

AN ABSTRACT OF THE THESIS OF

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Title: A COMPARISON OF STUDENT PERFORMANCE IN LOWER
DIVISION COLLEGIATE GENERAL CHEMISTRY PROGRAMS
BETWEEN SELECTED COMMUNITY COLLEGES AND FOUR-
YEAR INSTITUTIONS IN OREGON

Abstract approved: 
Fred W. Fox

This research was conducted to compare the performance of community college students to four-year institutional students both of which were enrolled in one of three different programs of general college chemistry for nonscience majors during the 1967-68 academic year. The three programs were defined as follows:

Program A - A Chemistry course for those students who have:

1. No high school chemistry background or;
2. A college board (S. A. T.) score of 451 or less in mathematics, or;
3. A total college board (S. A. T.) score of 861 or less in mathematics plus verbal or;
4. A high school grade point average (G. P. A.) of less than 2.5 (4.0 equals perfect)

This program is designed as an introductory elementary course of nine quarter hours credit and is a terminal course to be taken only by students who will not go on to take higher level chemistry courses.

Program B - This course is designed for students with the same background and scores as those in Program A, but who do plan to go on and take higher level chemistry courses. This course is a minimum of twelve quarter hours. The greater number of hours will allow a more thorough approach and provide a better background.

Program C - A chemistry course for those students who have:

1. High school chemistry background and;
2. A college board (S. A. T.) score of 452 or above in mathematics, and;
3. A total college board (S. A. T.) score of 862 or above in mathematics plus verbal or;
4. A high school chemistry background and a high school grade point average (G. P. A.) of 2.5 or above (4.0 equals perfect)

This course is designed for the science related majors (engineering, forestry, etc.) but not for science majors (chemistry, pre-medical, etc.). It is a modern, and strictly college level general chemistry course in which the majority of general chemistry students are enrolled. The objectives of this program are similar to those of Program B in that the course is designed to prepare students for

additional courses in chemistry. Therefore, the criterion instruments used in Program C were identical to those used in Program B.

Near the completion of these programs, measurements, of student performance from the two types of institutions, were taken in terms of two important objectives of chemistry teaching; critical thinking ability and knowledge of facts and principles. The criterion instruments used to measure these objectives were: The Cornell Critical Thinking Test, Form Z, developed by R. Ennis and J. Millman, and two knowledge of facts and principles tests developed by the researcher. To assure that the students from the two types of institutions, within the three programs, were comparable before the differential experimental treatment, they were matched by S. A. T. math scores or, where these were not available, high school math grade point averages were used.

The population for this investigation consisted of full-time students enrolled in one of the three different general college chemistry programs at either of four community colleges or two four-year institutions in Oregon. In Program A there were a total of 188 community college students and the same number of four-year institutional students. Similarly, there were 70 from each of the two types of institutions for Program B and 174 from each type for Program C.

Findings

The findings from this research were based on results of an analysis of variance statistical design with F values computed at the 5 percent level.

1. There was no significant statistical difference between community college and four-year institutional general chemistry Program A in terms of student critical thinking ability and student knowledge of facts and principles of chemistry.
2. There was no significant statistical difference between community college and four-year institutional general chemistry Program B in terms of student critical thinking ability.
3. There was a significant statistical difference between one of the four-year institutions and all the other participating institutions in terms of student knowledge of facts and principles of chemistry for Program B.

It was concluded that a significant factor influencing this finding was the procedural difference in course offering between the one four-year institution and all of the other participating colleges. For the one four-year institution Program B was offered in three sequential quarters in contrast to the other colleges offering Program

B in 4 quarters, three of which were sequential and a fourth offered sometime the next year. It was the conclusion of the author that this break in course continuity significantly impeded the success of students in Program B in terms of knowledge of facts and principles in chemistry.

4. There was no significant statistical difference between community college and four-year institutional general chemistry Program C in terms of student critical thinking ability and student knowledge of facts and principles of chemistry.

A Comparison of Student Performance in Lower Division
Collegiate General Chemistry Programs Between
Selected Community Colleges and Four-Year
Institutions in Oregon

by

Clifford Owen Denney

A THESIS

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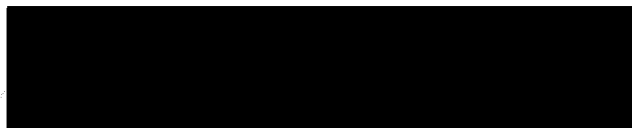
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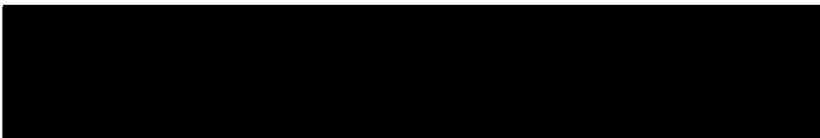
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TABLE OF CONTENTS

Chapter	Page
I. INTRODUCTION	1
Development of Community Colleges in Oregon	6
Statement of Problem	9
Definition of Terms	11
Community College Collegiate Student	11
Four-year Institution College Student	11
Critical Thinking	11
Knowledge of Facts and Principles	12
Basic Assumptions	13
Hypotheses To Be Tested	14
Preliminary Hypotheses	14
Basic Null Hypotheses	14
Delimitations of the Study	16
Importance of the Study	17
II. REVIEW OF RELATED RESEARCH	19
Objectives of Science Education	19
Studies in Critical Thinking	26
The Nature of Critical Thinking	26
The Teaching of Critical Thinking	28
Studies in Knowledge of Facts and Principles in General College Chemistry	36
Four-year Institution - Community College Comparative Studies	41
III. DESIGN OF THE STUDY	46
The Experimental Design	46
The Population	47
Community Colleges	48
Lane Community College (LCC)	48
Mt. Hood Community College (MHCC)	48
Portland Community College (PCC)	49
Southwestern Oregon Community College (SCC)	50

Chapter	Page
Four Year Institutions	51
Oregon State University (OSU)	51
Portland State College (PSC)	52
The Evaluation Instruments	52
<u>Cornell Critical Thinking Test</u>	52
Knowledge of Facts and Principles Tests	55
<u>Scholastic Aptitude Test</u>	56
Procedures Used in Collecting the Data	59
Criterion Test Scores	59
Scholastic Aptitude Test Scores	59
High School Math Grade Point Average	60
Statistics Utilized in Analysis of Data	60
Processing of the Data	62
IV. PRESENTATION AND INTERPRETATION OF THE FINDINGS	63
Presentation of the Data	64
Data Used in Matching Students	64
Data from Criterion Instruments	70
Tests of the Hypotheses	74
Preliminary Hypotheses	74
Basic Null Hypotheses	80
V. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS	84
Summary	84
Conclusions	88
Recommendations	91
BIBLIOGRAPHY	94
APPENDIX 1. Cornell Critical Thinking Test, Form Z	107
APPENDIX 2. Knowledge of Facts and Principles Test Program A	122
APPENDIX 3. Knowledge of Facts and Principles Test Programs B and C	134

LIST OF TABLES

Table	Page
1. Topics and Number of Items for Knowledge of Facts and Principles Test	57
2. Bloom's Taxonomy Classification for Each Question of the Two Criterion Instruments Used to Measure Student Knowledge of Facts and Principles of Chemistry	58
3. Data Used in Matching Four-year Institution Students to Community College Students in Program A	66
4. Data Used in Matching Four-year Institution Students to Community College Students in Program B	68
5. Data Used in Matching Four-year Institution Students to Community College Students in Program C	69
6. Summary of Data from Criterion Instruments Used in Program A	71
7. Summary of Data from Criterion Instruments Used in Program B	72
8. Summary of Data from Criterion Instruments Used in Program C	73
9. Reliability Calculations for Criterion Instruments Used in Program A, B, and C	75
10. The Number of Students from the Participating Institutions for the Three Different General Chemistry Programs	85

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I. INTRODUCTION

American higher education, with its roots in the educational institutions of Western Europe, has adapted itself in many ways to the peculiar social, economic, political, and cultural conditions and needs of its own society. Medsker (87, p. 5) notes that in this process, ". . . American Higher Education has created two unique institutions, found nowhere else in the world. They are the two-year college, increasingly called the community college, and the four-year liberal arts college."

Since its inception in the early years of the twentieth century, the two-year college has grown from an insignificant part of American Higher Education to a point where it can now be considered a major force in the dynamics of modern higher education. This growth is exemplified by Gleazer's (48, p. 3) report that one student in every four beginning his program of higher education during 1963 in America enrolled in a two-year college. In some parts of the country this proportion was much greater. In the 33 counties supporting two-year colleges in Florida, 64 percent of the Florida College freshman were enrolled in community colleges. In several

states, such as New York, Illinois, Michigan and Mississippi, it is expected that within a few years at least half of the beginning college students will go to community colleges. Moreover, Medsker (72, p. 7) showed an anticipation in California that about 80 percent of all college bound high school graduates will enroll in two-year colleges by 1970.

At present there are more than 700 two-year colleges operating in this country enrolling nearly 1,000,000 students. In describing the current situation Ruopp (115, p. 1) points out that one hundred and thirty new community colleges were organized between 1963 and 1966. He predicts that more than 250 additional community colleges will organize between 1967 and 1971. This growth indicates that eventually two-year college campuses will be within commuting distance of the total population.

Much of this recent growth of community colleges has resulted from a re-emphasis of the philosophy stated at the establishment of the first community college in Joliet, Illinois (104, p. 1) This philosophy of education stated the belief that:

The American way of life holds that all human beings are supreme, hence of equal moral worth and are, therefore, entitled to equal opportunities to develop to their fullest capacities. The basic function of public education then should be to provide educational opportunity by teaching whatever needs to be learned to whoever needs to learn it, whenever he needs to learn it.

In order to make this philosophy operational, an ideal image of the community college must also be stated. Gleazer (49, p. 1) enunciates the concept of this ideal when he says:

A good community college will be honestly, gladly, and clearly a community institution. It is in and of the community. The community is used as an extension of classroom and laboratory. Drawing upon the history, traditions, personnel, problems, assets and liabilities of the community, it declares its role and finds this accepted and understood by faculty, administration, students, and the citizenry.

With an operational philosophy and an ideal image of the community college in mind, one can better appreciate the development of the present day purposes of the community college. The purposes of the community college have been restated many times during the last forty years. Such statements support the ideology of an ideal type of educational institution standing between secondary schools and four year colleges and universities. One such statement by Crawford (24, p. 1-2) makes apparent the comprehensive view of the educational objectives of the community college in terms of the purposes it should serve:

. . . it is appropriate for community colleges to provide, for all persons above the twelfth-grade age levels, education consistent with the purposes of the individuals and the society of which they are a part, subject only to the restrictions in the state statutes. . . . The educational needs appropriate for community colleges to fulfill at this time include:

1. The need for programs of liberal arts and science courses, usual to the first and second years of

college, which will provide sound general and pre-professional education of such quality that credits may be transferred to a nationally or regionally accredited four year college or university and applied toward degrees of the baccalaureate level or higher.

2. The need for vocational and technical programs in the trades, industrial, agricultural, and semi-professional fields. Such programs may be of long or short duration, depending on the amount of time needed by the student to complete the requirements for entrance into the occupation.
3. The need for programs of courses for adults and other community college students, for which credit may or may not be given, designed to provide general education and to improve self-government, healthful living, understanding (of) civic and public affairs, avocational growth, constructive use of leisure time, personal and family living satisfactions, cultural depth, and to facilitate occupational advancement.
4. The need for individual services to students including guidance and counseling, assistance in career selection, removal of deficiencies in preparation for college programs, personality and health improvement.
5. The need for programs and services for individuals and groups interested in cultural, civic, recreational, or other community betterment projects.

This list of purposes concisely illustrates the uniqueness of the community college as compared with the secondary school and the university. Because the community college stands between these two segments of the public educational system, it must and does face simultaneously in both directions, serves the needs of students who intend to complete the requirements for a baccalaureate or higher degrees and at the same time, provides other needed educational

services to a complex society. These purposes can be viewed in a number of different ways. First, the college provides educational services for young people who will eventually transfer to four year colleges as well as for those who will terminate their formal studies at the end of one course, one term, or the two-year period. Second, the college makes available various adaptations of standard courses and sequences of study for specific individual and societal needs.

The two-year college is probably more diverse in defined functions, programs, clientele, and philosophical bases than any other educational institution in existence. Fields (40, p. 63-95), in his analysis of community and junior colleges, identified five fundamental characteristics which he thought clearly established the uniqueness of this institution.

1. Democratic - low tuition and other costs; nonselective admission policies; geographically and socially accessible; and popularized education for the largest number of people.
2. Comprehensive - a wide range of students with widely varying abilities, aptitudes, and interests; a comprehensive curriculum to meet the broad needs of such students.
3. Community centered - locally supported and controlled; local resources utilized for educational purposes; a community service improving the general level of the community.
4. Dedicated to life-long education - educational programs for individuals of all ages and educational needs.

5. Adaptable - to individual differences among students, differences in communities, and the changing needs of society.

Thus we see that the comprehensive community college is an organization of and for the people it serves. Its services are not confined exclusively to the traditional functions of the four-year colleges, but include activities which contribute to the general upgrading of society as a whole. Therefore, this study was confined to an evaluation of programs in only one phase of community college activity; that of the lower division collegiate transfer function.

Development of Community Colleges in Oregon

Population growth and society's changing educational demands in Oregon and throughout the nation have brought new responsibilities to Oregon's educational system. Important and revolutionary developments have taken place in industry, business, and agriculture and various means by which men and women earn their livelihood. The success of individuals depends upon their receiving an adequate education.

A great deal of study was given to post-high school education in Oregon and considerable legislation, as shown in Education Beyond the High School (107, p. 7-13) was produced during the second quarter of the century. But the legislation, which contained excellent philosophy, provided little financial assistance to implement the fine

intentions of its sponsors. Thus, after many years of consideration, the community college movement is relatively new in Oregon. The 1961 Oregon State Legislature finally came to grasp with the persisting issue and provided substantial state financial assistance for operation and building construction. The legislature passed Public Law ORS 341.510 establishing the comprehensive community college which was responsible to the State Board of Education, and was defined as (100, p. 1)

. . . a public secondary school established by a school district or by an area education district to provide terminal two-year programs for some, serve a transitional purpose for others who will continue college work, serve to determine future educational needs for other students, and provide means for adults to continue their academic education, vocational training, or attain entirely new skills as old occupations cease to exist and new technologies supplant them.

The comprehensive community college will carry an increasingly important role in the post-high school education of the youth and adults of Oregon's communities. The Oregon Community College Annual Report 1963-1964 (101, p. 33) states that in 1962 the total community college full time enrollment was 2884 or approximately 5 percent of all Oregon's post high school students. This report predicts that by 1980 there will be nearly 50,000 community college students or approximately 50 percent of all college students in Oregon. Various types of post-high school education are needed and desired. The community college has the resources and the capacity for flexible

organization to fulfill these needs and desires and to do so at a low cost to the student.

Although Oregon's community colleges have developed from diverse backgrounds within their individual locales, and their educational programs have been designed to meet the needs of given areas, every community college has the following structure for its program (101, p. 12):

1. Lower division collegiate
2. Vocational-technical and semi-professional programs
for full-time and part-time students.
3. General education for full-time and part-time students.

This study was concerned with lower division collegiate programs as designated by the Oregon State Department of Education (101, p. 11)

. . . as a transfer curriculum offering classes in the broad areas of fine arts, business, foreign languages, humanities, sciences, social sciences, and physical education. Students can complete freshman and sophomore requirements prior to pursuing a baccalaureate degree as a junior in a four year institution.

The curricula for these programs as described in The Oregon Community College Annual Report 1963-1964 (101, p. 18) are

. . . primarily transfer programs directed towards the pursuit of a baccalaureate degree, prescribed by the Oregon State System of Higher Education and intended to be parallel in content to freshman and sophomore courses in the state's four-year institutions of higher learning.

Statement of Problem

The purpose of this study was to compare the performance of community college students to four-year institutional students both of which are enrolled in one of three different programs of general chemistry for non-science majors. Therefore, after a completion of these programs, measurements, of student performance from the two types of institutions, were taken in terms of two important objectives of chemistry teaching; critical thinking ability and knowledge of facts and principles.

The three programs are defined as follows:

Program A - A Chemistry course for those students who have:

1. No high school chemistry background or;
2. A college board (S. A. T.) score of 451 or less in mathematics, or;
3. A total college board (S. A. T.) score of 861 or less in mathematics plus verbal or;
4. A high school grade point average (G. P. A.) of less than 2.5 (4.0 equals perfect)

This program is designed as an introductory elementary course of nine quarter hours credit and is a terminal course to be taken only by students who will not go on to take higher level chemistry courses.

Program B - This course is designed for students with the same

background and scores as those in Program A, but who do plan to go on and take higher level chemistry courses. This course is a minimum of twelve quarter hours. The greater number of hours will allow a more thorough approach and provide a better background.

Program C - A chemistry course for those students who have:

1. High school chemistry background and;
2. A college board (S. A. T.) score of 452 or above in mathematics, and;
3. A total college board (S. A. T.) score of 862 or above in mathematics plus verbal or;
4. A high school chemistry background and a high school grade point average (G. P. A.) of 2.5 or above (4.0 equals perfect)

This course is designed for the science related majors (engineering, forestry, etc.) but not for science majors (chemistry, pre-medical, etc.). It is a modern, and strictly college level general chemistry course in which the majority of general chemistry students are enrolled. The objectives of this program are similar to those of program B in that the course is designed to prepare students for additional courses in chemistry. Therefore, the criterion instruments used in Program C were identical to those used in Program B.

Definition of Terms

Many of the terms used in this study are defined as they are first introduced in the text of the dissertation. However, for purposes of clarity and emphasis, those terms which are cardinal to an understanding of the investigator's intent are here defined.

Community College Collegiate Student

Those students enrolled in the transfer program for twelve quarter hours or more per term at four selected Oregon Community Colleges; Lane Community College, Mt. Hood Community College, Portland Community College and Southwestern Oregon Community College.

