRISE TEST

Experimental Group			Control Group		
Individual Student Grade (X)	Deviation from the Mean Score $\lvert X - \overline{X} \rvert$	$\lvert X - X \rvert^2$	Individual Student Grade (Xi)	Deviation from the Mean Score $\lvert Xi - \overline{Xi} \rvert$	$\lvert Xi - Xi \rvert^2$
72	20	400	72	35	1225
64	12	144	64	27	729
64	12	144	60	23	529
60	8	64	48	11	121
60	8	64	48	11	121
60	8	64	40	3	9
56	4	16	40	3	9
56	4	16	40	3	9
56	4	16	40	3	9
52	4	16	32	5	25
44	8	64	20	17	289
40	12	144	16	21	461
40	12	144	16	21	461
40	12	144	12	25	625
20	32	1024	12	25	625

Notes: The mean score for the Experimental Group in this table (μ) is 52 percent. The mean score for the Control Group in this table (μ_1) is 37 percent. In addition, $\sigma = 16$, $t = 2.65$, and $p < 0.03$.

Let μ and μ_1 denote mean scores attained by students of each group in the May 1973 test. On the basis of a two-tailed test (with alpha = 0.05) and using thirty degrees of freedom, H_0 would be rejected if "t" were outside the range -2.04 to 2.04. The above results ("t" = 2.65) show that we must reject H_0 and we must conclude that there is a significant difference between μ and μ_1. The experimental group scored 52 percent and the control group scored 37 percent.

Discussion

Chemistry Achievement

The T-Tests results obtained from the data in Tables 1 and 5 were used to test the following research hypothesis:

> "If secondary school chemistry students with past records of below average math and science grades play a didactic game every third period during the final four months of the chemistry course, as part of the overall teaching strategy, the arithmetic mean of their final examination scores will be as high as or higher than the arithmetic mean scores of control subjects from the same population who do not play that didactic game".

The mean scores of the pre-test, 49% for the control subjects and 48% for the experimental group, (Table 1), were compared statistically using a T-Test with 30 degrees of freedom and were found not to differ (at the 0.05 level of significance). The post-test means, 51.4% for the control and 57.3% for the experimental group (Table 3), were similarly tested but it was not demonstrated that the experimental group differed from the control group ($p > .05$). Therefore, as originally designed, this project supports the conclusion that students who play the didactic game will do as well as those who do not (despite the elimination of one-third of the regular classes for the E group). They did not do better. However in adventitious unannounced test (about two-thirds of the way through the experiment) by the School Board's Science consultant showed the experimental group to be superior to the control group at that time (Table 5). It is possible that the lack of a statistically significant difference in the provincial examination reflects a relatively high incidence of study by both groups prior to that important examination. Further, the control group (like the experimental) was sufficiently small that close teacher-student contact was possible so students may have done better work than in a larger class.

It should be noted once again that the subjects of this study were of low ability in science and math achievement. These same students often stated that their main achievement desire in chemistry was to obtain a passing grade. All but one member of the experimental group succeeded in passing the junior matriculation exam where four members of the control group failed. An additional observation of the results listed in Table 3 is that the mean score of the experimental group is approximately seven percent above that of the control group. Furthermore four experimental subjects achieved second class standing or better (65% - 80%) whereas only one control subject did. It is the author's opinion that among the population of this study, passing grades and second class standings are important indicators of the experiment's influence. In light of the above arguments, it may be concluded that in this particular study, a mean difference of 5.9% in final grades in conjunction with a difference in failure rates of 19% constitute an important difference which, though not statistically significant, suggests the need for both further research on a large-scale (since even slight improvement on a province-wide basis is worthwhile) and refinements in the game.

Attitudinal Factors

Results obtained from the information in Tables 2 and 4 were used to test the research hypothesis:

> "If students play the didactic game, they will opt for fewer 'goof-off' periods than the members of the control group".

The mean 'goof-off' periods per student for a three month period, 13 for the control group and 1.7 for the experimental group (Table 4), were compared by means of a T-Test using thirty degrees of freedom. This showed there was a difference between the groups at the 0.01 level of significance. Initially there was no difference. It is concluded therefore that students prefer to attend chemistry classes (of which one-third are devoted to playing this didactic game) than to skip chemistry. The Author's interpretation is that basic needs provided by the 'goof-off' periods, discussion with friends, a change of pace, opportunity to speak with a teacher, were provided within the scope of the gaming situation.

The T-Test result obtained from the data in Table 5 was used to test the hypothesis:

"Students will do voluntary homework assignments"

The post-test means of Table 5, 27% for the control and 52% for the experimental group, were compared via a T-Test using thirty degrees of freedom and were found to differ significantly (at the 0.05 level of significance). These results were the outcome of a "surprise" diagnostic test administered to the control and experimental groups in the same afternoon. The test questions were compiled by the science consultant of the P.S.B.G.M. from a larger bank of questions that had been submitted by chemistry teachers in the P.S.B.G.M.'s High Schools (cf. Appendix C).

The results of the "surprise test" are offered as evidence that the gaming group, as compared with the control group, were better motivated to do voluntary study assignments, thereby keeping up to date in their chemistry studies. It is speculated that members of the control group did not do their homework regularly and, therefore, could not keep up to date with their studies. It is believed that the game playing and game strategy helped members of the experimental group to review the course concepts. In addition, the desire to be proficient at playing the game probably motivated students to complete their homework assignments regularly.

Other Outcomes of the Study

Additional outcomes of this study were based mostly on observation and informal interviews rather than being based on empirical data.

These observations were noted:

Some students who were disruptive during the lecture-discussion periods, were among the most enthusiastic and helpful members of the class during the gaming periods; they would offer to give out game equipment and would eagerly help other students in the solving of game problems.

The relatively small classes in this experiment were very conducive to the overall experiment, in that no special class was needed in which to play the game. In a school that was under modular scheduling a small "gaming class" could be easily programmed into a student's schedule. For large classes, 25 and above, provision of use of the cafeteria, or perhaps an additional classroom would be advantageous, as the noise level for large numbers of students playing the game in one small room might prove disruptive to individual groups of players.

The game was first introduced to the experimental group after they had been taught the unit on "density and specific gravity". The students were given detailed instructions how to play a short version of the game involving concepts from one unit. Additional cards and a larger master board were prepared by students in this one particular unit area. The students seemed eager to add their own cards to the prepared version of the game.

The instructor did not insist upon the formal game rules as the only rules in the playing of the game, and in many cases students adopted their own game rules. Some joined in pairs and competed with other pairs of players, aiming to see which group could match the most cards to the master boards within a specified time limit.

An additional outcome of the game was that some students began to make notes on cards of their own. These note cards had a question on one side and the answer to that question on the reverse side, or a concept on one side and an example or explanation on the reverse.

Students generally chose the members of their own game team. The usual type of choice was a member of the same sex and a student of comparable caliber academically. This method of selection usually meant that the students could learn at their own individual rate. In the month of May, the author encouraged a mixing of the game groups in order to introduce different members to certain groups. The author selected these members who he believed would either help or be helped by the other members of the group.

The author's concluding observation is that the teacher who uses a didactic game is a most important factor in the success of that game. It has already been pointed out that certain basic elements such as suitable background information, a convincing presentation of the worth of the game material, and most important, a form of feedback, must be an integral part of the game procedure. Therefore an instructor's manual would be required before dissemination. The author, who in addition to his teaching duties, is the audio-visual co-ordinator in a High School, is well aware of the teacher who abuses audio-visual software by not properly introducing the material or by showing the material completely out of context. This particular game, just as any other software, can become a waste of time and expense if presented simply as a fait accompli.

Conclusion and Recommendation

The applied research decision, to which this thesis is addressed, is simply stated: Does this experiment provide strong enough evidence to justify substituting this chemistry learning game system for one-third of the regular classes?

Having weighed the evidence we concluded that utilization of the game in its present form (1) clearly did not have a detrimental effect on student's performance on the provincial junior matriculation exam and increased scores on a school board exam; and (2) produced a marked alteration in attendance at all chemistry classes. Therefore, given its negligible cost it yields sufficient benefit (improvement in classroom life and individual initiative) to warrant its adoption on a large-scale basis.

However the game cannot be relied upon to replace all classroom teaching. Furthermore its use should be investigated with a large sample of chemistry classes to determine whether the effects observed here apply to a variety of classes (e.g. which include students, low, mixed or high motivation and capability) and teachers (e.g. who reflect a wide range in subject matter competence and teaching skill). Such large-scale investigation which is beyond the scope of this thesis, may pin-point areas of the game system which need revision or supplemental exercises. In addition, if the slight advantage of the experimental group over the control group on the provincial examination is sustained across a large sample then widespread utilization of this game would prove even more beneficial to students of chemistry.

APPENDICES

APPENDIX A

Directions for the Game

<u>Introduction to the Game:</u>

The game of "Decision" was designed to give a player the opportunity to review, organize and test his knowledge of many major concepts that are within the scope of a high school chemistry course. The game was designed to be played in groups by students within the classroom situation. The game may be played for twenty minute modules, or it can be played for an extended period of time. The player will attempt to match cards to master boards and, in addition, he may assume the role of teacher and attempt to explain the logic behind a particular play.

The game has been designed with three additions that it be used as part of an overall teaching strategy, that the worth of the elements of the game be explained to the students, and that student progress, in terms of 'challenge report cards', be monitored as part of the overall game plan.

The teacher who is required to follow the Quebec chemistry syllabus for grades x, and xi (chemistry 12-15-05) is permitted the freedom to use any number of reference books and a text that follows a loosely defined syllabus (see appendix E). This freedom permits the teacher of chemistry 12-15-05 to gear his course towards any combination of students who fall into the broad categories of:

a. a student taking the course for general interest

b. student wishing to select chemistry as a major in university.

c. students who must pass chemistry as a pre-requisite for a specific post secondary course e.g. nursing.

The philosophy of the committee that designed chemistry 12-15-05 is, "that the understanding of the basic principles of chemistry is of far greater importance than the memorization of unrelated details about elements and compounds. It also realizes that the understanding of these principles involves the learning and the retaining of a certain amount of subject matter." (Appendix F).

The author's personal evaluation of the chemistry 12-15-05 final exams (see Table 6) which was based on the cognitive domain of BLOOM's taxonomy revealed that 30% of the examination questions were of level #1
40% of the examination questions were of level #2
30% of the examination questions were of level #3

This evaluation showed that there was a high correlation between the above aim of the committee and the examinations that they prepared. There was, however, much less correlation among the aims, objectives of the committee and the matric question evaluation as per table 6. The above variables are charted in table 7 which follows. An additional variable, a table of objectives, was also introduced

APPENDIX A

DECISION - A Game to Teach High School Chemistry

Rules: The rules of the game are to (a) help your fellow student learn (b) match, buy and sell cards so profitably as to become the wealthiest player at the conclusion of the game.

Equipment: Periodic Table
money: chemdough $1, $2, $5, $10 denominations
boards: 12
cards: 112
stands: 6
answer sheets
challenge report cards
dice

Preparation: One of the players is elected banker.
Players dice to see who plays first
Players are given 1 @ $10, 1 @ $5
The number of boards to be played are selected.
The corresponding cards are then selected and mixed.
The boards are placed face up, the deck of cards face down.
The banker deals eight cards to each player.

To Start: Each player in turn is given two minutes in which to match as many of his eight cards to the board as possible. He may match two or more cards to a single board square.

Scoring: The player receives from the bank:

$1 ... for a one card match
$4 ... for a two card match

$(\$N)^2$ ... for a N card match

A successful challenge results in total single play earnings being transferred to the successful challenger.

Matched Cards: Matched cards may be handled by any player up until the challenge period is over, whereupon the banker collects the cards played and removes them from the game.

No Match:	A player who cannot match a card may give up his turn and trade one card out of the game for a card in the deck. The banker receives the card to be traded and treats it as a 'played card'. The player may also use his playing time to auction a card for another and perhaps money.
Challenge:	Players are given one minute (after a completed play) in which to call "challenge". Any player (first to call challenge) may challenge the validity of a played card. The banker then verifies the answer from the answer card. The successful challenger earns money from the bank that would normally go to the player having made the initial play. Incorrect plays and false challenges are to be reported on the <u>challenge report card</u>.
	An incorrect challenge results in an INSULT fine of \$5. to be paid by the challenger to the insulted player.
Insult:	All insults are reported on a CHALLENGE REPORT CARD. A false challenge results in a fine of \$5. to be paid by the challenger to the player.
Time:	A player must complete this turn within two minutes. Failure to do so results in a \$2. fine paid to the bank and the player loses his turn. The remaining players have one minute after any particular play in which they may call CHALLENGE.
Explanation:	A game may be delayed if half of the players call EXPLANATION and a player wishes to explain the thinking behind a particular play. No penalties or rewards are associated with EXPLANATION, but a \$2 payment is customary.
Bluff:	An undetected false answer is acknowledged as a correct play.
Bank:	Pays all monies for correct board answers. Collects <u>time</u> fines, collects 'played' cards, and verifies <u>all</u> CHALLENGES with the answer sheet.
Deck:	The pile of unused cards that remains face down on the playing surface.
Deck Used:	Once the deck is used, each player is permitted one last turn.