Four-year Institution College Student

Those students enrolled in a four-year undergraduate curriculum for twelve quarter hours or more per term at Oregon State University or Portland State College.

Critical Thinking

Good (50, p. 424) defines critical thinking as thinking that proceeds on the basis of careful evaluation of premises and evidence and comes to conclusions cautiously through the consideration of all

pertinent factors. This concept of critical thinking was more precisely defined by the author of the critical thinking test used in this study as, ". . . the ability to correctly assess statements" (38, p. 599). Statements on this test were designed to measure proficiency in:

1. Induction: ability to judge whether a simple generalization or hypothesis is warranted.
2. Reliability: ability to judge whether an observation statement is reliable.
3. Deduction: ability to judge whether a statement follows from the premises.
4. Assumption-finding: ability to judge whether a statement is an assumption.

Critical thinking, as used in this study, refers to student proficiency in these four abilities.

Knowledge of Facts and Principles

As used in this study, a knowledge of those facts and principles in chemistry that are judged most important to success in the three general chemistry programs under study. These facts and principles were selected by the investigator and evaluated by a critique jury of experienced community college and four-year institution chemistry teachers.

Basic Assumptions

In this study it was assumed that:

1. The College Entrance Examination Board's Scholastic Aptitude Test mathematics scores are a valid and reliable measure of the student's general chemistry aptitude.
2. The high school math G. P. A. is a valid and reliable measure of the student's general chemistry aptitude.
3. Any significant statistical difference between the selected community colleges and four-year institutions on the tests are the result of real differences in the variables under comparison.
4. The Cornell Critical Thinking Test measures the students' ability to think critically.
5. The instruments used in this study to measure the students' knowledge of facts and principles in chemistry are valid and reliable.
6. The non-science major chemistry programs at the four-year institutions used in this study are representative of those found at other four-year institutions in Oregon.
7. The non-science major chemistry programs at the community colleges used in this study are representative of those found at other community colleges in Oregon.

Hypotheses To Be Tested

In order to determine the quality of non-science major general chemistry curricula at Oregon's community colleges, the following null hypotheses were tested:

Preliminary Hypotheses

1. There is no significant statistical difference between four-year institutions as measured by the mean scores on the Cornell Critical Thinking Test.
2. There is no significant statistical differences between community colleges as measured by the mean scores on the Cornell Critical Thinking Test.
3. There is no significant statistical difference between four-year institutions as measured by the mean scores on the knowledge of facts and principles tests.
4. There is no significant statistical differences between community colleges as measured by the mean scores on the knowledge of facts and principles tests.

Basic Null Hypotheses

1. There is no significant statistical difference between the community college and four-year institutional general

chemistry Program A in terms of student critical thinking ability.

2. There is no significant statistical difference between the community college and four-year institutional general chemistry Program B in terms of student critical thinking ability.
3. There is no significant statistical difference between the community college and four-year institutional general chemistry Program C in terms of student critical thinking ability.
4. There is no significant statistical difference between the community college and four-year institutional general chemistry Program A in terms of student knowledge of the fundamental facts and principles of chemistry.
5. There is no significant statistical difference between the community college and four-year institutional general chemistry Program B in terms of student knowledge of the fundamental facts and principles of chemistry.
6. There is no significant statistical difference between the community college and four-year institutional general chemistry Program C in terms of student knowledge of the fundamental facts and principles of chemistry.

Delimitations of the Study

This study was subjected to the following delimitations:

1. The population for this study was limited to a sample of those students enrolled in one of three lower division general chemistry programs at Lane, Mount Hood, Portland and Southwestern Oregon Community Colleges, Oregon State University, and Portland State College during the 1967-68 academic year.
2. Critical thinking ability and knowledge of facts and principles of chemistry were the only factors of concern in this study.
3. The instrument used to measure critical thinking abilities was a 60 minute test limited to the following aspects of critical thinking:
 - a. Induction: evaluation of evidence for or against a hypotheses.
 - b. Reliability: evaluation of the reliability of information
 - c. Deduction: logical reasoning ability.
 - d. Assumption-finding: recognition of assumptions.
4. The instruments used to measure knowledge of facts and principles in chemistry were 60 minute tests limited to those topics presented in the three general chemistry programs at the selected institutions. The instruments were

developed by the researcher and evaluated by a critique jury of experienced general chemistry teachers.

5. Evidence used to match students from both types of institutions, in order to assure equal initial chemistry aptitude, came from the College Entrance Examination Board's Scholastic Aptitude Test mathematics scores or high school math G. P. A. obtained from the participating institutions.

Importance of the Study

Increasingly, the community college is the means by which states are equalizing and expanding educational opportunity beyond the high school. Many state universities and state colleges have raised their standards for admission as well as tuition rates, which means that students of lesser opportunities, either academically or economically, must turn to community colleges in the public educational system. Furthermore, according to Medsker and Knoell (72, p. 1), several heavily populated states such as California, New York, Ohio, and Illinois, are encouraging students to take the first two years of a four year program in the community college.

Although Oregon's young community college program is just beginning to reflect these national trends, pressures will increasingly be placed on the community college to furnish a greater percentage of the lower division collegiates' education in the state and to maintain

the principles of public post-high school education to which the people of Oregon subscribe. An example of this was seen in an October 1966 address to the Oregon League of Women Voters by Milosh Popovich, Dean of Administration at Oregon State University, who predicted that by 1980 nearly 80 percent of the Oregon State University student body would be comprised of upper division and graduate students. This statement certainly indicates the significant role that the Oregon community college will play in lower division collegiate education. Therefore, if success in additional education beyond the fourteenth year is to be assured to students whose aptitude and achievement qualify them for it, it is critical that the community colleges, in addition to their several other functions, offer lower division collegiate programs that are comparable in content and quality to that of the four-year institutions.

II. REVIEW OF RELATED RESEARCH

Objectives of Science Education

In 1961, Hurd (64, p. 33) stated that the objectives of science education, as they have appeared in the literature, have changed little during the past twenty-five years. The following chronology substantiates Hurd's statement:

The Thirty-First Yearbook of the National Society for the Study of Education was one of the first attempts to help set the course of science education in the United States. Since this yearbook was published, a great deal of importance has been placed upon the role of science education in our society and upon the formulation of concrete statements of objectives for science education.

One of the first statements of objectives of science education was in Education for All American Youth, a report by the Educational Policies Commission of the National Education Association in 1944 (31, p. 133):

1. An educated person will understand that science is based upon methods which man must slowly and painstakingly develop for discovering, verifying, interpreting, and organizing the facts of the world in which we live and about the people in it.
2. He will know that the use of scientific methods has made revolutionary changes in man's way of living and thinking.

3. He will know that scientific advances have depended upon precise measurement and accurate calculations.
4. He will recognize that problems in human society as well as in the physical world should be attacked by scientific methods and a scientific point of view.
5. He will be familiar with certain fundamental principles and facts from the sciences, which when taken together, gives him a sound view of the nature of the world in which we live.

In review, these objectives fall into three general areas:

1. Problem-solving
2. Attitudes
3. Skills and abilities

In Science Education in American Schools, Part I of the Forty-Sixth Yearbook of the National Society for the Study of Education (96, p. 28-29), the main objectives of science education are:

1. Functional information
2. Functional concepts
3. Functional understanding of principles
4. Instrumental skills
5. Problem-solving skills
6. Attitudes
7. Appreciations
8. Interests

Nelson (99, p. 20-21) placed these objectives into three classifications:

1. Knowledge
2. Intellectual abilities and skills
3. The affective domain

In 1948, McGrath (86, p. 9) stated that the most important things a person can get from a science course are to see what science and scientists are really like. He also stated (86, p. 7) that science education should encourage a scientific attitude and critical thinking in everyday life.

In 1957, Richardson (111, p. 8-9) stated that science should be presented in such a way that students will:

1. Develop the ability to think critically, to use the method of science effectively.
2. Acquire the principles, concepts, facts and appreciations through which they can better understand and appreciate the nature of the earth, its inhabitants, and the universe.
3. Use wisely and effectively the natural resources of our earth as well as the products of science and technology.
4. Understand the social function of science and think and act in relation to the implications of science and technology for society.
5. Develop understandings that will contribute positively to their physical and mental health and their recreational interest.
6. Acquire information, understandings, and appreciations that will contribute to their educational and vocational guidance.

Burnett (16) listed objectives of science education similar to those of Richardson, but he stated that they should all help in

obtaining the higher objective of improving the critical thinking ability of students.

In Rethinking Science Education, Hurd (64, p. 33-37) presented the following model for science curriculum development:

1. Understanding of science. Pupils should acquire a useful command of science concepts and principles . . . they should learn something about the character of scientific knowledge, how it has been developed, and how it is used.
2. Problem solving. Science is a process focused upon inquiry and subsequent action. A process of inquiry involves careful observing, seeking the most reliable data, and then using rational processes to give order to the data and to suggest possible conclusions of further research.
3. The social aspects of science. A student should understand the relation of basic research to applied research, and the interplay of technological innovations and human affairs.
4. Abilities. Students need to acquire those skills and abilities which will enable them to assume responsibility for expanding their own learning. Some of these are:
 - a. Locating authoritative sources of science information.
 - b. Making valid inferences and predictions from data.
 - c. Recognizing and evaluating assumptions.
 - d. Recognizing pertinency and adequacy of data.
 - e. Seeking new relationships.

In Science and Public Policy (65, p. 91), the United States President's Scientific Research Board said that students should gain an understanding of:

1. The methods of science

2. The influence of science upon human life and thought
3. The facts and principles essential to an understanding of themselves and their environment
4. An appreciation of the scientific enterprise

In 1961, the following long range objectives of science education were presented by the National Science Teachers Association (124, p. 28):

1. As a result of science education, students should habitually and skillfully employ sound thinking habits in meeting problem situations.
2. Students must acquire a working concept of the relations between science and individuals, and science and technology.
3. They should not only carry on sound thinking, they should have a fund of reliable knowledge with which to think.

In 1963, the Commission of Science of the American Association for the Advancement of Science presented the following objectives (70, p. 4-6):

1. Science as inquiry. Science is best taught as a procedure of inquiry. It is a structured and directed way of asking and answering questions.
2. The scientific attitude. The discipline of scientific inquiry demands respect for the work of the past together with a willingness to question the claims of authority. The attitude of intelligent caution, the restraint of commitment, the belief that difficult problems are always susceptible to scientific analysis, the courage to maintain doubt . . . will be learned through inquiry.
3. The processes of science. The statement of a problem . . . ability to recognize and use sources of reliable information . . . ability to observe . . . comparison of phenomena . . . and ability to evaluate evidence and draw conclusions . . . should be developed.

4. Scientific knowledge. A knowledge of the basic findings about the universe, the structure and reactions of matter, the conservation and transformation of energy, the interaction of living things and their environment . . . give boundaries and direction to scientific inquiry.

In 1964, Cohen (21, p. 32-33) presented the following goals for science teaching:

1. To provide enough understanding to enable the educated citizens to collaborate intelligently with those who are actively engaged in scientific pursuits.
2. To enable the citizen both to criticize and to appreciate the effects of the sciences on his society.
3. To give a practical grasp of scientific methods of grappling with problems, at least sufficient for problems which the student will face in his individual and social life.
4. To understand the place of science among other intellectual and esthetic pursuits; briefly, to see the sciences as being themselves a humanistic enterprise.
5. To provide our students with rich and various experiences of individual thinking and critical attitudes.

Also in 1964, the following statement appeared in Theory Into

Action (93, p. 32):

One of the first tasks in teaching science is to teach the inquiry process of science. By means of extensive experiences in inquiry the student learns to place objects and events in categories and classes. He establishes a conceptual framework. This conceptual framework, in turn, focuses his attention on other phenomena and helps him build new categories which are more comprehensive or more abstract. The conceptual scheme ties past experience to the present and serves as a guide for the comprehension and assimilation of new facts and concepts. It serves as a basis for prediction of what will happen in a new problem situation.

In 1966, Tyler (129, p. 11-14) presented the report of a committee of science teachers, curriculum specialists, and scientists called together by the Educational Testing Service. They stated that students should come to:

1. Know the fundamental facts and principles of science.
2. Possess the abilities and skills needed to engage in the processes of science.
3. Understand the investigative nature of science.
4. Have attitudes about and appreciations of scientists, science, and the consequences of science that stem from adequate understanding.

Hammond (55, p. 48), in discussing the objectives of undergraduate chemistry education, states:

Certainly an important objective of undergraduate chemistry education is to provide students with knowledge of fundamental chemical facts and principles. However, accumulated information has already reached such mammoth proportions that it is impossible to include everything of importance in a college curriculum. Therefore, course content should be selected with care and emphasis placed on teaching students to think more effectively.

Summary:

Although the statements of objectives of the various scientists, science educators, committees, and associations are not exactly the same, some general areas of agreement emerge. These common areas are:

1. To be able to think critically and to evaluate facts and data.
2. To gain an understanding of the fundamental facts and

principles of science.

3. To understand the investigative nature of science and its role in our society.
4. To have appreciations of science and scientists.

Studies in Critical Thinking

Burton, Kimball, and Wing (17), Dale (25), Dressel (28), Edwards (32), and many others have stated that one of the principle goals of education should be to teach students to think. Burnett (16) and Richardson (111) specify critical thinking as one of the major goals of science education.

The number of studies devoted to critical thinking is exceedingly large. To facilitate the review of this research, two categories were used; the nature of critical thinking and the teaching of critical thinking.

The Nature of Critical Thinking

Edwards (32, p. 269-270) stated:

The teaching of critical thinking in the schools is established as an objective by means of an authoritative, dogmatic statement. Accepting this objective there are many teachers who try hard to improve the critical thinking ability of their pupils. They are not content to assume that proof of the acquisition of knowledge is also proof that such knowledge will be rightly used.

It appears that ability to do critical thinking is a valid objective of the schools in that it is possible to isolate techniques

of critical thinking and test for the acquisition of skill in the use of these techniques.

On the other hand, if pupils are to be taught to think they must first be given something to think about. Thinking is possible only with familiar concepts for most people. Pupils will not, in general, be able to think about materials to which they have been merely exposed.

Many factors seem to be related to critical thinking abilities, but there are conflicting reports in the literature. The Watson-Glaser Critical Thinking Appraisal was reported to have a correlation of .48 to .68 to several intelligence tests. In a study involving high school students, Teichman (126, p. 268-279) reported that intelligence was related to the students' ability to reach conclusions on items in science. Alpern (1, p. 220-226) reported a positive correlation between intelligence quotient and high school students' ability to devise or choose tests of scientific hypotheses. The studies by Alpern (1), and also Furst (43), seem to support the hypothesis that students have a critical thinking ability in much the same manner as they have intellectual ability. However, Sorenson (121) reported no relationship between a student's mental ability and change in critical thinking ability, based on the results of the Watson-Glaser Critical Thinking Appraisal and the Cornell Critical Thinking Test, Form X. In a more striking contrast, Mandell (83) reported a negative relationship between intelligence quotient and improvement in critical thinking ability. His subgroups having average or below-average

intelligence scores showed a significant increase in critical thinking and achievement when compared to the sub-group having above average intelligence.

Kopans (75) stated that complex abilities, such as critical thinking, develop slowly. Using selected items from the Watson-Glaser Critical Thinking Appraisal, he found that when controlled by age and intelligence, social science majors showed significant improvement over science majors, but only on the controversial items on the appraisal form. There were no significant differences on the other aspects.

Fox (42, p. 357), in a discussion of the nature of critical thinking, stated:

Procedures which were reported to be most difficult to use require higher levels of critical thinking on the part of the students -- to analyse, interpret, and evaluate information; and to determine the most reasonable and logical conclusions. The procedures which were reported to be the least difficult to use are the procedures for gathering information, and most of them require only a passive type of thinking or learning on the part of the students -- to gain information from audio-visual aids, to gain information by listening to others. This doesn't mean that such activities are without value, on the contrary, they are essential procedures for developing skill in critical thinking and for solving problems. However, they are only preliminary steps in critical thinking, not ends in themselves.

The Teaching of Critical Thinking

Edwards (32) reviewed studies by Fawcett in geometry, Glaser

in language arts, and Thelen in Chemistry which concluded that pupils can be taught to think critically. He also reported that chemistry students in an experimental group showed significant gains over control groups after having been exposed to activities designed specifically to develop critical thinking abilities.

Hurd (65), in a review of several studies in science education, stated that Weisman found that students could be taught critical thinking skills when a course is structured about problems and problem-solving activities.

Brown (14) reported that chemistry students made greater gains in growth in critical thinking ability than non-chemistry students, as measured by the Cornell Critical Thinking Test, Form X.

Chenowith (19) and Herber (61) both reported that students made significant gains in critical thinking when exposed to materials which were specifically designed to improve this ability. Herber (61) also reported that sex, grade, and course affect the development of critical thinking ability.

In a study involving nineteen universities and colleges, Dressel and Mayhew (30, p. 390-391) stated that institutions offering special critical thinking courses had no advantage over other institutions, since only small gains were recorded in critical thinking ability in a course of this type. These researchers found that the greatest gain in critical thinking ability occurred during the freshman year and that

greater gains were registered when an entire curriculum was devoted to the development of critical thinking abilities. They concluded that the objective of critical thinking was frequently not attained because the activities only involved reading or studying about the thinking of others.

Mason (85, p. 283) in a study of scientific thinking in a college biological science course, concluded:

1. The ability to think scientifically can be a concomitant outcome of science education.
2. Ability to think scientifically can be taught more effectively when the students are given direct training in the methods of science than when they do not receive such training.
3. Problem-solving can be an effective method for teaching both facts and skills inherent in the methods of science.

Henderson (58) reported an experiment on the teaching of logical and critical thinking which involved approximately 1500 high school students in English, geometry, and social studies. Activities designed to foster critical thinking were used, and the mean gain during one school year was in favor of the experimental class when measured by the Watson-Glaser Critical Thinking Appraisal. Mean gains on the American Council on Education Test of Critical Thinking were not significant at the five percent level.