END OF GAME: The point in a game when a player has used up all of his cards, or after the players have used up the deck.

WINNER: The player with the most money at the end of the game is declared the winner.

SHORT VERSION OF THE GAME FOR TWO PLAYERS

No money is required. Players receive points for each card played, one point per card played. The game can be played as a competition between groups as to which group matches the most correct cards within a specified time limit.

PART B.

Rules: A PLAYER PICKS A CARD FROM THE DECK AND CHOOSES THE MINIMUM NUMBER OF BOARD SQUARES OF INFORMATION (THE BOARD SQUARES ARE NUMBERED FOR THIS PURPOSE) THAT ARE NEEDED TO FULLY ANSWER THE QUESTION ON THE CARD. EACH BOARD CHOICE IS OPEN FOR DISCUSSION. THE CHOICE OF A WINNER IS OPTIONAL, THE CRITERION TO BE DECIDED BY THE GROUP.

APPENDIX B

Pretest Examination

WAGAR HIGH SCHOOL

REGULAR CHEMISTRY

CHEMISTRY 588
Sections (01 to 03)

MID-TERM EXAMS
JANUARY 1973

CHEMISTRY 584
Sections (01 to 09)

MARKS 60
HOURS: 2

ON THE ANSWER SHEET, BLACKEN THE LETTER REPRESENTING THE WORD OR EXPRESSION THAT BEST COMPLETES THE STATEMENTS, OR ANSWERS THE QUESTION.

1. The number of milligrams in 0.0025 kilograms is;

(A) 25 (B) 2500 (C) 250 (D) 2.5 (E) 0.25

2. A centigrade (Celsius) thermometer reads 25 degrees. A Fahrenheit thermometer at this same temperature would read;

(A) 36 degrees (B) 57 degrees (C) 77 degrees

(D) 65 degrees (E) 45 degrees

3. Lavoisier concluded, after his experiments with red mercuric oxide, that burning was;

(A) the release of phlogiston
(B) the addition of oxygen
(C) the release of oxygen
(D) the addition of phlogiston
(E) all of these

4. A material that can be separated into its different components without any chemical change taking place is;

(A) sodium chloride (B) air (C) carbon dioxide

(D) water (E) steam

5. Dalton's Atomic Theory is capable of explaining ONLY ONE of the following;

(A) chemical reactions
(B) the existence of isotopes
(C) composition of compounds
(D) kinetic energy of molecules
(E) ratio of atoms in a compound

6. The freezing of water to ice is best explained by;

(A) Dalton's Atomic theory
(B) The Law of Conservation of Energy
(C) The Law of Conservation of Mass
(D) The Kinetic Molecular Theory
(E) The Law of Definite Composition

7. The total number of atoms in the formula $Al_2(SO_4)_3$ is;

(A) 5 (B) 3 (C) 14 (D) 10 (E) 17

8. The atomic weights of calcium, oxygen and hydrogen are 40, 16 and 1 respectively. What is the formula weight for the following compound?;

$$Ca(OH)_2$$

(A) 27 (B) 74 (C) 58 (D) 62 (E) 45

9. Scientists first used atomic spectra (optical) to;

(A) give atomic numbers to the elements
(B) show the presence of orbiting electrons in an atom
(C) calculate atomic weights of elements
(D) develope the electron microscope
(E) both B and C

10. Neutral atoms in the ground state of all elements must have

(A) all their orbitals filled with electrons
(B) all their main shells filled to maximum with electrons
(C) an equal number of protons, neutrons and electrons
(D) an equal number of protons and electrons
(E) an equal number of protons and neutrons

11. Which one of the following electronic notations INCORRECTLY REPRESENTS a neutral atom of carbon in the ground state?;

(A) $1s^2 \quad 2s^2 \quad 2p^2$

(B) 2 - 4

(C) C

(D) 1s $\boxed{\uparrow\downarrow}$ 2s $\boxed{\uparrow}$ 2p $\boxed{\uparrow}\boxed{\uparrow}\boxed{\uparrow}$

(E) 6p 6n 2e 4e

12. Isotopes of oxygen are similar in;

(A) atomic weights (B) atomic masses (C) atomic numbers
(D) physical properties (E) Both B and D

13. The maximum number of orbitals possible in the 3M shell of an atom is;

(A) 5 (B) 6 (C) 7 (D) 8 (E) 9

14. The atomic number of mercury is 80 and its atomic weight is 200. The nucleus of its atom will contain exactly;

(A) 280 neutrons (B) 200 protons (C) 80 neutrons

(D) 80 protons (E) 120 protons

15. Particles called "neutrons" may be used to explain the existence of;

(A) metals (B) nonmetals (C) Metalloids

(D) Ions (E) Isotopes

16. The atomic weights of most elements are not whole numbers <u>mainly</u> because;

(A) the weight of the electrons is neglected when atomic weights are calculated
(B) the means of calculating atomic weights are not accurate
(C) the atomic weight of an element is the average weight of all its natural isotopes
(D) the hydrogen atom is not used as the standard
(E) the weight of the hydrogen atom is approximately equal to the weight of a proton

17. An inert atom would have the following electronic configuration;

(A) 2 - 7
(B) 2 - 8 - 5
(C) 2 - 8 - 2
(D) 2 - 8 - 8
(E) 2 - 8 - 8 - 1

18. The atomic weight of a neutral atom is 59 and its atomic number is 27. The total number of electrons surrounding its nucleus is;

(A) 59 (B) 27 (C) 32 (D) 86 (E) 8

19. The metallic characteristics of elements in the periodic table DECREASE;

(A) FROM right to left and top to bottom
(B) from top to bottom
(C) from left to right and bottom to top
(D) from left to right and top to bottom
(E) from right to left and bottom to top

20. Which of the following scientists did not classify elements by their atomic weights?

(A) Meyer (B) Mosley (C) Dobereiner (D) Newland

(E) Mendeleef

21. All elements, in the periodic table, that have 3 electrons in their outer shells are located in;

(A) period 3M (B) group 3B (C) the triads (D) group 3A

(E) group 5A

22. Electrons in the outer shell of a neutral atom in the ground state;

(A) are called ions
(B) are called valence electrons
(C) are called electron octets
(D) take part in chemical activity
(E) both B and D

23. Chemists use the periodic table to predict properties of different compounds. Which of the following compounds would tend to have similar properties to the sodium chloride compound?;

(A) sodium carbonate
(B) calcium hydroxide
(C) potassium iodide
(D) sodium bi-carbonate
(E) aluminium chloride

24. Choose the INCORRECT statement about a period in the periodic table.

(A) A period is a horizontal row of elements.
(B) A period may contain 8 elements.
(C) The last element in a period is an inert element.
(D) The atomic numbers decrease, in a period, from left to right.
(E) A period may contain only 2 elements.