Rust (117) reported an attempt to teach critical thinking which involved approximately three thousand students. About one-third

served as a control, while the remainder were given activities involving critical thinking in connection with classes in English, mathematics, science, and social studies. Few significant differences were found between experimental and control groups, but the testing produced a low intercorrelation among the Watson-Glaser Critical Thinking Appraisal, the American Council on Education Test of Critical Thinking, and a test of critical thinking constructed by the investigator.

Wallen (132), in an investigation involving seven U. S. history teachers, found that the experimental group, which had received a three week introduction involving critical thinking activities, registered a significant increase in critical thinking ability over the control group, which did not receive the introduction. These results were obtained with the Induction, Deduction, Semantics Critical Thinking Test constructed by Ennis (35), but when tested by the Watson-Glaser Critical Thinking Appraisal, no significant differences were recorded.

Howe (63, p. 202) in a study of biology teaching in Oregon, reported that positive gains in critical thinking were obtained in 44 of 51 biology classes studied. He used the Watson-Glaser Critical Thinking Appraisal in a pretest and post-test design. The majority of the high gains in critical thinking ability were obtained in classes using the problem-solving approach with instruction and practice in

critical thinking.

Kastrinos (68) reported that two different levels of biology classes, which utilized a principles-critical thinking approach, produced significant improvements in critical thinking when compared to traditional courses taught by the same instructors. The results were obtained with the Watson-Glaser Critical Thinking Appraisal.

Sorenson (121) reported that students in laboratory-centered high school biology courses registered significant gains in critical thinking when mean scores on the Watson-Glaser Critical Thinking Appraisal and Cornell Critical Thinking Test, Form X were controlled by intelligence scores.

Crall (22), in a study of high school biology students, compared an experimental class involving learning and application of principles with a traditionally taught class. Both the control and experimental group registered gains in critical thinking ability as measured by written tests and teacher observation. He noted that a direct method of instruction produced a higher degree of gains in critical thinking ability.

Kemp (69), in a study involving students with "open" belief systems and "closed" belief systems, reported that students with "open" belief systems registered significantly higher achievement in critical thinking. He also reported that small groups of students involved in direct instruction showed the greatest gains in critical

thinking skills.

Yudin (136) found that an experimental college freshman group involved in a program designed to improve critical thinking showed no significant gains in critical thinking ability when comparing two methods of instruction.

Richert (112) reported that students involved in a one semester experimental physical science course which provided opportunities to analyze problems, to examine assumptions, to collect and organize data, and to test hypotheses, registered significantly greater gains on the American Council on Education Test of Critical Thinking than students in a physical science survey course and students in a physics course.

Lee (78), in a post-test only design, studied the effect of two methods of teaching high school chemistry upon critical thinking abilities. After an eleven-week period, there were no significant differences between the experimental group, which engaged in problem-solving activities, and the control group, as measured by the Watson-Glaser Critical Thinking Appraisal.

Anderson (7), in a comparative study involving Chemical Education Materials Study and traditional chemistry, reported no significant differences between the two groups, as measured by the Watson-Glaser Critical Thinking Appraisal.

Boeck (11), Edwards (32), and Montague (89) conducted separate

studies involving experimental chemistry classes emphasizing critical thinking processes, and in each case the experimental groups showed significant gains when compared to the control groups.

Fogg (41) evaluated the effect of two different testing techniques on the critical thinking ability of 551 university freshmen. In the experimental test, the student was required to indicate all alternatives which he felt were wrong. The control test was the standard five-choice multiple-choice type of examination. The gains registered by the experimental group were significantly greater than those of the control group, as measured by the Watson-Glaser Critical Thinking Appraisal.

Graham (51) investigated the effect of student-centered classes on critical thinking ability. Eighty students were matched using scores on the Otis Mental Ability Test and the Watson-Glaser Critical Thinking Appraisal as pre-tests. The experimental group registered significantly greater gains over the control group taught by the same instructor.

Dressel and Mayhew (30) concluded that minor changes in a course are not adequate to bring about changes in critical thinking ability when the major emphasis of a course remains on the coverage of content.

Lehmann (79) studied changes in critical thinking abilities of 1,051 students at Michigan State University from the beginning of

freshman orientation week until near the end of the senior year. Using the American Council on Education Critical Thinking Test, he found that the greatest change occurred during the freshman and sophomore years. He also found that males did not gain significantly in critical thinking abilities over females.

Craven (23), in a study involving teacher-candidates and in-service teachers at Oregon State University, reported that the critical thinking abilities of science teacher-candidates were significantly greater (at the five percent level) than those of freshmen in social science education, freshmen in science education, elementary teacher-candidates, and in-service science teachers.

Dressel and Mayhew (30, p. 180-181) summarized the nature of critical thinking research to date:

Much of the research accomplished to date has been divorced from teaching practice. In this same connection, there is a noticeable lack of suggestions and evidence as to how critical thinking can be taught. Still one further weakness in critical thinking research lies in the fact that the way it is presented too often suggests that emphasizing critical thinking can be a mechanical sort of operation tacked onto some particular college course.

Having pointed out the lack of adequate research to date, we are constrained to advance some ideas which we believe might be fruitful in the area of critical thinking. Perhaps the first step in the development of major research in this area is for teachers to become concerned about the development of thinking on the part of their students. So long as teachers are unaware or unconcerned about the apparent fact that imparting information by means of class lectures or reading textbooks is relatively ineffective in the development of the higher mental processes, the importance of

research in connection with critical thinking is likely to be overlooked.

To fulfill the major need of research in connection with critical thinking, it is essential for such research to be basically oriented toward and integrally related to classroom practice.

Glaser (47, p. 418), in discussing the objective of thinking, stated:

Such evidence as there is points to the development of critical thinking as a long term task in which but small gains will be shown for any particular course. It is, therefore, of the utmost importance that fostering the ability to think critically becomes the aim of all teachers for the entire period of a student's schooling . . . Critical thinking, then, is evidently the deserved goal of education in the achievement which promises that there will be a life-long interest in learning.

It appears, then, that critical thinking abilities can be developed in students when specific activities are directed toward this goal. Critical thinking should be an essential objective of modern education, and not simply something that is hoped will be developed during the pursuit of other objectives.

Studies in Knowledge of Facts and Principles in General College Chemistry

There are many studies dealing with all aspects and levels of chemistry instruction. The investigator will limit this section to include only those studies concerned with measurement of student knowledge of facts and principles encountered in general college

chemistry courses.

Vavoulis (131), randomly placed two hundred students in either an experimental laboratory-centered or traditional lecture-centered general college chemistry course. Both groups were taught by the same instructor and tested at the end of one semester for their knowledge of the subject matter and attitudes toward science. The instruments used in this study were composed of objective multiple-choice items developed by the investigator and evaluated by a critique jury. For statistical comparisons only those students that could be matched by College Entrance Examination Board (S. A. T.) Mathematics plus Verbal Test scores were used. The study revealed that there was no significant statistical difference (at the five percent level) between the two approaches in terms of student knowledge of subject matter and science attitudes.

Broberg (13), investigated the relative effectiveness of the mole approach and the ratio proportion method of solving mathematical problems with respect to a knowledge of laws, facts and principles, and mathematical problem solving in general college chemistry. This study was conducted at North Dakota State University during the 1959-1960 academic year. The comparability of students was established by use of ACE Psychological Examination, Form 1947 and a local Mathematics Achievement Examination. Final achievement was measured by an investigator-made examination

consisting of eleven mathematical problems in general chemistry (reliability .81) and sixty four objective type items measuring the ability to apply laws, facts and principles of chemistry (reliability .85). Using an analysis of covariance statistical approach the results indicated no statistical significant difference between the two approaches.

Riggs (113) compared students, with a high school chemistry background, who were now enrolled in different sections of a general chemistry course which employed one of two different laboratory approaches. One group used a laboratory manual following detailed instructions. The other group attempted to solve research type problems. The effectiveness of the two approaches was tested by employing two problem-solving examinations and two achievement examinations. One of the problem-solving examinations was developed by the investigator and was submitted to a critique jury for analysis. The other consisted of selected test items from several American Chemical Society Cooperative Examinations in General Chemistry. The testing was a pre and post-test situation. Analysis of the differences between pre and post-test individual scores on both type of examinations indicated there was no statistical difference in the two laboratory approaches.

Brewington (12), in an attempt to find reliable predictors for success in college chemistry, analyzed several variables of high and

low achieving general chemistry students at the University of Arkansas during the 1961-1962 academic year. He found high school math grade point average to be a reliable and statistically significant predictor of success in general chemistry courses.

Geller (45) in a study at New York University compared a group of general chemistry students taught solely by teaching machines during the lecture time to another group taught by more conventional lecture-demonstration techniques. Both groups had the same homework assignments and laboratory work. The students were originally matched by College Entrance Examination Board Test (S. A. T.) scores. The subject matter examination was an objective multiple-choice test developed by the researcher. The results indicated no statistical difference (at the five percent level) between the two approaches in terms of the students' knowledge of facts and principles of chemistry.

Montague (90), at Ohio State University, compared two hundred general college chemistry students using a laboratory manual in their laboratory work to a similar group that were given a series of problem-solving experiences involving open-ended experiments. The students were matched by scores on Ohio State Psychological Examination and A Test of Aspects of Scientific Thinking by Burmester. The post-tests included A Test of Aspects of Scientific Thinking, Watson-Glaser Critical Thinking Appraisal and a

performance test in laboratory problem solving developed by the researcher and evaluated by experienced general chemistry instructors. The results indicated a significant improvement (at the five percent level) in the experimental group's problem solving ability.

Milne (88), in 1964 investigated programmed instruction as a method of tutoring general chemistry students at Washington State University. He used a control group of three units of twenty four students each taught by a graduate student. The experimental group consisted of seventy two students using programmed instructional materials developed by the researcher. Students were originally matched by College Entrance Examination Board Test (S. A. T.) scores in mathematics. The post-test was an objective multiple-choice test developed by the researcher. The results of the study indicated no significant difference in the two approaches to tutoring general chemistry students.

Stoppel (125), compared two different methods of teaching general college chemistry at the University of Minnesota. Four hundred seventy two students were randomly placed in one of two different programs. The experimental program involved a mathematical approach to chemistry fundamentals while the control program was descriptive with a minimum of mathematics. Students were originally administered the School and College Ability Test (S. C. A. T.), Form IA, in order to match general academic ability.

Two criteria were selected for the purpose of contrasting the effectiveness of the two approaches:

1. Knowledge of facts and principles in chemistry;
2. Ability to apply such knowledge in the solution of practical and theoretical problem situations.

Both outcomes were measured through the use of multiple-choice objective examinations prepared by the investigator and evaluated by a critique jury of experienced chemistry instructors (knowledge reliability equals .82, application reliability equals .77). The results of the study indicated no significant difference between the two approaches as measured by the above criteria.

Although the above studies have quite different intentions from those of this study, the investigative procedures used give support to those selected for this research. It is also significant to note that there are no studies dealing with community college general chemistry curriculum which indicates a need for further research in this area.

Four-year Institution - Community
College Comparative Studies

The success of community or junior college students in upper division collegiate work has been reported by many investigators. Grossman (52) and Koos (74) found over thirty years ago that junior college students were able to pursue junior and senior level

coursework at universities with equal or greater success than native university students. Eells (33) reported similar findings over thirty years ago at Stanford University. More recently, Henry (60), Klitzke (71), Martorana (84), and Medsker (87) reported similar findings.

Although the above studies indicate that junior college transfers are capable of success in upper division university work, Hennessy (59) reported that transfer students at the University of Michigan had lower grade point averages than native university students. He also noted that female transfer students were particularly deficient.

Nall (92) reported that junior college transfer students at the University of Colorado are academically less successful in both scholarship and persistency than are native university students. One notable exception emerged, however--transfer students in the college of engineering equaled or excelled matched native students in scholastic average.

Hagie (54) reported that junior college students were different from university students in that they came from lower socio-economic families, were more interested in semi-professional preparation, were attracted by the lower cost of junior colleges, and generally lived within short commuting distance of the junior college. Some of these findings were supported by Rice (110) who reported that white Mississippi junior college students, when

compared with similar white undergraduate lower division university students, came from the lower socio-economic levels, scored significantly lower on tests of academic aptitude, and indicated a lower educational level reached by their parents.

Howard (62, p. 97-98) reported the following:

The typical male freshman at Oregon State University was primarily oriented toward specific vocational goals in the scientific and technological areas. He attended high school in a relatively large community in Oregon, and obtained a B grade point average. Although practically self-supporting, he believed his family capable of paying his college expenses. His interest was in acquiring knowledge because it was useful, but he had relatively little concern for aesthetic or social values. The community college male, who was somewhat older because his schooling had been interrupted, believed that education had value in attaining economic success. The income of his family was not sufficient to provide for college training, and he was expected to provide the financial cost himself. He expressed more concern for social welfare than his counterpart at Oregon State University, and the values most important to him were political and economic.

The female at Oregon State University came from a home in which economic level was high and the parents were college trained. She expressed more concern with maintenance of her high economic status and placed value on the activities which furthered this goal, in contrast to the community college female who placed less value on economic goals than on any other. The Oregon State University female was less religious than the community college female. However, there was no clear-cut differentiation between females at Oregon State University and the community college, other than the difference in socio-economic status and variables related to this status.

Fields (40), reporting in general terms, stated that average ability, as measured by college entrance tests, was lower for the junior college student than for the student attending a liberal arts college

or university.

Iffert (67) obtained 2661 classroom evaluations from former students at 170 two and four-year colleges. The results indicated a significant difference in favor of the two year school, based on such items as teaching ability, assistance from instructors, and opportunity to confer with the teacher. It should be noted, however, that these results did not provide a qualitative measure of the actual learning which took place.

In the only investigation reported to date involving a comparison of student performance in similar community college and university courses, Kochersberger (73) investigated achievement in similar undergraduate biology courses. He reported no significant difference between community college and university students as measured by a common test of the principles of biology. He reported that more D and F grades were given to the university students, and concluded that low ability students performed better in the community college atmosphere.

In summary, many studies have been carried out comparing the success of junior and community college transfer students with native upper division university students. The differences in attitude, socio-economic level, and ability have also been investigated. The presence of only one comparative study involving community college

students and university students in a course that is supposed to be equivalent in both institutions demonstrates the need for further research in this area.

III. DESIGN OF THE STUDY

The design of this study was directed toward investigating the performance of comparable students who are enrolled in one of three different general chemistry programs at either of four community colleges or two four-year institutions. Performance was measured in terms of two criteria: (1) critical thinking ability and (2) knowledge of facts and principles of chemistry.

The Experimental Design

The research design was a Posttest-Only Control Group model suggested by Campbell and Stanley (44, p. 195). They argue that:

While the pretest is a concept deeply embedded in the thinking of research workers in education, it is not actually essential to true experimental designs. . . . many problems exist for which pretests are unavailable, inconvenient, or likely to be reactive, and for which (this) design is greatly underused in educational and psychological research.

The research design described by Campbell and Stanley may be designated:

$$\begin{array}{ccc} R_{1A, 1B, 1C} & X & O_1 O_2 \\ R_{2A, 2B, 2C} & & O_1 O_2 \end{array}$$

Where R_1 , R_2 represent community college and four-year institution students respectively, A, B, and C represent the three different general chemistry programs. The experimental variable,

X, was the community college instruction in general college chemistry. The four-year institution groups served as controls. The Cornell Critical Thinking Test, Form Z and the knowledge of facts and principles tests were the criterion instruments, O_1 and O_2 .

To assure that the experimental and control groups were "equal" before the differential experimental treatment, the control groups were matched to the completely randomized experimental groups by Scholastic Aptitude Test scores in mathematics or, where these were not available, high school math grade point averages (G. P. A.) were used. Students were considered comparable if their S. A. T. math scores were in the same decile ranking or if their high school math grade point averages were within plus or minus .1.

The Population

The population for this investigation consisted of full-time students enrolled in one of three different general chemistry programs at either of four community colleges or two four-year institutions in Oregon. The purpose of this section is to provide a description of these six participating institutions and the students matriculating them.

Community Colleges

Lane Community College (LCC) located in Eugene, Oregon, began operation as a legally constituted tax supported institution on July 1, 1965. During the 1967-68 academic year the college enrollment for full time students reached 2100.

The college catalog (76, p. 7) states that the offerings

. . . vary from single courses to those necessary for an Associate of Arts or an Associate of Science degree. The college maintains an open door policy, affording educational opportunity for all.

Lane provides two years of post-high school education in three broad areas (76, p. 8).

1. Liberal arts and pre-professional lower division collegiate education for transfer to higher institutions offering baccalaureate degrees.
2. Occupational education for preparation for employment in technical and vocational fields.
3. General education for personal growth, enrichment and advancement.

The chemistry courses offered are (76, p. 117):

1. Ch 101, 102, 103 (Program A) 200 students enrolled
2. Ch 101, 102, 103, 241 (Program B) 18 students enrolled
3. Ch 201, 202, 203 (Program C) 84 students enrolled

Mt. Hood Community College (MHCC) located in Gresham, Oregon, offered its first courses in September 1966. During the 1967-68 academic year, 1340 full time students enrolled at the

college. As stated in the college catalog (91, p. 9)

The prime objective of MHCC is to offer education organized and conducted to provide, at appropriate levels, proper combinations of general and specific programs of study for students of varying abilities and occupational service to the entire community. . . . To that end the college offers the following programs:

- A. Lower division pre-professional courses comparable to the first two years in any senior college or university.
- B. Training to prepare students to take their places in the vocational-technical fields or to upgrade themselves while pursuing their vocations.
- C. General education for those desirous of personal improvement.

The chemistry courses offered are (91, p. 40):

- 1. Ch 101, 102, 103 (Program A) 60 students enrolled
- 2. Ch 101, 102, 103, 241 (Program B) 25 students enrolled
- 3. Ch 201, 202, 203 (Program C) 80 students enrolled

Portland Community College (PCC) located in Portland, Oregon, opened its doors for operation in September, 1961. It operates as part of the Portland Public Schools and is governed by the Portland School Board. During the 1967-68 academic year there were 5400 full time students enrolled.

Portland Community College believes that (105, p. 17):

All individuals in a democracy, regardless of age or ability, should be provided the opportunity to develop to the maximum of their potentials and interests.

Education is a lifelong process, and programs covering many facets of knowledge should be made available to all ages of the adult population.

Education should include the knowledge, skills, attitudes and understanding necessary for a rewarding and enriched life.

In keeping with their philosophy the college offers:

- A. Liberal arts and pre-professional education (transfer programs)
- B. Vocational-technical programs
- C. Adult enrichment

The chemistry courses are (105, p. 33):

- 1. Ch 101, 102, 103 (Program A) 100 students enrolled
- 2. Ch 101, 102, 103, 241 (Program B) 16 students enrolled
- 3. Ch 201, 202, 203 (Program C) 100 students enrolled

Southwestern Oregon Community College (SWOCC) located in Coos

Bay, Oregon, was officially voted into existence in December of 1960. During the 1967-68 academic year over 1600 students were enrolled.

The philosophy of Southwestern Oregon Community College is (122, p. 12):

To serve college-bound youth, youth aspiring to a career in a technical field, adults seeking cultural or general education experiences, and workers desiring to keep abreast of new developments in their field or to gain new skills.

To implement this philosophy the institution offers the following programs:

- A. Lower Division Collegiate

- B. Occupational-Vocational
- C. Continuing Education
- D. General Education
- E. Community Services

The chemistry courses offered are (122, p. 34):

- 1. Ch 101, 102, 103 (Program A) 45 students enrolled
- 2. Ch 101, 102, 103, 241 (Program B) 17 students enrolled
- 3. Ch 201, 202, 203 (Program C) 60 students enrolled

Four Year Institutions

Oregon State University (OSU) (102, p. 7) established in 1859 and located in Corvallis, Oregon, is a coeducational, land-grant university operated under the Oregon State Board of Higher Education. University undergraduates are enrolled in the liberal arts and sciences and in seven professional schools; agriculture, business and technology, education, engineering, forestry, home economics, and pharmacy. During the 1967-68 academic year nearly 13,000 full time students were enrolled at the university.

The chemistry courses offered are (102, p. 53):

- 1. Ch 101, 102, 103 (Program A) 300 students enrolled
- 2. Ch 104, 105, 106 (Program B) 300 students enrolled
- 3. Ch 201, 202, 203 (Program C) 900 students enrolled

Portland State College (PSC) (106, p. 7) established in 1955 and located in Portland, Oregon, is a coeducational, state public college operated under the Oregon State Board of Higher Education. College undergraduates are enrolled in the liberal arts and sciences and in the professional schools of education and business administration. During the 1967-68 academic year over 10,000 full time students matriculated the college.

The chemistry courses offered are (106, p. 23):

1. Ch 104, 105, 106 (Program A) 300 students enrolled
2. Ch 104, 105, 106, 223 (Program B) 50 students enrolled
3. Ch 201, 202, 203 (Program C) 100 students enrolled

The Evaluation Instruments

Cornell Critical Thinking Test

The Cornell Critical Thinking Test, Form Z was selected to evaluate student critical thinking ability. Form Z, an experimental edition copyrighted in 1961, consisted of 52 multiple choice items designed to reveal how well the student was able to correctly assess statements. Four aspects of critical thinking were measured by this test: (1) Induction: evaluation of evidence for or against a hypothesis; (2) Reliability: evaluation of the reliability of information; (3) Deduction : logical reasoning ability; and (4) Assumption-finding:

recognition of assumptions.

Ennis, author of the test, precisely defines critical thinking as follows (38, p. 599):

As a root notion, critical thinking is here taken to mean the correct assessing of statements. . . . if we set about to find out what a statement means to determine whether to accept or reject it, we would be engaged in thinking, which, for lack of a better term, we shall call critical thinking.

A critical thinker is characterized by proficiency in judging whether:

1. A statement follows from the premises.
2. Something is an assumption.
3. An observation statement is reliable.
4. A simple generalization is warranted.
5. A theory is warranted.
6. An argument depends on an ambiguity.
7. A statement is overvague or overspecific.
8. An alleged authority is reliable.

In order to develop an operational definition of critical thinking for the purpose of designing a measuring instrument, the following important aspects of critical thinking were deliberately excluded (38, p. 600): (1) The judging of value statements; (2) Creative thinking; and (3) Judging whether a problem has been identified. Several aspects of critical thinking which are measured by the Cornell Critical Thinking Test have been amplified by Ennis (38, p. 604) as follows:

Judging whether a hypothesis is warranted. A hypothesis is warranted to the extent that:

1. It explains a bulk and variety of reliable data

2. It is itself explained by a satisfactory system of knowledge.
3. It is not inconsistent with any evidence.
4. Its competitors are inconsistent with the evidence. This is the basis of controlled experiments.
5. It is testable. It must be, or have been, possible to make predictions from it.

Judging whether an observation statement is reliable. Observation statements tend to be more reliable if the observer:

1. Was skilled at observing the sort of thing observed.
2. Had good sensory equipment in good condition.
3. Has a reputation for veracity.
4. Used precise techniques.
5. Had no preconception about the way the observation would turn out.

The above statements provide examples of the preciseness with which aspects of critical thinking have been defined by the author of the Cornell Critical Thinking Test. Several of the preceding statements of aspects of critical thinking are consistent with generally accepted objectives of science education.

General agreement between concepts of critical thinking measured by this test and those measured by other critical thinking tests analyzed by Dressel (30) and Rust (117) supports the validity of the criterion instrument. The previously mentioned consistency between generally accepted objectives of science education and the rather precisely defined aspects of critical thinking measured by the Cornell Critical Thinking Test, constitutes additional evidence of the validity of this test for use with science students.

The author of the CCTT supplied standardization data based

upon administration of the test to graduate and undergraduate students at Cornell University. Although limited, the data relative to the split-half reliability estimate does indicate an acceptable reliability level (.84) for the CCTT, Form Z.

Knowledge of Facts and Principles Tests

Two subject matter tests were developed by the researcher specifically for this investigation. Each test consisted of 60 multiple choice items representing 27 different topics. The topics were selected on the basis that they were common to all the general chemistry course outlines of the participating institutions. One test was developed for those students enrolled in Chemistry Program A and the other for Programs B and C. Selection of the test items for the different topics came from Dressel and Nelson's Questions and Problems in Science (28), A.C.S. Cooperative Examinations in General Chemistry (2), Chemistry advanced tests for the Graduate Record Examination (53), examinations furnished by instructors at all participating institutions, and items developed by the researcher. Nearly 1000 items were initially selected and classified into one of the 27 different topics. To provide a balance in types of test item, the questions were further classified according to the educational objectives in Bloom's Taxonomy. This classification consists of the following categories for test items (10).

1. Knowledge of specifics
2. Comprehension - interpretation
3. Application
4. Analysis - relationships, problem solving
5. Synthesis
6. Evaluation - judgments

The researcher reduced the original number of test items to 300 within the 27 topics. This number was submitted to a critique jury of ten experienced community college and four-year institutional general chemistry instructors for final selection of the 60 items for the two tests.

Table 1 lists the 27 topics and the number of items selected from each topic for each test. Table 2 provides Bloom's taxonomy classification for each question of the two criterion instruments used to measure student knowledge of facts and principles of chemistry.

Scholastic Aptitude Test

The College Entrance Examination Board's Scholastic Aptitude Test, (S. A. T.), mathematics section, was selected as the evaluation instrument for matching students in terms of general chemistry aptitude. This test is a national college placement examination, professionally administered to candidates for college entrance, and has been widely used as a predictor of success in college science and math subjects. The national mean for this test is 500 with a standard deviation of 100.

Table 1. Topics and Number of Items for Knowledge of Facts and Principles Test

Topic	No. Topic Items Program A Test	No. Topic Items Program B and C Test
1. ACID-BASE-AMPHOTERISM	2	2
2. ATOMS-ATOMIC THEORY	3	3
3. CHANGES OF STATE	3	3
4. CHEMICAL BONDING	3	2
5. CHEMICAL EQUILIBRIUM	2	3
6. COLLOIDS-SOLS-GELS	1	1
7. COMPOUNDS	3	3
8. ELECTROCHEMISTRY	2	2
9. GASES	4	4
10. HISTORY	2	1
11. KINETIC THEORY	2	3
12. LIQUIDS	4	3
13. MATTER-ENERGY	2	2
14. NOMENCLATURE	2	2
15. NUCLEAR CHEMISTRY	1	2
16. OXIDATION-REDUCTION	2	2
17. ORGANIC CHEMISTRY	2	2
18. PERIODIC PROPERTIES-GENERAL	2	2
19. PERIODIC PROPERTIES-METALS	3	3
20. PERIODIC PROPERTIES-NON METALS	2	2
21. PERIODIC PROPERTIES TRANSITION- LANTHANIDE METALS	2	2
22. QUALITATIVE ANALYSIS-SOLUBILITY PRODUCT	1	2
23. REACTION KINETICS	3	2
24. SOLIDS	2	2
25. SOLUTIONS	2	2
26. STOICHIOMETRY	2	2
27. THERMODYNAMICS	1	2

Table 2. Bloom's Taxonomy Classification for Each Question of the Two Criterion Instruments Used to Measure Student Knowledge of Facts and Principles of Chemistry

Classification Categories		Program A Test			Programs B and C Test		
1. Knowledge of Specifics	1. 3	21. 2	41. 1	1. 3	21. 2	41. 1	
2. Comprehension	2. 1	22. 2	42. 2	2. 1	22. 2	42. 2	
3. Application	3. 4	23. 4	43. 2	3. 4	23. 4	43. 2	
4. Analysis	4. 4	24. 4	44. 2	4. 4	24. 4	44. 2	
5. Synthesis	5. 2	25. 1	45. 2	5. 2	25. 1	45. 2	
6. Evaluation	6. 3	26. 1	46. 1	6. 3	26. 1	46. 1	
	7. 2	27. 4	47. 1	7. 2	27. 4	47. 1	
	8. 1	28. 2	48. 1	8. 1	28. 2	48. 4	
	9. 4	29. 1	49. 5	9. 4	29. 4	49. 5	
	10. 4	30. 5	50. 1	10. 4	30. 5	50. 1	
	11. 1	31. 2	51. 3	11. 1	31. 2	51. 3	
	12. 2	32. 2	52. 3	12. 2	32. 2	52. 3	
	13. 1	33. 3	53. 2	13. 1	33. 3	53. 2	
	14. 1	34. 2	54. 2	14. 1	34. 2	54. 2	
	15. 2	35. 4	55. 2	15. 3	35. 4	55. 2	
	16. 4	36. 3	56. 6	16. 4	36. 3	56. 6	
	17. 1	37. 6	57. 4	17. 1	37. 6	57. 4	
	18. 3	38. 2	58. 2	18. 3	38. 2	58. 2	
	19. 3	39. 1	59. 3	19. 3	39. 1	59. 3	
	20. 6	40. 2	60. 2	20. 6	40. 4	60. 2	

The mathematics section is a two part one hour test designated as Arithmetic Reasoning but also includes algebra and geometry. Standard scores were available so that students could receive percentile scores and decile ratings as well as raw scores.

Procedures Used in Collecting the Data

Criterion Test Scores

The Cornell Critical Thinking Test and the knowledge of facts and principles tests were administered to the experimental (community college) and control (four-year institution) groups at their respective institutions sometime during the week of May 27, 1968. Both criterion tests were given at the same session with 60 minutes allotted for each. Reusable test booklets were used and students recorded their responses on standard I. B. M. answer sheets which were machine scored.

Scholastic Aptitude Test Scores

Scholastic Aptitude Test scores in mathematics were acquired from the Registrar's Office of the participating institutions during the Spring term of 1967-68 academic year.

High School Math Grade Point Average

High school math G. P. A. records were acquired from high school transcripts located in the Registrar's office of the participating institutions during the Spring term of the 1967-68 academic year.

Statistics Utilized in Analysis of Data

General chemistry aptitude was measured by mathematics scores on the Scholastic Aptitude Test. This test was administered to all four-year institution students and most community college students prior to beginning their freshman year at college. In cases where Scholastic Aptitude Test mathematics scores were not available, high school math grade point averages were used as predictors of general chemistry aptitude. These scores were used to initially match four-year institution students to randomly selected community college students enrolled in one of three different general chemistry programs.

Group sample means, rather than individual student scores, were used as the unit of analysis, since it was the participating groups, not the individual students, which had been subjected to the instructional variations under comparison.

The reliability of the criterion instruments was estimated by using the Kuder-Richardson formula (98, p. 92):

$$r = \frac{K}{K - 1} \left(1 - \frac{M - M^2/K}{S^2} \right)$$

where,

r = reliability

K = number of items in the test

M = sample mean score

S = sample deviation

Nedelsky states (98, p. 92),

This formula gives an excellent estimate of r if the items are objective and if they measure the same ability (e. g. knowledge of subject matter); otherwise the formula is likely to underestimate the test's reliability.

In the tests of the null hypotheses, both preliminary and basic, the analysis of variance statistical design was used. Computational procedures for this model followed those outlined by Li (81, p. 167-185). These procedures yielded an output of sample means, sample deviations, degrees of freedom, and a resultant F - distribution value which was the basis for determining the significance of the relationship between the sample groups being compared. The F - distribution values are determined from a ratio of the individual treatment mean squares to the experimental error mean squares with their appropriate degrees of freedom. The F test of the analysis of variance is a one tailed test. In other words, a hypothesis is rejected only because the F ratio is too large and never because it is too small.

Processing of the Data

Data from the criterion tests were tabulated on data sheets, then punched on I. B. M. cards for analysis. Using the statistical designs cited in the previous section, a program was written and punched for execution on the I. B. M. 1620 computer. The program was processed in its entirety at the Oregon State University Computer Center. At least one calculation of the computer output for each equation was checked on the desk calculator in order to assure accuracy of the computer program.

IV. PRESENTATION AND INTERPRETATION OF THE FINDINGS

It was the purpose of this study to compare the performance of community college students to four-year institutional students both of which are enrolled in one of three different programs of general chemistry for non-science majors. Therefore, near the completion of these programs, measurements, of student performance from the two types of institutions, were taken in terms of two important objectives of chemistry teaching; critical thinking ability and knowledge of facts and principles.

The investigation was conducted at Lane Community College, Mt. Hood Community College, Portland Community College, Southwestern Oregon Community College, Oregon State University and Portland State College during the 1967-68 academic year. All data were collected during the week of May 27, 1968. Data were obtained through: (A) analysis of student records obtained from the registrars' offices at the participating institutions and (B) single administrations of the instruments selected to measure aspects of critical thinking ability and knowledge of facts and principles of chemistry. Data secured from these sources were tabulated on data sheets then punched on I. B. M. cards for processing.

The data collected in this study were used in the following ways:

(A) Scholastic Aptitude Test mathematics scores or high school mathematics G. P. A. were used to match students from each of the two types of institutions in the three different programs; and (B) analysis of the criterion test scores to compute group means, standard deviations and F ratios for testing preliminary and basic null hypotheses.

In the tests of null hypotheses, the statistical model employed was the analysis of variance. Group means, rather than individual student scores, were used as the unit of analysis, since it was the participating groups, not the individual students which were being compared.

The null hypotheses under examination have been stated in Chapter I and will be reviewed in this chapter when tests of hypotheses are considered. The criterion measure in each of the tests of the hypotheses was either the group mean on the Cornell Critical Thinking Test or the group mean on the knowledge of facts and principles tests.

Presentation of the Data

Data Used in Matching Students

Program A. A chemistry course for those students who have:

1. No high school chemistry background or;

2. A college board (S. A. T.) score of 451 or less in mathematics, or;
3. A total college board (S. A. T.) score of 861 or less in mathematics plus verbal or;
4. A high school grade point average (G. P. A.) of less than 2.5 (4.0 equals perfect)

Three hundred community college chemistry students from four institutions enrolled in Program A were assigned numbers (1 to 300). From a table of random numbers (81, p. 589) two hundred students were selected for this investigation. Because of unavailability of data on 12 students, 188 was the final community college sample size used in Program A. To this number of community college students an equal number of four-year institution students were matched to the community college sample by either S. A. T. math scores or high school math G. P. A. A summary of the data used in matching students in Program A is found in Table 3.

Program B. This course is designed for students with the same background and scores as those in Program A, but who do plan to go on and take higher level chemistry courses. This course is a minimum of twelve quarter hours. The greater number of hours will allow a more thorough approach and provide a better background.

Since the total community college population enrolled in Program B was small, all 76 students were to be used. However, because of unavailability of data on 6 students, the final community college sample size for Program B was 70. An equal number of

Table 3. Data Used in Matching Four-year Institution Students to Community College Students in Program A

Institution	n	Students matched by S. A. T. math scores	Range S. A. T. math scores	Average S. A. T. math scores	Students matched by high school math G. P. A.	Range H. S. math G. P. A.	Average H. S. math G. P. A.
Community Colleges:							
L. C. C.	44	21	348 - 650	432	23	1.6 - 4.0	2.7
M. H. C. C.	56	35	296 - 620	430	21	1.9 - 3.5	2.5
P. C. C.	46	30	290 - 652	426	16	1.5 - 3.8	2.6
S. W. O. C. C.	42	29	300 - 644	440	13	1.7 - 3.4	2.6
Four-year Institutions:							
O. S. U.	96	58	320 - 636	448	38	1.6 - 3.8	2.6
P. S. C.	92	57	290 - 650	420	35	1.5 - 3.9	2.6

four-year institution students were matched to the community college sample by either S. A. T. math scores or high school math G. P. A. A summary of the data used in matching students in Program B is found in Table 4.

Program C. A chemistry course for those students who have:

1. High school chemistry background and;
2. A college board (S. A. T.) score of 452 or above in mathematics, and;
3. A total college board (S. A. T.) score of 862 or above in mathematics plus verbal, or;
4. A high school chemistry background and a high school grade point average (G. P. A.) of 2.5 or above (4.0 equals perfect).