25. The following 3 elements which have the electronic configurations 2 - 1   2 - 8 - 1   2 - 8 - 8 - 1

(A) belong to the same period in the periodic table
(B) are all nonmetals
(C) belong to the same group in the periodic table
(D) are all metals
(E) both C and D

26. The electronic configuration which represents the most active metallic element is;

(A) 2 - 8 - 2
(B) 2 - 7
(C) 2 - 8 - 3
(D) 2 - 8 - 7
(E) 2 - 8 - 1

27. An element that has a valence of negative 2 would most likely be in the periodic table under group;

(A) 2A (B) 3A (C) 4A (D) 5A (E) 6A

28. Which of the following elements is likely to be the most chemically active?;

(A) aluminium (B) silicon (C) phosphorus (D) sulfur (E) chlorine

29. A neutral atom, of an element, and its corresponding ion DIFFER in;

(A) the number of protons in their nuclei
(B) the number of electrons in their shells
(C) the number of protons and neutrons in their nuclei
(D) atomic weights
(E) atomic numbers

30. The correct formula for ferrous sulfide (iron II sulfide) is;

(A) Fe_2S (B) FeS_2 (C) FeS (D) $FeSO_4$ (E) Fe_3S_2

31. The chemical bond between two chlorine atoms in the molecule of chlorine is most likely;

(A) an ionic bond
(B) a double covalent bond
(C) a non-polar covalent bond
(D) a triple covalent bond
(E) a polar covalent bond

32. The correct name for the compound whose formula is $NaHSO_3$ is;

(A) sodium sulfide
(B) sodium sulfate
(C) sodium sulfite
(D) sodium bisulfate
(E) sodium bisulfate

33. The ammonium ion ;

(A) is called a radical
(B) has a positive charge of plus 1
(C) contains a co-ordinate covalent pair of electrons
(D) contains the elements nitrogen and hydrogen
(E) is all of these

34. An electrovalent bond is the same as ;

(A) an ionic bond
(B) a polar covalent bond
(C) a non-polar covalent bond
(D) a hydrogen bond
(E) none of these

35. The attraction which a neutral atom has for electrons in a bond between itself and another atom is called;

(A) valence
(B) ionization potential
(C) electron repulsion
(D) electronegativity
(E) electrostatic attraction

36. Which of the following has a positive electrical charge ? ;

(A) hydroxyl ion
(B) sulfate ion
(C) sodium atom
(D) sulfite ion
(E) none of these

37. A polar covalent bond results when ;

(A) the electronegativities of the atoms are equal
(B) the electrons are attracted equally by the bonding atoms
(C) an ionic compound forms
(D) the electrons are shared unequally by the bonding atoms
(E) the electrons are repulsed equally by the bonding atoms

38. Which of the following tends to be a polar covalent molecule ?;

(A) CO_2 (B) CCl_4 (C) CH_4 (D) HCl (E) N_2

39. Ionic compounds tend to form when elements from the following two groups combine chemically;

(A) Groups 1A and 2A
(B) Groups 1A and 7A
(C) Groups 4A and 5A
(D) Groups 6A and 7A

40. Oxygen ;

(A) is the most abundant element on the earth's crust
(B) does not burn
(C) is slightly heavier than air
(D) exists in the free state as a diatomic molecule
(E) is all of these

41. THE BEST AND LEAST EXPENSIVE method for the laboratory preparation of oxygen is by ;

(A) the decomposition of mercuric oxide
(B) fractional distillation of liquid air
(C) the decomposition of potassium chlorate with a catalyst
(D) the electrolysis of pure water
(E) the decomposition of hydrogen peroxide

42. One of the following is the normal test for oxygen gas ;

(A) moist blue litmus paper turns red in the presence of the gas.
(B) A flaming splint causes the gas to explode or "pop"
(C) Moist red litmus paper turns blue in the presence of the gas.
(D) a glowing splint bursts into flames in presence of the gas.
(E) The gas has an odour similar to garlic

43. A piece of copper wire is held in the outer cone of a non luminous bunsen burner flame. At the end of 15 minutes the wire is removed. Observations reveal that the wire has ;

(A) become slightly heavier
(B) formed an oxide on its surface
(C) turned black in colour on its surface
(D) undergone a chemical change on its surface
(E) done all of these

44. Which of the following compounds is not an oxide ? ;

(A) Water (B) Iron rust (C) heavy water
(D) sodium hydroxide (E) carbon monoxide

45. A substance was burned in a jar of pure oxygen. A small amount of pure distilled water was then added to dissolve the product of combustion. The resulting solution turned a piece of red litmus blue. The substance that was burned could have been ;

(A) charcoal (B) phosphorus (C) magnesium
(D) sulfur (E) hydrogen

46. Choose the odd member ;

(A) burning gasoline (B) candle flame (C) bunsen flame
(D) boiling water (E) exploding firecracker

47. Hydrogen gas is rarely found in the free state on the earth's surface mainly because it ;

(A) forms an explosive mixture with air
(B) is ligher than air
(C) diffuses rapidly
(D) is soluble in water
(E) easily combines with most metals

48. Choose the INCORRECT STATEMENT.
Impure hydrogen gas can be prepared by the replacement of hydrogen in ;

(A) dilute acids by certain metals
(B) water by certain active metals
(C) hydroxides by certain metals
(D) steam by certain hot metals
(E) steam by hot incandescent coke

49. The removal of oxygen from metallic oxides is called ;

(A) adsorption (B) absorption (C) hydrogenation
(D) reduction (E) hydration

50. Three isotopes of hydrogen are known. The atoms of all these isotopes have ;

(A) similar chemical properties
(B) similar physical properties
(C) the same atomic mass
(D) one or more neutrons in their nucleii
(E) occur naturally on the earth's surface

51. The main reason why hydrogen is located in Group 1A of the periodic table is because it ;

(A) has similar properties as the elements in this group
(B) has one valence electron
(C) is the lightest element
(D) forms diatomic molecules
(E) forms so many compounds

52. The ratio of hydrogen to oxygen, by weight, in the water molecule is respectively;

(A) 1 to 2 (B) 2 to 1 (C) 1 to 8 (D) 8 to 1
(E) 1 to 9

53. Which is the INCORRECT STATEMENT? ;

(A) Pure water is a poor conductor of electricity
(B) Thermometer scales are standardized by using the freezing and boiling points of water
(C) Pure water is tasteless
(D) Water becomes more dense when it solidifies
(E) Water is a poor conductor of heat