The objectives of this program are similar to those of program B in that the course is designed to prepare students for additional courses in chemistry. Therefore, the criterion instruments used in Program C were identical to those used in Program B.

Three hundred community college chemistry students from four institutions enrolled in Program C were assigned number (1 to 300). From a table of random numbers (81, p. 589) two hundred students were selected for this investigation. Because of unavailability of data, the final community college sample population for Program C was reduced to 174. An equal number of four-year institution students were matched to the community college sample by either S. A. T. math scores or high school math G. P. A. A summary of the

Table 4. Data Used in Matching Four-year Institution Students to Community College Students in Program B

Institution	n	Students matched by S. A. T. math scores	Range S. A. T. math scores	Average S. A. T. math scores	Students matched by high school math G. P. A.	Range H. S. math G. P. A.	Average H. S. math G. P. A.
Community Colleges:							
L. C. C.	16	10	330 - 640	468	6	1.8 - 3.8	2.7
M. H. C. C.	22	13	350 - 730	452	9	1.7 - 3.4	2.5
P. C. C.	16	9	316 - 612	444	7	1.6 - 3.8	2.5
S. W. O. C. C.	16	11	290 - 634	460	5	2.2 - 3.2	2.6
Four-year Institutions:							
O. S. U.	33	17	290 - 732	458	16	1.8 - 3.9	2.6
P. S. C.	37	16	314 - 640	456	21	1.6 - 3.8	2.6

Table 5. Data Used in Matching Four-year Institution Students to Community College Students in Program C

Institution	n	Students matched by S. A. T. math scores	Range S. A. T. math scores	Average S. A. T. math scores	Students matched by high school math G. P. A.	Range H. S. math G. P. A.	Average H. S. math G. P. A.
Community Colleges:							
L. C. C.	40	24	345 - 743	540	16	2.1 - 3.9	2.6
M. H. C. C.	48	31	380 - 673	534	17	2.2 - 4.0	2.8
P. C. C.	40	19	402 - 714	556	21	2.4 - 3.8	2.8
S. W. O. C. C.	46	27	392 - 672	542	19	2.2 - 3.8	2.7
Four-year Institutions:							
O. S. U.	86	49	392 - 745	542	37	2.1 - 3.9	2.7
P. S. C.	88	52	380 - 737	540	36	2.1 - 4.0	2.7

data used in matching students in Program C is found in Table 5.

The Scholastic Aptitude Test mathematic section has a national mean of 500 with a standard deviation of 100. High school math grade point averages are based on 4.0 as perfect or straight A.

Data from Criterion Instruments

The Cornell Critical Thinking Test, Form Z, a 52 item multiple choice test and two 60 item multiple choice tests dealing with the knowledge of facts and principles of general college chemistry were the criterion instruments used in this investigation. Tables 6, 7 and 8 summarize the means and standard deviations calculated from data obtained from student responses to these criterion instruments. The tables categorize information first into the three different programs of general college chemistry and secondly into the six participating institutions.

The reliability of the criterion instruments was estimated by the Kuder-Richardson formula (98, p. 92):

$$r = \frac{K}{K - 1} \left(1 - \frac{M - M^2/K}{S^2} \right)$$

where,

r = reliability

K = number of items in the test

M = mean score (average community college and four-year institution means)

Table 6. Summary of Data from Criterion Instruments Used in Program A

Institution	n	Cornell Critical Thinking Test		Knowledge of Facts and Principles Tests	
		mean score	standard deviation	mean score	standard deviation
Community Colleges:					
L. C. C.	44	29.217	6.284	20.870	6.134
M. H. C. C.	56	28.655	7.254	22.724	7.354
P. C. C.	46	29.174	7.585	20.957	7.525
S. W. O. C. C.	42	26.950	6.286	21.200	6.186
Four-year Institutions:					
O. S. U.	96	28.640	6.756	22.640	6.750
P. S. C.	92	28.978	7.281	21.889	7.287

Table 7. Summary of Data from Criterion Instruments Used in Program B

		Cornell Critical Thinking Test		Knowledge of Facts and Principles Tests	
Institution	n	mean score	standard deviation	mean score	standard deviation
Community Colleges:					
L. C. C.	16	27.375	7.153	25.875	7.258
M. H. C. C.	22	30.818	6.191	26.364	6.197
P. C. C.	16	28.111	7.374	26.444	7.384
S. W. O. C. C.	16	28.875	6.970	25.624	6.976
Four-year Institutions:					
O. S. U.	33	28.800	7.265	31.680	7.235
P. S. C.	37	28.560	7.083	26.520	7.380

Table 8. Summary of Data from Criterion Instruments Used in Program C

		Cornell Critical Thinking Test		Knowledge of Facts and Principles Tests	
Institution	n	mean score	standard deviation	mean score	standard deviation
Community Colleges:					
L. C. C.	40	29.900	7.656	30.100	7.600
M. H. C. C.	48	30.750	6.780	28.583	7.826
P. C. C.	40	30.050	6.662	28.600	7.662
S. W. O. C. C.	46	28.391	7.246	29.043	7.137
Four-year Institutions:					
O. S. U.	86	29.512	7.654	28.465	7.144
P. S. C.	88	28.773	6.630	29.432	7.863

S = standard deviation (average community college and four-year institution standard deviation)

Table 9 provides a summary of the reliability calculations for the criterion instruments used in this research. The reliabilities of the criterion instruments fall within the range of "acceptable hour long tests" which is .75 - 1.0 and rarely exceeds .90 for science tests (98, p. 94). In Programs A and B the reliability value for both criterion tests was larger for four-year institution students and in Program C the reliability value for both tests favored the community college population.

All criterion instruments used in this research are located in Appendices 1, 2 and 3.

Tests of the Hypotheses

Preliminary Hypotheses

1. There is no significant statistical difference between four-year institutions as measured by the mean scores on the Cornell Critical Thinking Test.

Program A

	Mean Score	Standard Deviation
Oregon State University	28.640	6.756
Portland State College	28.978	7.281

The F value at the 5 percent level with 1 and 186 degrees of freedom equals 1.69. This value is not statistically significant, therefore,

Table 9. Reliability Calculations for Criterion Instruments Used In Program A, B, and C.

	Cornell Critical Thinking Test				Knowledge of Facts and Principles Tests			
	K	M	S	r	K	M	S	r
PROGRAM A								
Community Colleges	52	28.499	6.852	.78	60	21.621	6.650	.77
Four-year Institutions	52	28.809	7.015	.82	60	22.250	7.019	.84
PROGRAM B								
Community Colleges	52	28.792	6.813	.77	60	26.024	6.911	.78
Four-year Institutions	52	28.680	7.163	.83	60	29.019	7.305	.80
PROGRAM C								
Community Colleges	52	29.041	7.184	.81	60	29.033	7.587	.82
Four-year Institutions	52	29.154	7.140	.80	60	28.975	7.494	.80

the hypothesis is accepted for Program A.

If the hypotheses are accepted, then the two four-year institutions can be grouped together and treated statistically as one population.

<u>Program B</u>	Mean Score	Standard Deviation
Oregon State University	28.800	7.265
Portland State College	28.560	7.083

The F value at the 5 percent level with 1 and 68 degrees of freedom equals .020. This value is not statistically significant, therefore, the hypothesis is accepted for Program B.

<u>Program C</u>	Mean Score	Standard Deviation
Oregon State University	29.512	7.654
Portland State College	28.773	6.630

The F value at the 5 percent level with 1 and 172 degrees of freedom equals 2.42. This value is not statistically significant, therefore, the hypothesis is accepted for Program C.

2. There is no significant statistical differences between community colleges as measured by the mean scores on the Cornell Critical Thinking Test

<u>Program A</u>	Mean Score	Standard Deviation
Lane Community College	29.217	6.284
Mount Hood Community College	28.655	7.254

	Mean Score	Standard Deviation
Portland Community College	29.174	7.585
Southwestern Oregon Community College	26.950	6.286

The F value at the 5 percent level with 3 and 184 degrees of freedom equals 2.56. This value is not statistically significant, therefore, the hypothesis is accepted for Program A.

Similarly as with the four-year institutions, if the hypotheses are accepted, the community colleges can be grouped together and treated statistically as one population.

Program B

	Mean Score	Standard Deviation
Lane Community College	27.375	7.153
Mount Hood Community College	30.818	6.191
Portland Community College	28.111	7.374
Southwestern Oregon Community College	28.875	6.970

The F value at the 5 percent level with 3 and 66 degrees of freedom equals 2.36. This value is not statistically significant, therefore, the hypothesis is accepted for Program B.

Program C

	Mean Score	Standard Deviation
Lane Community College	29.900	7.656
Mount Hood Community College	30.750	6.780
Portland Community College	30.050	6.662
Southwestern Oregon Community College	28.391	7.246

The F value at the 5 percent level with 3 and 170 degrees of freedom equals .79. This value is not statistically significant, therefore, the hypothesis is accepted for Program C.

3. There is no significant statistical difference between four-year institutions as measured by the mean scores on the knowledge of facts and principles tests.

Program A

	Mean Score	Standard Deviation
Oregon State University	22.640	6.750
Portland State College	21.889	7.287

The F value at the 5 percent level with 1 and 186 degrees of freedom equals 2.33. This value is not statistically significant, therefore, the hypothesis is accepted for Program A.

Program B

	Mean Score	Standard Deviation
Oregon State University	31.680	7.235
Portland State College	26.520	7.380

The F value at the 5 percent level with 1 and 68 degrees of freedom equals 8.42. This value is statistically significant, therefore, the hypothesis is rejected for Program B.

There is a significant difference between the mean scores on the knowledge of facts and principles test in chemistry for Program B between the two four-year institutions. Before they could be grouped into one population for comparison with community college students in Program B, there was a statistical adjustment made for

mean differences. This consisted of adjusting O. S. U. scores to those of P. S. C.

<u>Program C</u>	Mean Score	Standard Deviation
Oregon State University	28.465	7.144
Portland State College	29.432	7.863

The F value at the 5 percent level with 1 and 172 degrees of freedom equals .46. This value is not statistically significant, therefore, the hypothesis is accepted for Program C.

4. There is no significant statistical differences between community colleges as measured by the mean scores on the knowledge of facts and principles tests.

<u>Program A</u>	Mean Score	Standard Deviation
Lane Community College	20.870	6.134
Mount Hood Community College	22.724	7.354
Portland Community College	20.957	7.525
Southwestern Oregon Community College	21.200	6.186

The F value at the 5 percent level with 3 and 184 degrees of freedom equals 2.25. This value is not statistically significant, therefore, the hypothesis is accepted for Program A.

<u>Program B</u>	Mean Score	Standard Deviation
Lane Community College	25.875	7.258
Mount Hood Community College	26.364	6.197
Portland Community College	26.444	7.384
Southwestern Oregon Community College	25.624	6.976

The F value at the 5 percent level with 3 and 66 degrees of freedom equals .77. This value is not statistically significant, therefore, the hypothesis is accepted for Program B.

Program C

	Mean Score	Standard Deviation
Lane Community College	30.100	7.600
Mount Hood Community College	28.583	7.826
Portland Community College	28.600	7.662
Southwestern Oregon Community College	29.043	7.137

The F value at the 5 percent level with 3 and 170 degrees of freedom equals 1.45. This value is not statistically significant, therefore, the hypothesis is accepted for Program C.

Basic Null Hypotheses

1. There is no significant statistical difference between the community college and four-year institutional general chemistry Program A in terms of student critical thinking ability.

	Mean Score	Standard Deviation
Community Colleges	28.499	6.852
Four-year Institutions	28.809	7.015

The F value at the 5 percent level with 1 and 374 degrees of freedom equals .15. This value is not statistically significant, therefore, the hypothesis is accepted.

2. There is no significant statistical difference between the community college and four-year institutional general chemistry Program B in terms of student critical thinking ability.

	Mean Score	Standard Deviation
Community Colleges	28.792	6.813
Four-year Institutions	28.680	7.163

The F value at the 5 percent level with 1 and 138 degrees of freedom equals .02. This value is not statistically significant, therefore, the hypothesis is accepted.

3. There is no significant statistical difference between the community college and four-year institutional general chemistry Program C in terms of student critical thinking ability.

	Mean Score	Standard Deviation
Community Colleges	29.041	7.184
Four-year Institutions	29.154	7.140

The F value at the 5 percent level with 1 and 346 degrees of freedom equals .08. This value is not statistically significant, therefore, the hypothesis is accepted.

4. There is no significant statistical difference between the community college and four-year institutional general chemistry Program A in terms of student knowledge of the fundamental facts and principles of chemistry.

	Mean Score	Standard Deviation
Community Colleges	21.621	6.650
Four-year Institutions	22.250	7.019

The F value at the 5 percent level with 1 and 374 degrees of freedom equals .32. This value is not statistically significant, therefore, the hypothesis is accepted.

5. There is no significant statistical difference between the community college and four-year institutional general chemistry Program B in terms of student knowledge of the fundamental facts and principles of chemistry.

As stated earlier there was a significant difference between the two four-year institutions in terms of student knowledge of the fundamental facts and principles of chemistry in Program B. Therefore, adjusted four-year institution means were used for this hypothesis.

	Mean Score	Standard Deviation
Community Colleges	26.024	6.911
Four-year Institutions (adjusted)	27.200	7.305

The F value at the 5 percent level with 1 and 138 degrees of freedom equals .70. This value is not statistically significant, therefore, the hypothesis is accepted.

6. There is no significant statistical difference between the community college and four-year institutional general chemistry Program C in terms of student knowledge of the fundamental facts and principles of chemistry.

	Mean Score	Standard Deviation
Community Colleges	29.033	7.587
Four-year Institutions	28.975	7.494

The F value at the 5 percent level with 1 and 346 degrees of freedom equals .07. This value is not statistically significant, therefore, the hypothesis is accepted.

V. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The objective of this investigation was to determine whether or not Oregon community college students, enrolled in one of three different general chemistry programs, received comparable educational experiences to that of four-year institutional students enrolled in parallel programs. This objective was accomplished by comparing the performance of community college students to four-year institutional students in terms of two important objectives of chemistry teaching; critical thinking ability and knowledge of facts and principles. These comparisons were made by statistical analysis of the group mean test scores calculated from student responses to the criterion instruments administered near the completion of the programs. To assure that the community college and four-year institution students within the three programs were comparable, the four-year students were matched to the completely randomized community college students by S. A. T. scores in mathematics or, when these were not available, by high school math G. P. A. , before the differential experimental treatment.

The populations for this study are summarized in Table 10.

All of these students were enrolled full time at either of the

four community colleges or the two four-year institutions during the 1967-68 academic year.

Table 10. The Number of Students from the Participating Institutions for the Three Different General Chemistry Programs

	Program A	Program B	Program C
Community Colleges:			
L. C. C.	44	16	40
M. H. C. C.	56	22	48
P. C. C.	46	16	40
S. W. O. C. C.	42	16	46
Four-year Institutions:			
O. S. U.	96	33	86
P. S. C.	92	37	88

The criterion tests were the Cornell Critical Thinking Test, Form Z, developed by Robert Ennis of Cornell University, and the knowledge of facts and principles tests developed by the researcher and evaluated by a critique jury of ten experienced community college and four-year institutional general chemistry instructors.

Since this investigation was a Post-Test only design, the criterion instruments were administered only once with 60 minutes of time allotted for each. Calculations of reliability for the criterion instruments by the Kuder-Richardson formula revealed that the

instruments were satisfactory for this research. The average reliability values were:

	Reliability		
	Program A	Program B	Program C
Cornell Critical Thinking Test	.800	.800	.805
Knowledge of Facts and Principles Test for Program A	.805	----	----
Knowledge of Facts and Principles Test for Programs B and C	----	.790	.810

In the tests of the null hypotheses, both preliminary and basic, the analysis of variance statistical design was used. Computational procedures yielded an output of sample means, standard deviations, degrees of freedom, and a resultant F - distribution value which was the basis for determining the significance of the relationship between the sample groups being compared.

The F values at the 5 percent level, for the preliminary hypotheses indicated no significant statistical differences between community colleges within the three different general chemistry programs in terms of student critical thinking ability and knowledge of facts and principles of chemistry. These results allowed the four community colleges to be grouped together and treated statistically as one community college population within each of the three

different programs.

The F values at the 5 percent level also indicated no significant statistical difference between four-year institutions within the three different general chemistry programs in terms of student critical thinking ability.

For Programs A and C, in terms of knowledge of facts and principles of chemistry, the F values at the 5 percent level did not indicate any significant statistical difference between four-year institutions. However, the F value for Program B, in terms of knowledge of facts and principles of chemistry, did indicate a significant statistical difference between the two four-year institutions participating in this investigation. Therefore, after a statistical adjustment was made for the mean differences for Program B, the results allowed the four-year institutions to be grouped together and treated statistically as one four-year institution population within each of the three programs.

The F values at the 5 percent level for the basic hypotheses indicated no significant statistical difference between community colleges and four-year institutions for Programs A, B and C in terms of the students' critical thinking ability or the knowledge of facts and principles of chemistry.

Conclusions

The conclusions to be drawn from the results of this research will be stated at the end of a review of each basic hypothesis.

1. There is no significant statistical difference between the community college and four-year institutional general chemistry Program A in terms of student critical thinking ability.

The hypothesis was accepted. Under the assumptions of Chapter I, Program A at the participating community colleges and four-year institutions is representative of Program A at other community colleges and four-year institutions in Oregon. Therefore, the statistical inference can be made that community college students in Oregon, enrolled in general chemistry Program A, receive comparable educational experiences to those received at four-year institutions in terms of student critical thinking ability as measured by the Cornell Critical Thinking Test, Form Z.

2. There is no significant statistical difference between the community college and four-year institutional general chemistry Program B in terms of student critical thinking ability.

The hypothesis was accepted. Under the assumptions of Chapter I, Program B at the participating community colleges and four-year institutions is representative of Program B at other community colleges and four-year institutions in Oregon. Therefore, the statistical inference can be made that the community college students in Oregon, enrolled in general chemistry Program B,

receive comparable educational experiences to those received at four-year institutions in terms of student critical thinking ability, as measured by the Cornell Critical Thinking Test, Form Z.

3. There is no significant statistical difference between the community college and four-year institutional general chemistry Program C in terms of student critical thinking ability.

The hypothesis was accepted. Under the assumptions of Chapter I, Program C at the participating community colleges and four-year institutions is representative of Program C at other community colleges and four-year institutions in Oregon. Therefore, the statistical inference can be made that the community college students in Oregon, enrolled in general chemistry Program C, receive comparable educational experiences to those received at four-year institutions in terms of student critical thinking ability as measured by the Cornell Critical Thinking Test, Form Z.

4. There is no significant statistical difference between community college and four-year institutional general chemistry Program A in terms of student knowledge of the fundamental facts and principles of chemistry.

The hypothesis was accepted. It can be inferred that community college students in Oregon enrolled in general chemistry Program A, receive comparable educational experiences to those received at four-year institutions in terms of developing their knowledge of the fundamental facts and principles of chemistry.

5. There is no significant statistical difference between the community college and four-year institutional general chemistry Program B in terms of student knowledge of the fundamental facts and principles of chemistry.

The hypothesis was accepted. However, this hypothesis was accepted after a statistical adjustment for the significant difference between the two four-year institutions had been made. It should be noted that Program B at Oregon State University was significantly superior to both Portland State College and the community college population, in terms of student knowledge of fundamental facts and principles of chemistry. Most certainly there may be many factors which contribute to this difference, but one of the more important factors is the procedural difference in the course offering. Portland State College offers Program B in four quarters, the sequence being Ch 104 Fall with 3 credit hours, Ch 105 Winter with 3 credit hours, Ch 106 Spring with 3 credit hours and Ch 223 with 4 credit hours offered the succeeding Fall and Spring terms. The community colleges also offer Program B in four quarters, the sequence being Ch 101 Fall with 3 credit hours, Ch 102 Winter with 3 credit hours, Ch 103 Spring with 3 credit hours and Ch 241 with 5 credit hours offered in the succeeding Spring. This lack of continuous course sequence certainly impedes the success of the students in Program B. On the other hand, Oregon State University offers Program B in a continuous three term sequence; Ch 104 Fall with 5 credit hours,

Ch 105 Winter with 4 credit hours, and Ch 106 Spring with 4 credit hours. It is the conclusion of this researcher that the continuity of the Program B offering at Oregon State University contributed significantly to its superiority over the other participating institutions in this investigation, in terms of student knowledge of fundamental facts and principles of chemistry.

6. There is no significant statistical difference between the community college and four-year institutional general chemistry Program C in terms of student knowledge of the fundamental facts and principles of chemistry.

The hypothesis was accepted. It can be inferred that community college students in Oregon enrolled in general chemistry Program C, receive comparable educational experiences to those received at four-year institutions in terms of developing their knowledge of the fundamental facts and principles of chemistry.

Recommendations

On the basis of the data presented in this study, the investigator recommends that:

1. Those community colleges and four-year institutions in Oregon offering Program B of general college chemistry use a three quarter sequential course offering similar to that offered at Oregon State University.
2. Other investigations in the areas of physics, physical

- science, and biology be conducted to assess the overall quality of community college science instruction.
3. Other investigations in the areas of social sciences, humanities and fine arts be conducted to determine whether or not improved critical thinking abilities are a product of these educational experiences.
 4. Improved communication within subject matter disciplines be made between community college and four-year institutional instructors.
 5. Instructors of college science courses precisely define the aspects of critical thinking and knowledge of subject matter which students should develop as a result of having studied a given course.
 6. Instructors of college science courses provide learning activities specifically designed to develop in students critical thinking abilities and knowledge of specific subject matter.
 7. Instructors of college science courses place appropriate emphasis on evaluation procedures and test items which will require the students to demonstrate proficiency in aspects of critical thinking and to reveal knowledge of fundamental subject matter.

Increasingly, the community college is the means by which states are equalizing and expanding educational opportunity beyond the high school. In Oregon, within a decade, the community colleges will furnish a greater percentage of the lower division collegiate education than the four-year institutions. Therefore, it seems cardinal to this investigator that community college transfer curriculum be continuously evaluated and improved to assure the success of students beyond the fourteenth year.

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APPENDIX 1

CORNELL CRITICAL THINKING TEST, FORM Z

SECTION IA: In the first five items two men are debating about voting by eighteen-year-olds. Mr. Pinder is speaker in the first three items, Mr. Wilstings in the last two. Each item presents a set of statements and a conclusion. In each item, the conclusion is underlined. Do not be concerned with whether or not the conclusion or statements are true.

Mark items 1 through 5 according to the following system:

- a) The conclusion follows necessarily from the statement given.
- b) The conclusion contradicts the statements given.
- c) The conclusion neither follows necessarily nor contradicts the statement given.

If a conclusion follows necessarily, a person who accepts the statement is unavoidable committed to accepting the conclusion. When two things are contradictory, they cannot both be true at the same time.

CONSIDER EACH ITEM INDEPENDENTLY OF THE OTHERS.

1. "Mr. Wilstings says that eighteen-year-olds haven't faced the problems of the world, and that anyone who hasn't faced these problems shouldn't vote. What he says is correct, but eighteen-year-olds still should be able to vote. They're mature human beings, aren't they?"
 - a) Conclusion follows necessarily from the statements given.
 - b) Conclusion contradicts the statements given
 - c) Neither
2. "Furthermore, eighteen-year-olds should be allowed to vote because anyone who will suffer or gain from a decision made by the voters ought to be permitted to vote. It is clear that eighteen-year-olds will suffer or gain from the decision of the voters."
 - a) Conclusion follows necessarily from the statements given
 - b) Conclusion contradicts the statement given.
 - c) Neither
3. "Many eighteen-year-olds are serving their country. Now there can be no doubt that many people serving their country ought to be allowed to vote. From this you can see that many eighteen-year-olds ought to be allowed to vote."
 - a) Conclusion follows necessarily from the statements given
 - b) Conclusion contradicts the statements given
 - c) Neither

4. "I agree with Mr. Pinder that anyone who will suffer or gain from a decision made by the voters ought to be permitted to vote. And it is true that eighteen-year-olds will suffer or gain from these decisions. But so will ten-year-olds. Therefore, eighteen-year-olds shouldn't be allowed to vote."
 - a) Conclusion follows necessarily from the statements given
 - b) Conclusion contradicts the statements given
 - c) Neither
5. "Most eighteen-year-olds don't know the difference between right and wrong. The right to vote should not be possessed by a group, if most of its members don't know this difference. It is obvious then that eighteen-year-olds shouldn't have the right to vote."
 - a) Conclusion follows necessarily from the statements given
 - b) Conclusion contradicts the statements given
 - c) Neither

Section IB: In the next five items, the two men are debating about immigration. Mr. Pinder is speaking in the first three items, Mr. Wilstings in the last two.

CONSIDER EACH ITEM INDEPENDENTLY OF THE OTHERS.

6. "Mr. Wilstings has proposed that we open our doors to all the foreigners who want to enter our beloved country. But foreigners always have made trouble and they always will. Most of them can't even speak English. Since any group that makes trouble is bad, it follows that foreigners are a bad bunch."
 - a) Conclusion follows necessarily for the statements given
 - b) Conclusion contradicts the statements given
 - c) Neither
7. "You may not know it, but for the past ten years the Communists in our country have been supporting a policy of unrestricted immigration. It is obvious why they support this policy of opening our doors to the foreigners. Now I hate to say this, but Mr. Wilstings' support of this policy leaves us but one conclusion. Mr. Wilstings is a Communist."
 - a) Conclusion follows necessarily from the statements given.
 - b) Conclusion contradicts the statements given
 - c) Neither

8. "Mr. Wilstings has said that most foreigners have made positive contributions to our country. This is true. I will also admit that a group is not bad, if most of its members do make positive contributions. But don't be deceived by Mr. Wilstings' fine-sounding language. Foreigners are a bad lot and shouldn't be admitted."
- a) Conclusion follows necessarily from the statements given
 - b) Conclusion contradicts the statements given
 - c) Neither
9. "I'm sorry that Mr. Pinder feels that way about it. Sure, foreigners make trouble and most of them can't speak English. But even though it's true that groups that make trouble ought not be admitted, we still ought to admit foreigners to our country. You don't want to be selfish do you?"
- a) Conclusion follows necessarily from the statements given
 - b) Conclusion contradicts the statements given
 - c) Neither
10. "All of you think it was all right to open our doors to all people from distant lands in the nineteenth century. Any person who thinks it was all right to do so at that time ought also to be in favor of doing so now. Thus, you ought to be in favor of opening our doors now to those from distant lands who are seeking admission to our country."
- a) Conclusion follows necessarily from the statements given
 - b) Conclusion contradicts the statements given
 - c) Neither

Section II: The discussion that follows is divided into parts to correspond to items 11 through 21. There is faulty thinking going on in each part. Your job for each item is to pick the one best reason why the thinking is faulty.

To take this part of the test you need not know anything about the chlorination of water supplies.

11. DOBERT: I hear that you and some other crackpots are trying to get Gailton to chlorinate its water supply. You seem to think that this will do some good. There can be no doubt that either we should chlorinate or we shouldn't. Only a fool would be in favor of chlorinating the water, so we ought not do it.

ALGAN: You are correct at least in saying that we are trying to get the water chlorinated

Pick the best reason why some of this thinking is faulty.

- a) Dobert is mistakenly assuming that there are only two alternatives
- b) Dobert is using a word in two ways
- c) Dobert is using emotional language which doesn't help to make his argument reasonable

12. DOBERT: I guess you know that to put chlorine in the water is to threaten the health of every one of Gailton's citizens, and that, you'll admit, is bad.

ALGAN: What right do you have to say that our health will be threatened?

DOBERT: "Healthy living" may be defined as living according to nature. Now we don't find chlorine added to water in nature. Therefore, everyone's health would be threatened if chlorine were added.

Pick the one best reason why some of this thinking is faulty.

- a) Dobert is using emotional language which doesn't help to make his argument reasonable.
- b) Dobert's thinking is in error.
- c) Dobert is using a word in two different ways.

13. DOBERT: Furthermore, Gailton's water is pure already. I know this from the report, which you haven't seen yet, that will soon be released by the State Water Survey.

ALGAN: You can't know that Gailton's water is pure. The State Water Survey didn't test all the water that we have available to us. They only took samples. Furthermore, you can't know that they didn't make an error in their investigation, because there's always a chance for error in any investigation. Therefore, you could never know that Gailton's water is pure.

Pick the one best reason why some of this thinking is faulty.

- a) Algan is not using "know" in its ordinary sense, yet he is expecting the effect that follows from its being used in the ordinary sense.
- b) Dobert, in using secret evidence, is not being fair, since this evidence isn't available to everyone for inspection.
- c) Algan can't know that an error was made in the investigation.

14. DOBERT: I understand that you look on this thing as an experiment. I'm sure that the citizens of Gailton don't want to be guinea pigs in this matter.

ALGAN: This is a demonstration. Nobody ought to object to a demonstration, since the purpose of a demonstration is not to find out something, but rather to show us something that is already known. An additional value of this demonstration of chlorination is that its purpose is also to test for the long-range effects of chlorination on the human body. This objective of the demonstration is a worthy one.

Pick the one best reason why some of this thinking is faulty.

- a) Algan has not shown that testing for the long-range effects of chlorination is a worthy objective.
- b) Algan is using a word in two ways.
- c) There is an error in thinking in this part.

15. ALGAN: The question boils down to two alternatives. Either we want clean, chlorinated water or we want bad-smelling, disease-ridden water. The citizens of Gailton certainly don't want bad-smelling, disease-ridden water. What is left but to chlorinate?

Pick the one best reason why some of this thinking is faulty.

- a) Algan hasn't shown that there are only two alternatives.
- b) Algan is using emotional language which doesn't help to make the argument reasonable.
- c) Algan is using the same word in two ways.

16. DOBERT: Laying aside the question of whether medication is bad or good, wouldn't you say that you are proposing a plan for medication?

ALGAN: Not at all. Is killing germs in the water supply the same as treating a disease of the human body? Certainly not. Therefore, my plan cannot be called a plan for medication.

DOBERT: Oh, but it is medication. Isn't one of your stated goals the prevention of disease? Medication is the process of trying to restore or preserve health in any manner whatsoever. Whether your plan actually would result in preserving or restoring health doesn't matter. The point is that you would be trying to do so and thus would be medicating people.

Pick the one best reason why some of this thinking is faulty.

- a) There is a serious mistake in the thinking in this part.
- b) Dobert's conclusion doesn't necessarily follow from the reasons given.
- c) Dobert and Algan are using the same word differently.

17. DOBERT: Can you prove that chlorination is useful in making water safe?

ALGAN: Yes, I can. Devton gets its water from the same place that we do. Three years ago, Devton had nine cases of typhoid fever. Two years ago they started to chlorinate and they had only two cases that year. That's proof enough.

Pick one best reason why some of this thinking is faulty.

- a) Algan is using the same word in two ways.
 - b) That's not a big enough reduction. If there were no typhoid at all the second year, then Algan would have proven his statement.
 - c) One such comparison is not enough to prove such a statement.
18. DOBERT: In reality you are proposing to poison our water supply when you propose to put chlorine gas in the water. Chlorine gas has been used in war to kill human beings, it is a deadly poison. Nobody wants to be poisoned.

ALGAN: But when chlorine is mixed 3 1/2 parts per million nobody will be hurt at all.

DOBERT: That's not the point. You'd still be putting a deadly poison in the water. That's what it means to poison the water. So anyone drinking the water would necessarily be poisoned.

Pick the one best reason why some of the thinking is faulty.

- a) Algan is missing the point.
 - b) Dobert is using the same word in two ways.
 - c) Dobert's thinking is in error.
19. DOBERT: Furthermore, Gailton's water is safe now.

ALGAN: That's not true. Nothing is safe as long as there's a conceivable chance for something to go wrong. From this it follows that Gailton's water is not safe.

Pick the one best reason why some of the thinking is faulty.

- a) Algan has made the word "safe" useless for communication information.
- b) Algan hasn't said what he means by "safe."
- c. There is a flaw in Algan's thinking about safety.

20. DOBERT: The citizens of Gailton will have to make a choice. Either we want absolutely pure water or we should keep our present set-up. Now any chemist can tell you that from a practical point of view it is impossible to remove all the impurities from a water supply. So we should leave things the way they are.

Pick the one best reason why some of the thinking is faulty.

- a) Dobert hasn't shown that there are only two alternatives.
 - b) Dobert is using the same word in two ways.
 - c) The conclusion doesn't necessarily follow the reasons given.
21. DOBERT: To add chlorine is to add a drug to Gailton's water supply. Obviously, we don't want our citizens to be drugged every time they take a drink of water.

ALGAN: What right do you have to say that chlorine is a drug?

DOBERT: The term "drug" is defined in section 201 (g) of the Federal Food, Drug and Cosmetic Act, as an article intended for use in the diagnosis, cure, treatment or prevention of disease in man or other animals. Now since chlorine is intended for use in the prevention of disease, it is a drug.

Pick the one best reason why some of the thinking is faulty.

- a) Dobert's thinking is in error.
- b) Algan should realize that a person has a right to use a word in a special way. The important thing is that there be understanding of what is said.
- c) Dobert is using a word in two different ways.

SECTIONS III, IV AND V REFER TO THE FOLLOWING EXPERIMENT:

An experiment was performed by Drs. E. E. Brown and M. R. Kolter in the veterinary laboratory of the British Ministry of Agriculture and Fisheries. The doctors were interested in what happens to ducklings that eat cabbage worms. Several cases had been reported to them in which ducklings had "mysteriously died after being in cabbage patches containing cabbage worms."

Two broods of each of three types of ducklings were secured (Mallards, Pintails, and Canvas-backs). Each brood was split into two equal groups, as much alike as possible. For a one-week period they were fed an approved diet for ducklings. All had this diet, except that half of each brood had something more: two cabbage worms per duckling each day. The condition of the ducklings at the end of the week was observed and is reported in the following chart:

TYPE OF DUCKLING	ORIGINAL NUMBER IN BROOD	REGULAR DIET			REGULAR DIET PLUS WORMS		
		Healthy	Ill	Dead	Healthy	Ill	Dead
Mallard	8	3	1			2	2
	6	3					3
	6	2		1			3
Pintail	8	3	1		1		3
	8	4				1	3
Canvas-back	8	3	1			1	3
TOTALS	44	18	3	1	1	4	17

The doctors draw this conclusion: CABBAGE WORMS ARE POISONOUS TO DUCKLINGS.

Section III: The experiment attracted a great deal of attention. Many statements were made about the experiment and about the protection of ducklings.

Each of items 22 through 25 contains a pair of such statements. Each statement is underlined. In each case you are to decide which one of the pair is probably more reliable than the other. In making your decisions, use the information provided in the experiment and the information given in parentheses after each statement.

Marks items 22 through 25 according to the following system:

- a) The first statement is probably more reliable
 - b) The second statement is probably more reliable
 - c) Neither statement is probably more reliable than the other.
22. a) Cabbage worms are poisonous to ducklings. (said by Dr. Kolter)
b) Six Canvas-backs died during the week of the experiment. (said by Dr. Kolter)
c) Neither
23. a) Six Pintails were healthy at the end of the experiment. (said by Dr. Brown)
b) Four worm-fed ducklings were ill at the end of the experiment. (said by Dr. Brown)
c) Neither

24. a) During the week following the experiment, all of the ill ducklings died. (from the article in a magazine that is to be found on almost every newsstand. The author, a popular American writer, stated that he obtained his information from Drs. Brown and Kolter.)
- b) During the week following the experiment, the rest of the worm-fed ducklings died. (from the report written by Drs. Brown and Kolter)
- c) Neither
25. a) Independent laboratory studies have shown conclusively that ducklings sprayed with Wrodane will not be harmed by eating cabbage worms. (from an article in a magazine published by the chemical company that makes Wrodane)
- b) No satisfactory way has yet been found to counteract the poisonous effects of cabbage worms on ducklings. (from the magazine article mentioned in Item #24. This article appeared two months after the Wrodane article)
- c) Neither

SECTION IV: From the original experiment the doctors drew the conclusion: CABBAGE WORMS ARE POISONOUS TO DUCKLINGS

Mark items 26 through 38 according to the following system:

- a) If true, it would make the conclusion more certain.
- b) If true, it would make the conclusion less certain.
- c) It would do neither.