54. A nonmetallic oxide that reacts with water to form an acid is called;

(A) an acid anhydride (B) a basic anhydride (C) a hydrate
(D) a hydroxide (E) a hydride

55. The high boiling point of water is due mainly to ;

(A) the stability of the water molecule
(B) the high solvent action of water molecules
(C) its inability to burn
(D) the hydrogen bonds between the molecules
(E) the high kinetic energy of its molecules

56. The best method for obtaining chemically pure water is by;

(A) chlorination (B) distillation (C) electrolysis
(D) de-ionization (E) fractional electrolysis

57. A closed jar contains 17 milliliters of hydrogen and 5 milliliters of oxygen. This mixture is ignited to form water. The amount of gas remaining will be;

(A) 7 milliliters of oxygen
(B) 12 milliliters of hydrogen
(C) 12 milliliters of oxygen
(D) 7 milliliters of hydrogen
(E) 13 milliliters of hydrogen and 4 milliliters of oxygen

58. The total weight of aluminium in 1000 pounds of $Al_2\ O_3$ is approximately;

(A) 130 lbs. (B) 230 lbs. (C) 330 lbs (D) 430 lbs.
(E) 530 lbs.

59. The empirical formula for a compound which CONTAINS 80% carbon and 20% hydrogen by weight is;

(A) CH (B) CH_2 (C) CH_3 (D) C_2H (E) C_3H

60. A compound has the empirical formula of CH_3O. Its molecular weight is 62. The molecular formula for this compound is;

(A) $CH_3\ O$ (B) $C_2\ H_6\ O_3$ (C) $C_3\ H_9\ O_3$ (D) $C_2\ H_6\ O$
(E) $CH_3\ O_2$

APPENDIX C

MAY TEST

EXAMINATION

FORM A REVIEW CHEMISTRY TEST CH. 7-17

1. If a substance is burned in air it increases in weight because :

   A. heat is added to the substance
   B. the substance combines with oxygen.
   C. carbon dioxide is formed.
   D. water is formed.
   E. carbon monoxide is formed.

2. Which one of the following is NOT a characteristic of hydrogen ?

   A. hydrogen is the lightest element
   B. hydrogen atoms are covalently bonded
   C. hydrogen exists as three different isotopes
   D. hydrogen can be absorbed readily by certain metals.
   E. hydrogen is found in the free state on the earth.

3. Water is a good solvent because:

   A. it is a polar compound
   B. it has a high boiling point
   C. it is a liquid
   D. it is highly ionized
   E. it has very small molecules.

4. In which one of the following compounds is oxygen 50% by weight?

   A. NO
   B. CO
   C. CO_2
   D. SO_2
   E. CaO

5. A non-metallic oxide which reacts with water to form an acid is called (an)

   A. basic oxide
   B. hydroxide
   C. acid hydrate
   D. basic anhydride
   E. acid anhydride

6. The sum of the atomic weights in the formula of a substance is the;

   A. formula weight.
   B. mole
   C equivalent weight
   D. density
   E. gram-molecular weight.

7. Before a chemical equation can be written, one must know:

   A. the composition of all reactants and products.
   B. the valences of all the metals involved.
   C. the atomic weights of all the elements involved.
   D. the changes which take place in oxidation state
   E. The molecular weights of all the compounds.

8. Crystals which become wet and dissolve upon exposure to moist air are described as:

   A. absorbent
   B. effervescent
   C. efflorescent
   D. deliquescent
   E. homogenous

9. Which compound is properly named?

   A. FeO ferric oxide
   B. $AgNO_3$ silver nitrite
   C. $CaSO_4$ calcium sulfite
   D. $NaCl$ sodium chlorate
   E. H_2SO_3 sulfurous acid

10. If the pressure on a gas is doubled and at the same time the absolute temperature is halved, the gas will have its volume:

   A. doubled
   B. unchanged
   C. halved
   D. become four times as small
   E. become four times as large

11. Under standard conditions 32 grams of oxygen occupies:

   A. 1 liter
   B. 22.4 liters
   C. 44.8 liters
   D. 32 liters
   E. 16 liters

12. Bases are NOT:

   A. bitter tasting
   B. soapy feeling
   C. proton donors
   D. proton accepters
   E. electrolytes

13. In $KClO_3$, the oxidation number of chlorine is:

A. -1
B. +1
C. -5
D. +5
E. +7

14. Chemical reactions are reversible if:

A. a precipitate forms.
B. a gas forms
C. water is a product
D. the reactants do not react.
E. all products ionize

15. In the electrolysis of hydrochloric acid the chloride ions:

A. move to the cathode.
B. lose electrons
C. share electons
D. combine with hydrogen ions
E. gain electrons

16. Which one of the following 0.5 molar solutions has the lowest freezing point?

A. $CaCL_2$

B. $NaC_2H_3O_2$

C. $NaNO_3$

D. C_2H_5OH (alcohol)

E. HCl

17. A term that is not a quantitative expression of solution concentration is:

A. saturated B. molar C. molal D. normal
E. dilute

18. A 10% solution of NaOH contains :

A. 10g of NaOH in 100 g of water.
B. 5g of NaOH in 45 g of water
C. 40g of NaOH in 60 g of water
D. 10 g of NaOH in 50 g of water
E. 10 g of NaOH in 90 g of solution.

19. An acid is neutralized with a base and the resulting solution is evaporated. The residue will be:

A. an acid salt
B. an anhydride
C. an hydroxide
D. a normal salt
E. a basic salt

20. If 8.5 liters of nitrogen and 25.5 liters of hydrogen combine to produce ammonia (At S.T.P.) the volume of ammonia is:

A. 17 liters
B. 34 liters
C. 51 liters
D. 3.5 liters
E. 68 liters

21. The weight of hydrochloric acid reacting with zinc to yield 67.2 liters of hydrogen at S.T.P. is:

A. 73 g
B. 36.5 g
C. 146 g
D. 67.2 g
E. 219 g

22. If 92 g of ethyl alcohol (C_2H_5OH) is dissolved in 500 g of water, the resulting solution will freeze at about:

A. -1.86 C
B. -7.44 C
C. -3.72 C
D. -5.58 C
E. -9.30 C

23. The molecular weight of a gas having a vapor density of 22 is :

A. 44
B. 22
C. 22.4
D. 88
E. 44.8

24. A compound is 92.3% carbon and 7.7% hydrogen. Its molecular weight is 78. Its molecular formula is :

A. C_4H_{30}

B. C_5H_{18}

C. C_6H_6

D. C_3H_8

E. C_7H_{14}

25. In an oxidation - reduction reaction the substance which is reduced :

A. always gains electrons.
B. always loses electrons.
C. neither gains nor loses electrons
D. sometimes loses electrons
E. always combines with oxygen.