Consider each item independently of the others.

26. The experiment is repeated. The results are similar.
27. The experiment is repeated with three different varieties of ducklings, which are younger than the ones used in the original experiment. At the end of the week two of the regular-diet ducklings are dead and twenty of the worm-diet ducklings are dead.
28. At the time of the original experiment there was an apple tree shedding apples into the cages of both sets of ducklings. The experimenters did not expect this to happen. About the same number of apples fell into each cage. This kind of apple does not affect the health of ducklings.
29. The experiment is repeated in Canada with twice as many ducklings. None of the ducklings die. At the end of the week two of the regular-diet ducklings are ill and three of the worm-diet ducklings are ill.

30. The experiment is repeated in Scotland. At the end of the week all of the worm-fed ducklings are dead and all of the regular-fed ducklings are alive and healthy. But it is discovered that the man who handled the worms had been spraying fruit trees with arsenic and had carelessly transferred some arsenic to the feeding pan of the worm-fed ducklings. Arsenic is a deadly poison.
31. A team of expert biologists examines the body structure and processes of ten common varieties of ducklings including the three used in the experiment. The biologists can find no significant difference between the varieties examined except for coloring.
32. It is discovered that during the original experiment the regular-fed ducklings had less sunlight than the worm-fed ducklings. It is not known whether or not the difference in amount of sunshine would have an effect on the health of ducklings.
33. A group of well-known Canadian duck breeders report that they discovered long ago that it was dangerous to ducklings to let them run in a cabbage patch.
34. It is discovered that both sets of ducklings reached through their cages and drank water from a little ditch that ran past both cages. They drank practically no water out of the pans that were in the cages. The water in the ditch was ordinary water.
35. The experiment is repeated in Canada with three different varieties of ducklings. All of the ducklings die, whether worm-fed, or not.
36. The experiment is repeated in the United States with twice as many ducklings. At the end of the week, 40 out of the 44 regular-fed ducklings are alive and healthy and 39 out of the 44 worm-fed ducklings are alive and healthy.
37. It turns out that at the time of the original experiment a large oak tree was dropping acorns into the cages of the worm-fed ducklings only. The effect of this kind of acorn on the health of ducklings is not known.
38. A similar experiment with young dogs is performed. Another is performed with young turtles. In both cases the results are similar to those of the original ducklings experiment.

Section V: A research worker sets out to test the truth of the statement: If any duckling eats a cabbage worm, the duckling will die within six hours.

The research worker has developed accurate stomach-examining methods of telling whether a duckling has eaten a cabbage worm during the previous twelve hours.

In planning his experiments he needs to make some "predictions" from the above underlined statement.

- a. "PREDICTIONS" TELL WHAT WOULD BE TRUE, IF THE STATEMENT WERE TRUE.
- b. "PREDICTIONS" SHOULD BE USEFUL IN GUIDING AN ACTUAL EXPERIMENT.

Remembering these two rules about "predictions," answer items 39 through 42. The items refer to the seven possible "predictions" listed after item 42.

39. Of j, k, and l, which is the best "prediction"? A) j B) k C) l
40. Of k, l, and m, which is the best "prediction"? A) k B) l C) m
41. Of m, n, and o, which is the best "prediction"? A) m B) n C) o
42. Of n, o, and p, which is the best "prediction"? A) n B) o C) p

Possible "predictions":

- j. If any duckling eats a cabbage worm, the duckling will be dead within six hours; and if a stomach test is performed within twelve hours after eating the worm, the results of the stomach test will show that the duckling has eaten at least one cabbage worm.
- k. If any duckling does not die within six hours after a given period, then it did not eat any cabbage worms during that period.
- l. Suppose six hungry Pintail ducklings are put for one hour in a cabbage patch containing cabbage worms and then put in a clean cage for six hours; if any do not die during that period, the results of the stomach test will show that these ducklings did not eat any cabbage worms.
- m. If one Mallard duckling is selected at random from each of six different broods, and each selected duckling is fed a cabbage worm; all six ducklings will be dead within six hours.
- n. If one Mallard duckling is selected at random from each of ten different broods, then all ten ducklings are kept away from cabbage worms for a twelve-hour period; then none will die during the last six hours of the twelve-hour period.

- o. If twelve hungry, randomly-selected Canvas-back ducklings are turned loose for one hour in a cabbage patch containing cabbage worms and then put in a clean cage for six hours; if each dies during that period, and results of the stomach tests will show that each has eaten a cabbage worm.
- p. If a group of ten healthy Canvas-back ducklings that would probably live if not fed cabbage worms is randomly split in half, and each half treated the same except that the five of one group eat cabbage worms; then the worm-fed ducklings will die within six hours and the other ducklings probably will not.

SECTION VI: Items 43 through 46 provide situations in which a definition of a word is called for. From the three choices after each description, pick the one definition that best gives the meaning.

43. "That's a nice stock car you have there, Bill," his mother remarks.

"Stock car." exclaims Bill. "That's no stock car. Did you ever see a car in a dealer's showroom with bumpers made out of heavy pipe? Do the automobile manufacturers turn out cars with no fenders? Of course not."

Bill's mother then asks, "Just what do you mean by 'stock car'?"

Of the following, which is the best way to state Bill's notion of a stock car?

- a) A stock car is an automobile that is for the most part made of standard parts put out by automobile manufacturers, but which might have missing fenders and special bumpers.
 - b) A stock car is an automobile that has fenders and doesn't have bumpers made out of pipe.
 - c) A stock car is a standard automobile, as turned out by the factory and sold to the public.
44. "It certainly is a stock car," says Jim. "It has an ordinary engine that hasn't been changed since it came off the assembly line. That alone makes it a stock car and that's all that matters."

Of the following what is the best way to state Jim's notion of a stock car?

- a) A stock car is an automobile that is for the most part made of standard parts put out by automobile manufacturers, but which might have missing fenders and special bumpers.
- b) A stock car is an automobile with a standard engine
- c) A stock car is where the engine is standard.

45. "What are you making with that dough?" asked Mary's father.

"Dough!" exclaimed Mary. "Did you ever see anything made with yeast that was baked immediately after it was mixed? Naturally not," she said as she put the mixture into the oven immediately after mixing it. "Therefore, it's not dough."

"What do you mean by 'dough'?" her father asked.

Of the following, which is the best way to state Mary's notion of dough?

- a) Dough is a mixture of flour and other ingredients, including yeast.
 - b) Dough is a mixture of flour and other ingredients, not baked immediately.
 - c) Dough is a mixture of flour and other ingredients, often baked in an oven.
46. "Why, of course that's dough," said Joan. "You're making cookies, aren't you? It's not even called dough, unless it's used for cookies."

Of the following, which tells best the way to state Joan's notion of dough?

- a) Dough is a mixture of flour and other ingredients not baked immediately unless it's used for cookies.
- b) Dough is a mixture of flour and other ingredients which is used for cookies.
- c) Dough is a mixture of flour and other ingredients, which is used for cookies, unless it's baked immediately.

SECTION VII: In items 47 through 52 someone is speaking, but in each case there is an unstated assumption. An assumption is a statement that is taken for granted. Select the one that is most probably the unstated assumption. Consider each item by itself.

47. MR. DOBERT: The fact that Gailton's children have been forced to work explains their misbehavior.

- a) Children who have never been forced to work behave properly.
- b) Children who behave improperly have been forced to work.
- c) Children who have been forced to work behave improperly.

48. MRS. DOBERT: What we should do is not make them work. They would be all right. I know it.

- a) Children who are forced to work will misbehave.
- b) Children who are not forced to work will behave properly.
- c) Children who behave properly have not been forced to work.

49. MRS. ALGAN: We ought to make them work. That will cure them.
- a) Children who aren't forced to work will misbehave.
 - b) Children who are forced to work will behave properly.
 - c) Children who behave properly have been forced to work.
50. MR. ALGAN: The explanation of the misbehavior of Gailton's present-day crop of youngsters is a simple one. These children have been severely punished at some time or other. That's the trouble.
- a) Children who have been severely punished misbehave.
 - b) Children who misbehave have been severely punished at some time.
 - c) Children who haven't been severely punished behave properly.
51. MRS. DOBERT: Their behavior can be explained by realizing that most of these youngsters have never been punished.
- a) Children who are punished behave properly.
 - b) Children who behave improperly have never been punished.
 - c) Children who have never been punished behave improperly.
52. MR. DOBERT: What we should do is never punish them. That would take care of things.
- a) Children who behave badly have been punished at some time.
 - b) Children who are punished will misbehave.
 - c) Children who behave properly have never been punished.

THE END. GO BACK AND CHECK YOUR ANSWERS.

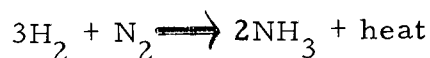
APPENDIX 2

KNOWLEDGE OF FACTS AND PRINCIPLES TEST

PROGRAM A

- _____ 5. When an atom uses two hybrid orbitals, constructed out of one s orbital and one p orbital, in making bonds to two other atoms, we expect the angle between the two bonds to be
- | | |
|----------------|--------------------|
| a) 90° | c) $109^\circ 28'$ |
| b) 180° | d) 120° |
| | e) 104.5° |

- _____ 6. In the manufacture of ammonia, hydrogen is combined with nitrogen. All substances are gaseous. The following equilibrium is known to exist:



Starting from a system in equilibrium an increase in pressure:

- | |
|---|
| a) will favor production of NH_3 |
| b) will favor decomposition of NH_3 |
| c) will have no effect upon production of NH_3 |
| d) will favor production of H_2 |
- _____ 7. Colloidal suspensions are dispersions of very small particles representing aggregates of many molecules in a liquid such as water.
- Which of the following statements, which refer to colloidal systems in water, is not true?
- | |
|---|
| a) the particles exhibit a Brownian motion |
| b) the particles are usually electrically charged |
| c) the suspension appears to the eye to have many of the characteristics of a true solution |
| d) the particles do not settle out because their density is less than that of water. |
- _____ 8. The principal commercial source material for preparing oxygen is
- | | |
|--------------------|----------------------------|
| a) liquid air | d) HgO |
| b) KClO_3 | e) H_2SO_4 |
| c) KNO_3 | |
- _____ 9. Referring to the activity of E. M. F. series: Li-K-Ca-Na-Mg-Al-Zn-Fe-Sn-H-Ag-Au, in which case will a reaction occur?
- | | |
|---------------------------------|------------------------------------|
| a) $\text{Na}^+ + \text{Li}^+$ | d) $\text{Al}^{+++} + \text{Zn}^+$ |
| b) $\text{Mg}^{++} + \text{Zn}$ | d) $\text{Sn} + \text{Ag}$ |
- _____ 10. From the generalization that "All gases at the same temperature have the same average molecular kinetic energy", it is possible to deduce that at the same temperature

- a) heavy molecules should move more slowly than light molecules.
 - b) light molecules should move more slowly than heavy molecules.
 - c) light molecules move at the same speed as heavy molecules.
 - d) the relative speeds of light and heavy molecules have no relation to the molecular kinetic energies
 - e) more than one of the above could be considered correct
- _____ 11. Millikan's oil-drop experiment determined the
- a) value of the ratio e/m
 - b) number of electrons in the 1st energy level.
 - c) value of the charge on the electron
 - d) magnitude of Planck's constant
- _____ 12. The vapor collecting in the space above a liquid in a container is considered to saturate the space when
- a) the density of the vapor equals the density of the liquid
 - b) molecules leave and enter the liquid at equal rates
 - c) no more molecules leave the liquid
 - d) the liquid boils
 - e) the vapor density is equal to 1
- _____ 13. When an electron moves from the 1st energy level to the 2nd energy level there is an accompanying
- a) absorption of energy
 - b) emission of beta particles
 - c) emission of x-rays
 - d) emission of gamma rays
- _____ 14. Oxygen and ozone have the formulas O_2 and O_3 respectively. Which term applies to them?
- a) Isomers
 - b) Isobars
 - c) Allotropes
 - d) Ampholytes
 - e) Isotopes
- _____ 15. The chemical nature of the atom is determined by the
- a) atomic weight
 - b) number of neutrons
 - c) electrons
 - d) weight of the protons
- _____ 16. Balance the following equation: $aS + bHNO_3 \rightarrow cH_2SO_4 + dNO_2 + eH_2O$ How many moles of H_2O are formed per gram atom of sulfur consumed?
- a) 1
 - b) 2
 - c) 4
 - d) 6
 - e) none of these

- _____ 17. Which of the following functional groups tends to confer acidic properties upon an organic substance?
- a) $-\text{CHO}$
 - b) $-\text{CO}$
 - c) $-\text{COOH}$
 - d) $-\text{NH}_2$
 - e) $-\text{CN}$

Items 18 through 20 are based on the following observations which have been made on four metals, X, Y, Z, and W.

- a) Metal X dissolved in hydrochloric acid
 - b) When metal Y is heated with the oxide of metal X, metal X is liberated and the oxide of metal Y is formed with the evolution of a great deal of heat
 - c) metal Z does not dissolve in hydrochloric acid
 - d) Metal W is displaced by metal X in a solution of WCl_2
- _____ 18. Which is the more active, metal X or metal Y?
- a) Metal X
 - b) Metal Y
 - c) Both are equally active
 - d) It is not possible to tell
- _____ 19. Which is the better reducing agent, metal Z or hydrogen?
- a) Metal Z
 - b) Hydrogen
 - c) It is not possible to tell
 - d) both are equally good reducing agents
- _____ 20. Which is the better reducing agent, metal Z or metal W?
- a) Metal Z
 - b) Metal W
 - c) It is impossible to tell
 - d) both are equally good reducing agents
- _____ 21. As the atomic number of the halogen increases, the halogens
- a) lose their outermost electrons less easily
 - b) become less dense
 - c) become lighter in color
 - d) gain electrons less easily
- _____ 22. Transition metal complexes are often colored because
- a) they have d-electrons
 - b) high oxidation states are common
 - c) they are paramagnetic
 - d) differences in d-electron energy levels often fall in the visible region

23. A 0.3M HCl solution contains the following ions: Hg^{++} , Cd^{++} , Sr^{++} , Fe^{++} , Cu^{++} . The addition of H_2S to the above solution will precipitate
- Cd, Cu, and Hg
 - Cd, Fe, and Sr
 - Hg, Cu, and Fe
 - Cu, Sr, and Fe

24. Kinetic data for the overall net reaction $2\text{A} + 2\text{B} \rightarrow 2\text{C} + \text{D}$ is as follows:

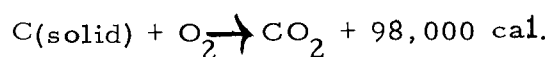
Exp.	Initial A	Initial B	Initial rate of D formation
1	0.10	0.10	0.25 mole $\text{l}^{-1} \text{min}^{-1}$
2	0.20	0.20	2.0
3	0.10	0.20	1.0
4	0.20	0.40	8.0

The rate law for the above reaction is:

- rate = $k[\text{A}][\text{B}]$
 - rate = $k[\text{A}]^2[\text{B}]$
 - rate = $k[\text{A}][\text{B}]^2$
 - rate = $k[\text{A}]^2[\text{B}]^2$
25. A fundamental equation in x-ray spectroscopy is
- $\text{H} = \text{E} + pV$
 - $n\lambda = 2d \sin \theta$
 - $PV = nRT$
 - $nFE^\circ = RT \ln K$

26. A molal solution is one that contains one mole of solute per
- liter of solvent
 - liter of solution
 - 1000 g of solvent
 - 1000 g of solution

27. The heat of combustion for one mole of carbon is 98,000 calories



The reaction is exothermic to the right. How many calories of heat would be liberated on the complete combustion of 60 grams of carbon?