APPENDIX D

EVALUATION OF THE QUEBEC CHEMISTRY COURSE 12-15-05

TABLE 6

DIAGNOSTIC OF CHEMISTRY COURSE 12-15-05 EXAMINATIONS

Objectives	Corresponding Categories as per Bloom 16	Examination Weighting	Percent of Syllabus
1. development of understanding of fundamental concept and theories	A.0 1 to 11 C.0 1 only	90%	70%
2. development of appreciation of scientific method	C.0 1 to 4 D.0 1 to 6 E.0 1 to 6 F.0 1 to 3	nil	2%
3. development of correlation between lab and class work	B.0. 1 to 5	10%	10%
4. training pupils in laboratory write-up	G.0 1 & 2	nil	10%
5. inspire and prepare students for future work in chemistry	H.0 1 to 6	nil	2%
6. understanding of the importance of science in living	F.0 1 to 3	nil	2%
7. stimulate further interest in chemistry	E.0. H.0. I.0. 1 to 6	nil	2%
8. encourage use of reference material	F.0. 1 to 3 H.0 1 to 6 I.0 1 to 6	nil	2%

Notes: This table is a comparison among:

a. The objectives of the committee of chemistry 12-15-05 (Appx.C)

b. A table of categories used to evaluate the depth of a particular curriculum in science (Bloom et al. Handbook on Formative and Summative Evaluation of Student Learning. N.Y., McGraw Hill, 1971, pp. 563 and 564.

c. Evaluation of Examination Questions (Appendix F) Table 6)

d. The syllabus of chemistry 12-15-05 (Appendix G).

TABLE 7

ASSIGNMENT OF CATEGORY VALUES TO
QUEBEC CHEMISTRY MATRICULATION EXAMS 1967-72
(CATEGORY VALUES ARE IN CONJUNCTION WITH
THE COGNITIVE DOMAIN TAXONOMY OF BLOOM)

Question Number	Date of Examination				
	June 1968	Aug. 70	June 70	71	72
1	2	2	2	2	2
2	1	1	2	3	2
3	3	1	1	2	2
4	3	2	1	1	2
5	3	2	3	3	2
6	3	2	1	1	2
7	1	2	1	2	2
8	3	2	3	2	2
9	2	1	1	1	1
10	2	3	3	2	2
11	1	1	2	2	2
12	2	2	2	1	1
13	2	1	3	3	2
14	2	1	3	2	2
15	3	1	2	2	1
16	3	1	2	2	3
17	1	1	2	2	1
18	2	2	2	2	2
19	2	2	2	2	3
20	2	2	2	1	2
21	2	1	1	2	3
22	3	1	1	2	3
23	2	1	2	2	3
24	3	1	2	3	1
25	2	2	1	3	3
26	2	1	2	2	3
27	1	2	1	3	1
28	1	3	2	3	3
29	1	2	3	3	3
30	1	1	1	3	3
31	1	2	1	3	3
32	3	1	3	3	3
33	3	1	2	3	3
34	2	2	2	1	3
35	2	2	3	1	2
36	2	2	3	1	2
37	3	2	1	2	3

(cont.)

Question Number	Date of Examination				
	June 1968	Aug. 70	June 70	71	72
38	2	1	3	1	3
39	1	3	3	2	1
40	1	1	2	3	1
41	1	1	1	2	1
42	1	2	1	1	2
43	2	2	1	2	2
44	3	2	2	2	2
45	3	2	2	2	2
46		2	2	3	3
47		2	3	3	2
48		1	2	2	1
49		2	1	1	2
50					

Notes:

June 1968
Category 1 - 30%
Category 2 - 40%
Category 3 - 30%

August 1970
Category 1 - 35%
Category 2 - 40%
Category 3 - 25%

June 1970
Category 1 - 38%
Category 2 - 42%
Category 3 - 25%

June 1971
Category 1 - 24%
Category 2 - 46%
Category 3 - 30%

June 1972
Category 1 - 20%
Category 2 - 44%
Category 3 - 36%

June 1973
Category 1 - 20%
Category 2 - 40%
Category 3 - 40%

HARDWARE AND SOFTWARE AVAILABILITY (PERSONAL CASE STUDY)

LABORATORY MATERIALS:	Chemicals and basic apparatus are available for laboratory work. Generally speaking, however, cramped quarters and poor ventilation prevent lab studies with all "dangerous" gases. eg. H_2, O_2, H_2S
CHEMISTRY FILMS:	School board films are of the 1930's. One tries to rent or borrow C.I.L. or N.F.B. movies.
PROGRAMMED LEARNING:	A few samples available that deal with such topics as OXIDATION & REDUCTION
FILMSTRIPS & SLIDES:	Not available unless prepared by the teacher himself. (Camera and film are available free of charge)
VIDEO:	The author made one video presentation.

SUMMARY

A major responsibility of the teacher is to prepare the student for the external examination (matric). This responsibility would result in the teacher preparing the student for the final exam, rather than teaching the course in the light of the objectives as per appendix G.

The resulting course is likely to be taught as an information and comprehension course with little or no treatment of chemistry as an experimental science.

I believe that the student who has completed this course should now be prepared to carry out further studies in scientific inquiry such as the CHEM-STUDY COURSE.

A further limitation of the above course is that the student's evaluation feedback is merely a summative evaluation of his knowledge, comprehension, and narrow application of concepts in a general chemistry course.

<u>RECOMMENDATIONS</u>: The author recommends that the above course be offered as a preparation course for those students in level III who plan to take chemistry on level 4.

Students of levels IV and V who will not need to further specialize in chemistry at the University level may also benefit from this course in terms of general scientific knowledge.

APPENDIX E

SYLLABUS IN CHEMISTRY

APPENDIX E

SYLLABUS IN CHEMISTRY

Grades X & XI

UNIT 1. THE BASIS OF CHEMISTRY

Chapter 1. The Meaning of Chemistry.

a) Matter, Energy, and their Changes.

1. What is Chemistry?
2. The nature of matter.
3. The states of matter.
4. Physical and chemical properties of matter.
5. Changes in matter.
6. Energy.
7. The relation between matter and energy.

b) Systems of Measurement.

8. Fundamental quantities of measurement.
9. English and metric systems.
10. The measurement of temperature---omit Fahrenheit temperature.
11. Significant figures.
12. Powers-of-ten notation.

c) Methods of Science

13. Lavoisier's famous experiment.
14. The scientific method and attitude

Chapter 2. A Classification of Matter

1. Classes of matter
2. What are the elements?
3. Metals and non-metals
4. Naming the elements.
5. Mixtures.
6. Solutions and uniform mistures.
7. Compounds
8. The Law of Definite Proportions or The Law of Definite Composition.

Chapter 3. Smallest Pieces of Matter.

1. The value of theories.
2. Dalton's Atomic Theory.
3. Definition of an atom.
4. Atomic weights.
5. Significance of symbols.
6. Molecules.
7. Make-up of molecules
8. Molecular properties
9. Molecules and formulas
10. Significance of formulas
11. The Kinetic Molecular Theory.
12. Molecular motion in gases.
13. Molecular motion in Liquids.
14. Molecular motion in solids.

Chapter 4. The Structure of the Atom...the particle concept of the electron only: electron orbits; energy levels (shells); diagrams of atoms limited to the first twenty elements of the Periodic Table.

a. The Atom as Matter.

1. Need for a new theory.
2. parts of an atom.
3. The electron theory of atomic structure.
4. Electron shells and orbitals.
5. An orderly arrangement of electrons.

b. Examples of Atomic Structure.

9. Atomic number.
10. Chemical activity.
11. Examples of atomic structure
12. Neutrons and isotopes.
13. Atomic weights and isotopes...atomic weights based on the most common carbon isotope, carbon 12.

Chapter 5. The Periodic Classification of the Elements.

1. Early classification.
2. Mendeleyev's Periodic Law.
3. Moseley's atomic number
4. An orderly arrangement of properties
5. The modern Periodic Table of the elements.
6. The horizontal periods of the elements.
7. Features of the periods.
8. The groups or families of the elements.
9. Value of the Periodic Table.

Chapter 6. Valence and Chemical Bonding.

1. The meaning of valence.
2. Valence and atomic structure.
3. Valence electrons and chemical bonds.
4. Ionic bonding.
5. Covalent bonding
6. Electronegativity (See Basic Modern Chemistry by Madras, Hall and Holcomb; pages 147 and 148) and polar compounds.

Chapter 6 (continued)

7. Metals and non-metals.

b. Writing Formulas.

8. Valence and formulas.
9. Using valence to determine formulas.
10. Writing more complicated formulas.
11. Naming chemical compounds.
12. Radicals.

UNIT 2. TWO IMPORTANT ELEMENTS

Chapter 7. Oxygen and Oxidation.

a. Oxygen.

1. An indispensable and abundant element.
2. History of oxygen.
3. Preparation of oxygen...omit sodium peroxide.
4. Atomic and molecular structure of oxygen.
5. Physical properties of oxygen.
6. Chemical properties of oxygen.
7. Uses of oxygen.

b. Combustion or Burning

8. Oxidation.
9. Burning and weight.
10. Kindling temperature
11. Spontaneous combustion.
12. Extinguishing fires.
13. The Bunsen burner.
14. Dust explosions

Chapter 8. Hydrogen the Simplest Element.

1. Occurrence of hydrogen.
2. Discovery of hydrogen.
3. Preparation of hydrogen.
4. The simplest element.
5. Physical Properties of Hydrogen
6. Chemical properties of Hydrogen
7. Reduction
8. Uses of hydrogen.

Chapter 9

1. Occurrence and preparation
2. Molecular structure of Water
3. Physical properties of water
4. Water as a standard
5. Chemical Properties of Water
6. The solvent action of Water
7. Deuterium oxide or heavy water
8. The composition of water
9. Distillation.

UNIT 3. CHEMICAL CALCULATIONS

Chapter 10. Formulas and Composition.

1. Symbols and formulas.
2. Molecular formulas and empirical formulas.
3. Molecular weight and formula weight.
4. Determination of formula weights.
5. Formula weights and the combining weights of atoms.
6. Percentage Composition.
7. Calculation of the empirical formula.
8. Calculation of the molecular formula.

Chapter 11. Equations and their Weight Relations.

1. Formulas and equations.
2. Significance of a chemical equation.
3. Writing equations.
4. Balancing equations.
5. Types of chemical reactions.
6. Calculating weights from equations.
7. Procedure for solving weight--weight problems.
   (Omit the Mole Method)
8. Special points about problems.

Chapter 12. The Gas Laws.

a. Physical Behaviour of Gases.

1. Molecules of gases.
2. Standard conditions of temperature and pressure.
3. Relation of volume to pressure--Boyle's Law.
4. Relation of volume to temperature---Charles' Law.
5. The General Gas Law combines Boyle's and Charles Laws.

Chapter 12 (continued)

b. Chemical Behaviour of Gases.

8. Gay-Lussac's Law of Combining Volumes.
9. Avogadro's Law.
10. Examples of molecular structures of gases.
11. Real gases vs. perfect gases or ideal gases.

Chapter 13. Molecular Weights and Volume Relationships of Gases.

a. Molecular Weights of Gases.

1. Density and specific gravity of solids and liquids.
2. Density and specific gravity of gases.
3. Molecular weights and densities of gases.
4. Molecular weights and specific gravities of gases.
5. Using molecular weights to determine molecular formulas.

b. Volumes of Reacting Gases.

6. Volume--volume problems.
7. Weight-volume and volume-weight problems.

UNIT 4. SOLUTIONS, IONS, AND EQUILIBRIA

Chapter 14. Solutions and Crystals.

a. Solutions.

1. The nature of solutions. 2. Suspensions.
3. Types of solutions. 4. The process of solution
5. Terms used in referring to solutions.
6. Saturation and solubility.
7. The effect of temperature on solubility.
8. The effect of pressure on solubility.
9. Factors affecting the rate of solution.
10. Expressing the concentration of solutions.
11. Effect of solute on solvent properties (no problem, qualitative treatment only)

b. Crystals.

12. The nature of crystals. 13. Types of crystal structure.
17. Water of crystallization.
18. Efflorescence and deliquescence.
19. Noncrystalline solids.

Chapter 15. Ions and Electricity.

1. Faraday and solutions.
2. Arrhenius and charged particles.
3. Occurrence of ions.
4. Ions and atoms.
5. Groups of ions.
6. Water, a dipole molecule.
7. The action of water on ionic compounds.
8. Ionic equations.
9. Ionization of covalent compounds.
10. Ionization reviewed.
11. Electrical conductivity in solutions.
12. Supply and demand of electrons.
13. Chemical changes at electrodes.
14. Secondary products of electrolysis.
15. Precipitation from solution.
16. Degrees of conductivity.
17. Effect of electrolytes on boiling and freezing points of water.
18. Apparent degree of ionization.
19. The ionosphere.

Chapter 16. Acids, Bases and Salts.

a) Acids.

1. Acids, a class of compounds.
2. What is an acid?
3. Properties of acids.
4. The action of acids on metals (Activity Series)
6. Preparation of Hydrogen chloride
7. Physical properties of hydrogen chloride
8. Chemical properties of hydrochloric acid.
9. Uses of hydrochloric acid.
10. Naming acids.

b) Bases.