- 490,000 calories
 - $12 \times 98,000$ calories
 - $44 \times 98,000$ calories
 - $60 \times 98,000$ calories
28. If a compound has a negative heat of solution at high temperatures it dissolves
- more rapidly and is more soluble
 - more rapidly and is less soluble
 - less rapidly and is less soluble
 - less rapidly and is more soluble

- _____ 29. The conjugate base of NH_4^+ is
 a) NH_3 c) KOH
 b) NH_4OH d) OH^-
- _____ 30. The best evidence that electrons have definite energy levels is based on the observation that
 a) atomic spectra consist of lines and not continuous bands
 b) electrons in the beta-ray have high kinetic energy
 c) the penetrating power of cathode ray electrons depends on the voltage used to produce them
 d) electrons revolve around the nucleus
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 c) the heat of vaporization plus the heat of fusion
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 a) cause the high melting point of most salts
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 c) disappear when gases are liquefied.
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- _____ 33. The equilibrium expression or condition for the following reaction: $2\text{C(s)} + \text{O}_2\text{(g)} = 2\text{CO(g)}$, is
 a) $\text{Ke} = \frac{2\text{CO}}{2\text{C} + \text{O}_2}$ c) $\text{Ke} = \frac{(\text{CO})^2}{(\text{O}_2)^1}$
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- _____ 34. If the formula of an oxide is X_2O_3 , what is the formula of the chloride of X?
 a) XCl_3 d) XCl_6
 b) XCl e) a formula not listed above
 c) X_3Cl
- _____ 35. If a direct current deposits 11.5 grams of sodium (Atom weight = 23) in 1000 seconds, the number of grams of aluminum (Atomic weight = 27) deposited by the same current in the same period of time would be
 a) 4.5 c) 11.5
 b) 9.0 d) 13.5

- _____ 36. To halve the pressure on a given mass of gas at 27°C ., keeping its volume constant, changes the temperature to
a) 54°C d) $600^{\circ}\text{Absolute}$
b) $150^{\circ}\text{Absolute}$ 3) -27°C
c) 13.5°C
- _____ 37. Which one of the following is the best observational evidence for the statement in the kinetic theory that molecules are in continual motion?
a) Convection takes place in gases
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c) small suspended particles in a solution move about
d) on collision with the walls of a container, molecules of a gas suffer no net loss of kinetic energy
- _____ 38. A student made a barometer by filling a long glass tube (closed at one end) with mercury, holding his finger over the open end and inverting the tube, then placing the open end in a dish of mercury and finally removing his finger. As a result, some of the mercury ran out of the tube but eventually the height of the mercury column was 75 cm. of mercury which checked rather closely with the laboratory barometer. Experimenting further, he introduced a drop of water into the lower end of the tube and noted that the drop of water worked its way upward and after reaching the top, the barometer read 73 cm. of mercury. This relatively large decrease in the readings is explained as follows:
a) the weight of the water drop on top of the mercury caused the decrease
b) the drop contained a lot of dissolved air which destroyed the vacuum.
c) the drop vaporized and exerted a vapor pressure
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- _____ 39. According to Raoult's law
a) the freezing points of all aqueous solutions of the same percentage concentration are identical.
b) a molal solution of a very soluble substance in a given solvent boils at a higher temperature than a molal solution of a substance less soluble in that solvent
c) the vapor pressure of a solution is directly proportional to its molecular concentration
d) in a solution the lowering of vapor pressure of the solvent is proportional to the mole fraction of the solute

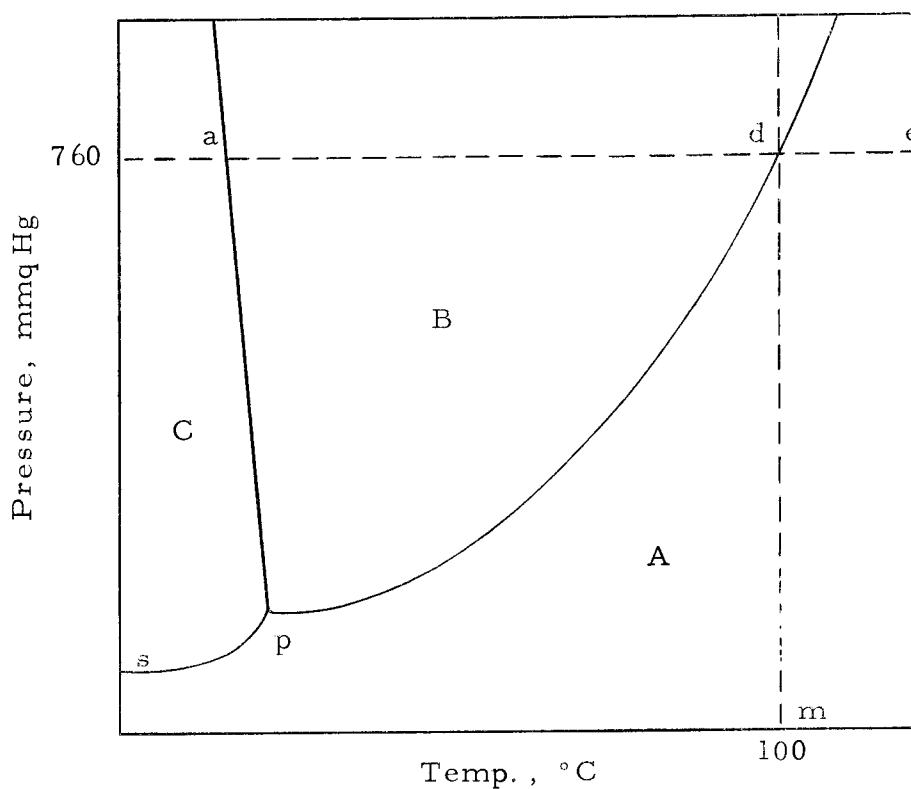
- _____ 40. The energy possessed by a falling rubber ball at the middle of its flight is
 a) largely heat energy
 b) partly kinetic and partly potential
 c) all potential
 d) all kinetic
 e) impossible to predict because the ball is elastic
- _____ 41. The common name for HNO_2 is
 a) nitric
 b) ammonia
 c) hydrazine
 d) nitrous acid
- _____ 42. When a radioactive atom emits a beta particle from the nucleus, the new substance produced
 a) has the same atomic number
 b) gains one unit in atomic mass
 c) gains one atomic number unit
 d) gains one neutron
- _____ 43. The principle characteristic of all oxidation-reduction reactions is
 a) the formation of water
 b) the transfer of electrons
 c) complete irreversibility
 d) the production of non-ionized compounds
- _____ 44. Carefully controlled oxidation of normal propyl alcohol produces an aldehyde containing the same number of carbon atoms in the molecule as does the propyl alcohol. The molecular composition of the aldehyde is
 a) $\text{C}_2\text{H}_5\text{C}\begin{smallmatrix} \text{=O} \\ \text{H} \end{smallmatrix}$
 b) $\text{C}_2\text{H}_4\text{C}\begin{smallmatrix} \text{=O} \\ \text{H} \end{smallmatrix}$
 c) $\text{C}_2\text{H}_5\text{C}\begin{smallmatrix} \text{H} \\ \text{H} \end{smallmatrix}\text{-OH}$
 d) $\text{C}_3\text{H}_5\text{C}\begin{smallmatrix} \text{H} \\ \text{H} \end{smallmatrix}\text{-OH}$
 e) $\text{C}_2\text{H}_6\text{C}\begin{smallmatrix} \text{=O} \\ \text{H} \end{smallmatrix}$
- _____ 45. As the atomic number of the elements in the second period of the periodic table increases, the ionization potential
 a) general increases
 b) generally decreases
 c) first increases then decreases
 d) first decreases then increases

- _____ 46. In the diamond,
a) unbound electrons are abundant
b) all the four valence electrons of each carbon atom are used in firmly binding that carbon atom to four other carbon atoms
c) the molecules have the formula C_8
d) separate planes of carbon atoms slip over one another easily, under slight pressure
- _____ 47. The rare earths
a) are a group of elements whose chemical behavior is very similar because all have eight electrons in the outside shell
b) are a series of elements which combine with no other elements
c) are a series of elements whose chemical similarity is due to the fact that the two outermost electron shells are identical
d) are a group of elements with the same atomic number
- _____ 48. Linus Pauling received a Nobel Prize for his work on
a) atomic structure
b) chemical bonds
c) photosynthesis
d) genetic effects of radiation
- _____ 49. A collision of two molecules produces a chemical reaction only when
a) they can form a covalent bond
b) enough kinetic energy is present to more than provide the "energy of activation" for the reaction
c) there is no change in potential energy
d) no change in kinetic energy
- _____ 50. The simplest crystalline symmetry in a solid is
a) cubic
b) rhombic
c) tetragonal
d) triclinic
- _____ 51. A solution containing 40.0 g. of a covalent molecular compound in 500 g. of water freezes at -3.72°C . The molal freezing point constant for water is 1.86° . What is the molecular weight of the solute?
a) 40
b) 80
c) 20
d) 50

APPENDIX 3

KNOWLEDGE OF FACTS AND PRINCIPLES TEST
PROGRAMS B AND C

- _____ 1. If twenty-five ml of an acid are needed to neutralize exactly 50 ml of a 0.2N solution of a base, the normality of the acid is:
- a) 0.1 c) 0.4
b) 0.2 d) 2.0
- _____ 2. Isotopes are elements
- a) with two or more forms, like graphite and the diamond
b) which have both positive and negative valences
c) which can exist in two or more states at the same temperature
d) with the same atomic number but a different number of neutrons

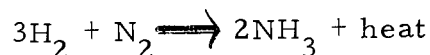


The above represents a phase diagram for water. Answer the questions below using the above diagram.

- _____ 3. The state of the water in region A is a
- a) solid c) gas
b) liquid d) none of these
- _____ 4. Gas, boiling liquid and solid ice can exist together at only one point on the diagram.
- a) s c) a
b) d d) p

- _____ 5. When an atom uses two hybrid orbitals, constructed out of one s orbital and one p orbital, in making bonds to two other atoms, we expect the angle between the two bonds to be
- | | |
|----------------|--------------------|
| a) 90° | c) $109^\circ 28'$ |
| b) 180° | d) 120° |
| | e) 104.5° |

- _____ 6. In the manufacture of ammonia, hydrogen is combined with nitrogen. All substances are gaseous. The following equilibrium is known to exist:



Starting from a system in equilibrium an increase in pressure:

- | |
|---|
| a) will favor production of NH_3 |
| b) will favor decomposition of NH_3 |
| c) will have no effect upon production of NH_3 |
| d) will favor production of H_2 |
- _____ 7. Colloidal suspensions are dispersions of very small particles representing aggregates of many molecules in a liquid such as water.
- Which of the following statements, which refer to colloidal systems in water, is not true?
- | |
|---|
| a) the particles exhibit a Brownian motion |
| b) the particles are usually electrically charged |
| c) the suspension appears to the eye to have many of the characteristics of a true solution |
| d) the particles do not settle out because their density is less than that of water. |
- _____ 8. The principal commercial source material for preparing oxygen is
- | | |
|--------------------|----------------------------|
| a) liquid air | d) HgO |
| b) KClO_3 | e) H_2SO_4 |
| c) KNO_3 | |
- _____ 9. Referring to the activity of E. M. F. series: Li-K-Ca-Na-Mg-Al-Zn-Fe-Sn-H-Ag-Au, in which case will a reaction occur?
- | | |
|---------------------------------|------------------------------------|
| a) $\text{Na}^+ + \text{Li}^+$ | d) $\text{Al}^{+++} + \text{Zn}^+$ |
| b) $\text{Mg}^{++} + \text{Zn}$ | d) $\text{Sn} + \text{Ag}$ |
- _____ 10. From the generalization that "All gases at the same temperature have the same average molecular kinetic energy", it is possible to deduce that at the same temperature

- a) heavy molecules should move more slowly than light molecules.
 - b) light molecules should move more slowly than heavy molecules.
 - c) light molecules move at the same speed as heavy molecules.
 - d) the relative speeds of light and heavy molecules have no relation to the molecular kinetic energies
 - e) more than one of the above could be considered correct
- _____ 11. Millikan's oil-drop experiment determined the
- a) value of the ratio e/m
 - b) number of electrons in the 1st energy level
 - c) value of the charge on the electron
 - d) magnitude of Planck's constant
- _____ 12. The vapor collecting in the space above a liquid in a container is considered to saturate the space when
- a) the density of the vapor equals the density of the liquid
 - b) molecules leave and enter the liquid at equal rates
 - c) no more molecules leave the liquid
 - d) the liquid boils
 - e) the vapor density is equal to 1
- _____ 13. When an electron moves from the 1st energy level to the 2nd energy level there is an accompanying
- a) absorption of energy
 - b) emission of beta particles
 - c) emission of x-rays
 - d) emission of gamma rays
- _____ 14. Oxygen and ozone have the formulas O_2 and O_3 respectively. Which term applies to them?
- a) Isomers
 - b) Isobars
 - c) Allotropes
 - d) ampholytes
 - e) Isotopes
- _____ 15. Radioactive Pb^{201} has a half-life of 8 hours, starting with 1 gram of this isotope, how much will remain at the end of 24 hours?
- a) $1/2$ gram
 - b) $1/3$ gram
 - c) $1/8$ gram
 - d) none
- _____ 16. Balance the following equation: $aS + bHNO_3 \rightarrow cH_2SO_4 + dNO_2 + eH_2O$ How many moles of H_2O are formed per gram atom of sulfur consumed?
- a) 1
 - b) 2
 - c) 4
 - d) 6
 - e) none of these

- _____ 17. Which of the following functional groups tends to confer acidic properties upon an organic substance?
- a) -CHO
 - b) -CO
 - c) -COOH
 - d) -NH₂
 - e) -CN

Items 18 through 20 are based on the following observations which have been made on four metals, X, Y, Z, and W.

- a) Metal X dissolved in hydrochloric acid
 - b) When metal Y is heated with the oxide of metal X, metal X is liberated and the oxide of metal Y is formed with the evolution of a great deal of heat
 - c) metal Z does not dissolve in hydrochloric acid
 - d) Metal W is displaced by metal X in a solution of WCl₂
- _____ 18. Which is the more active, metal X or metal Y?
- a) Metal X
 - b) Metal Y
 - c) Both are equally active
 - d) It is not possible to tell
- _____ 19. Which is the better reducing agent, metal Z or hydrogen?
- a) Metal Z
 - b) Hydrogen
 - c) It is not possible to tell
 - d) both are equally good reducing agents
- _____ 20. Which is the better reducing agent, metal Z or metal W?
- a) Metal Z
 - b) Metal W
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- _____ 21. As the atomic number of the halogen increases, the halogens
- a) lose their outermost electrons less easily
 - b) become less dense
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- a) they have d-electrons
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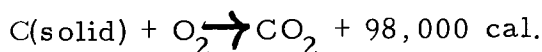
23. A 0.3M HCl solution contains the following ions: Hg^{++} , Cd^{++} , Sr^{++} , Fe^{++} , Cu^{++} . The addition of H_2S to the above solution will precipitate
- Cd, Cu, and Hg
 - Cd, Fe, and Sr
 - Hg, Cu, and Fe
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24. Kinetic data for the overall net reaction $2\text{A} + 2\text{B} \rightarrow 2\text{C} + \text{D}$ is as follows:

Exp.	Initial A	Initial B	Initial rate of D formation
1	0.10	0.10	0.25 mole $\text{l}^{-1} \text{min}^{-1}$
2	0.20	0.20	2.0
3	0.10	0.20	1.0
4	0.20	0.40	8.0

The rate law for the above reaction is:

- rate = $k[\text{A}][\text{B}]$
 - rate = $k[\text{A}]^2[\text{B}]$
 - rate = $k[\text{A}][\text{B}]^2$
 - rate = $k[\text{A}]^2[\text{B}]^2$
25. A fundamental equation in x-ray spectroscopy is
- $\text{H} = \text{E} + pV$
 - $n\lambda = 2d \sin \theta$
 - $PV = nRT$
 - $nFE^\circ - Rt \ln K$
26. A molal solution is one that contains one mole of solute per
- liter of solvent
 - liter of solution
 - 1000 g of solvent
 - 1000 g of solution
27. The heat of combustion for one mole of carbon is 98,000 calories



The reaction is exothermic to the right. How many calories of heat would be liberated on the complete combustion of 60 grams of carbon?

- 490,000 calories
 - $12 \times 98,000$ calories
 - $44 \times 98,000$ calories
 - $60 \times 98,000$ calories
28. The driving force of a chemical reaction is most closely related to the concept of
- heat of formation
 - heat of reaction
 - entropy
 - free energy

- _____ 29. The pH of a 0.3M solution of HCl is correctly expressed by
 a) $\log 3.3$ c) $1/\log 0.3$
 b) $\text{antilog } 3.3$ d) $\log 0.3$
- _____ 30. The best evidence that electrons have definite energy levels is based on the observation that
 a) atomic spectra consist of lines and not continuous bands
 b) electrons in the beta-ray have high kinetic energy
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- _____ 31. The heat necessary to convert one mole of ice at one torr directly into water vapor is approximately equal to:
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- _____ 34. If the formula of an oxide is X_2O_3 , what is the formula of the chloride of X?
 a) XCl_3 d) XCl_6
 b) XCl d) a formula not listed above
 c) X_3Cl
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d) in a solution the lowering of vapor pressure of the solvent is proportional to the mole fraction of the solute

- _____ 40. Two specific energy levels of an atom differ by 3×10^{-12} erg. Assuming Planck's constant to be 6×10^{-27} erg-sec the wavelength of the radiation emitted when an electron jumps from one of these levels to the other is
- a) 3×10^{-12} cm
 - b) 1.67×10^{-4} cm
 - c) 5×10^{14} cm
 - d) 16,700 Å
 - e) 6000 Å
- _____ 41. The common name for HNO_2 is
- a) nitric
 - b) ammonia
 - c) hydrazine
 - d) nitrous acid
- _____ 42. When a radioactive atom emits a beta particle from the nucleus, the new substance produced
- a) has the same atomic number
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 - c) gains one atomic number unit
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- _____ 43. The principle characteristic of all oxidation-reduction reactions is
- a) the formation of water
 - b) the transfer of electrons
 - c) complete irreversibility
 - d) the production of non-ionized compounds
- _____ 44. Which one of the following best describes the double bond in ethylene C_2H_4 ?
- a) sigma bond
 - b) bond around which the carbon atoms are free to rotate
 - c) sp^3 hybrid orbital
 - d) sigma-pi bond
- _____ 45. As the atomic number of the elements in the second period of the periodic table increases, the ionization potential
- a) generally increases
 - b) generally decreases
 - c) first increases then decreases
 - d) first decreases then increases

- _____ 46. In the diamond,
a) unbound electrons are abundant
b) all the four valence electrons of each carbon atom are used in firmly binding that carbon atom to four other carbon atoms
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b) are a series of elements which combine with no other elements
c) are a series of elements whose chemical similarity is due to the fact that the two outermost electron shells are identical
d) are a group of elements with the same atomic number
- _____ 48. The solubility of CaF_2 is 2×10^{-4} moles per liter; its solubility product constant is
a) 2.6×10^{-9} c) 3.2×10^{-11}
b) 4×10^{-8} d) 8×10^{-12}
- _____ 49. A collision of two molecules produces a chemical reaction only when
a) they can form a covalent bond
b) enough kinetic energy is present to more than provide the "energy of activation" for the reaction
c) there is no change in potential energy
d) no change in kinetic energy
- _____ 50. The simplest crystalline symmetry in a solid is
a) cubic c) tetragonal
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a) 40 c) 20
b) 80 d) 50