11. Introduction of bases.
12. What is a base?
13. The characteristics of bases.
16. Neutralization.
17. Naming the bases.
18. The strength of acids and bases.
19. The hydrogen ion concentration. (Omit the idea of pH as a logarithm)

c) Salts.

20. Salts defined.
22. Naming and classifying salts.

d) Standard Solutions and Titration.

d) continued

24. Expressing solution conventrations.
25. Acid solutions of known normality.
26. Base solutions of known normality.
27. Salt solutions of known normality.
28. Molar and molal solutions

Chapter 17. Principles of Chemical Reaction.

1. Electrons and chemical change.
2. Measurement of heat
3. Heat from combining elements
4. Heat in chemical reactions
5. Stability and instability
7. Combination or synthesis
6. Classification of chemical reactions
8. Decomposition or analysis
9. Single replacement
10. Double replacement
11. Oxidation-reduction reactions
12. Oxidation numbers and valence.
14. Reversible reactions
15. Factors controlling chemical equilibrium
16. La Chatelier's Principle.
17. Changing the Temperature.
18. Changing the Pressure
19. Changing the Concentration.

UNIT 5. THE FAMILIES OF METALS

Chapter 19. The Properties of Metals

a) Crystal Structure of Metals.

1. Metals and Man.
2. Metals in general
3. Solids.
4. The crystalline structure of solids
6. Mobile electrons in a metal crystal.

b) Chemical Properties of Metals.

15. Electrons structure and chemical properties
16. Metals are electropositive.
17. The ionization potential
18. Chemical reactions of metals.

Chapter 20. The Alkali Metals

1. Group 1 of the Periodic Table.
2. Atomic structure of the alkali metals
3. Similarity of properties.

UNIT 6. THE CARBON FAMILY

Chapter 29. The Forms of Carbon.

2. Structure of the carbon atom.
3. Forms of uncombined carbon.
4. Diamonds
5. Graphite.

Chapter 30. The Oxides of Carbon.

Carbon Dioxide

1. Importance of carbon dioxide.
2. Occurrence and discovery of carbon dioxide.
3. Preparation of carbon dioxide
4. Physical properties of carbon dioxide
5. Chemical properties of carbon dioxide
6. Carbonic Acid
7. Test for carbon dioxide
8. Test for the carbonate radical
9. Industrial uses of carbon dioxide

UNIT 7. THE FAMILIES OF NON-METALS

Chapter 31. The Nitrogen Family and the Inert Gases---Groups V and O.

a) Nitrogen

1. The nitrogen family as a group.
2. Occurrence and importance of nitrogen.
2. Preparation of nitrogen
4. Physical properties of nitrogen.
5. Chemical properties of nitrogen

b) Air and the Inert Gases.

6. Composition of air
7. The inert gas family
8. Helium.
9. Neon.
10. Argon
11. Krypton, Xenon and Radon.

Chapter 32. Compounds of Nitrogen.

Ammonia

1. The importance of nitrogen compounds
2. Natural formation of ammonia
3. Laboratory preparation of ammonia
4. Commercial preparation of ammonia
5. Physical properties of ammonia
6. Chemical properties of ammonia
7. Ammonia water
8. Uses of ammonia
9. Ammonium salts.
10. Tests for ammonia and ammonium ion.

Chapter 33. The Oxygen-Sulphur Family---Group VI

a) Elements of Group VI

1. Comparison of the Group VI elements.

b) Sulphur

3. Importance of sulphur in industry.
4. Occurrence and extraction of sulphur (Frash)
5. Allotropic forms and physical properties of sulphur
6. Chemical properties of sulphur.

c) Hydrogen Sulphide and Metallic Sulphides.

OMIT

d) Oxides of Sulphur

11. Occurrence of sulphur dioxide.
12. Preparation of sulphur dioxide
13. Physical properties of sulphur dioxide.
14. Chemical properties of sulphur dioxide
15. Uses of sulphur dioxide
16. Sulphur trioxide.

e) Sulphuric Acid and Sulphates.

17. Commercial preparation of sulphuric acid...(Contact Process; omit Lead Chamber Process)
18. Physical properties of sulphuric acid.
19. Chemical properties of sulphuric acid.
20. Uses of sulphuric acid.
21. Test for sulphate ions.
22. Relationship of the common compounds of sulphur.

Chapter 34 The Halogen Family---Group VII

a) The Halogens

1. The family of salt-makers. 2 Family resemblances.
3. A non-metallic displacement series.

b) Fluorine

6. Physical and chemical properties of fluorine

c) Chlorine.

9. Occurance and importance of chlorine.
10. Preparation of chlorine.
11. Physical properties of chlorine
12. Chemical properties of chlorine
13. Chlorine as a bleaching agent and as a disinfectant
14. Chlorides.
15. Test for chloride ions.
16. Other uses of chlorine.

d) Bromine

19. Physical and chemical properties of bromine

e) Iodine

24. Physical and chemical properties of iodine
27. Colour tests for bromine and iodine.

APPENDIX G

Objectives

THE CHEMISTRY SYLLABUS FOR GRADES X AND XI

THE OBJECTIVE OF HIGH SCHOOL CHEMISTRY

1. To develop an understanding of the fundamental concepts and theories of a general chemistry course and to present these concepts and theories in such a way that the students may always be ready to modify them in the light of additional experimental information in the rapidly expanding world of chemistry.

2. To develop an appreciation of the scientific method.

3. To develop a careful correlation between laboratory work and class work.

4. To train pupils to keep accurate records of laboratory work expressed in clear, concise English.

5. To inspire and prepare students who are planning to contine their study of chemistry at a university level of education.

6. To develop in the students who will not continue the study of chemistry after high school an understanding of the importance of science in their lives.

7. To stimulate the development of interests and hobbies which are scientific in nature.

8. To encourage students to use reference text-books and scientific periodicals.

THE SCOPE AND STRUCTURE OF THE CHEMISTRY COURSE

During the quarter-century since the previous syllabus was authorized, tremendous advancements have been made in chemistry. A great amount of information that students need to learn has accumulated and new knowledge is being added at an alarming rate. In revising the present syllabus the Committee considered the two new high school chemistry studies in the United States (the CBA and CHEM studies), the subject matter most desirable in a general chemistry course, the teaching time available, and the readability and teachability of the subject matter in available textbooks of chemistry.

The Committee adopted the premise that the understanding of the basic principles of chemistry is of greater importance than the memorization of unrelated details about elements and their compounds. It also realises that the understanding of these principles involves the learning and retaining of a certain amount of subject matter.

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