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THE EFFECT OF VARYING INCENTIVE AND DEGREE
OF LEARNER CONTROL IN PROVIDING COMPUTERIZED HELP
WITH ESSENTIAL MATHEMATICS REQUIRED IN CHEMISTRY
(CHEMRIC)

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By

Stanley T. Marcus, A.B., M.A.

The Ohio State University
1973

Reading Committee:
Dr. Robert Steiner
Dr. Robert Ouellette

Approved by

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Minor Field: Science (Chemistry). Professor W. Thomas Lippincott.
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<td>CAI</td>
<td>On-line Computer Assisted Instruction</td>
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<tr>
<td>CBIM</td>
<td>Computer Based Instructional Management</td>
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<tr>
<td>CHEMRIC</td>
<td>Computerized Help With Essential Mathematics Required in Chemistry</td>
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<tr>
<td>DF</td>
<td>Degrees of Freedom</td>
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<tr>
<td>DOSPIDRIM</td>
<td>Degree of Student Participation in Deciding Remedial Instructional Needs</td>
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<td>Treatment Condition in which Incentive was offered</td>
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CHAPTER I

NEED FOR THE STUDY

Chemistry departments in this country have always had to face the problem of providing instruction in chemistry for students having an extremely wide range of ability and interest. A recent report states:

Most freshman and sophomore chemistry students... are not chemistry majors but premedical students, engineering students, nursing majors, physics and biology majors, education majors, veterinary students, agricultural students, and others, for whom chemistry is merely a required course or two but is not a prime vocational objective. (Sanders, 1972, p. 20).

Recognizing the fact that the chemistry needs of all students are not the same, most departments have developed more than one series of courses, tailoring each to specific groups (Sanders, 1972). The Division of General Chemistry at The Ohio State University, for example, has developed four sequences of instruction: the first, for nonmajors, including students in home economics, agriculture, nursing and allied medical sciences; the second, for majors, including students planning to major in a science or having a deeper understanding of inorganic and physical chemistry; the third, for engineering students; and the fourth, for honors students.
Problems with Series for Non-Science Majors

Nearly all colleges and universities offer chemistry courses for non-science majors. This series of courses is often considered to be the most challenging from an instructional viewpoint, for while the students enter them least prepared in terms of prerequisite skills and understandings, their need for learning chemistry is as great as, or greater than, that of students in the other sequences. They must learn the subject in terms of both its qualitative and quantitative aspects. Unfortunately, many of these students find themselves unprepared to cope successfully with the quantitative portions.

Possible Strategies for Dealing with the Situation

To deal with this problem, one could choose from several alternative courses of action, three of which will be considered. One is to teach the qualitative aspects of chemistry, simply omitting the quantitative. While this has been tried, and there remain some who favor such an approach, most educators share the opinion that this is a pseudo-solution and can serve only to lead the student into believing he knows something when he has no more than a very superficial type of knowledge.

A second approach, which is most typically used at The Ohio State University and other universities and colleges, is to teach the course in an intellectually honest fashion, realizing that many students
will not be able to cope with the material. Although due to fairly rigorous prerequisites the average chemistry student is probably more able than the average student in the university, it is found that only four students out of five (Gault, 1972) who begin the first course in the series at The Ohio State University manage to pass it. Twenty percent either drop out or fail to meet the minimum standards for performance. Furthermore, whether or not another fifteen to twenty percent who barely managed to survive learned much chemistry is open to conjecture (most professors demand an achievement level of only about fifty percent in order to pass the course).

A third way to deal with the problem is to build remedial help into the course as it is taught in order to make it possible for more students to understand the subject matter. While this strategy is appealing at first glance, it is very inefficient in many respects. For one thing, the instructor must replace valuable time he could be using to illuminate the concepts of chemistry with time spent on remedial help. In addition, since he is pressed for time (fewer than thirty, forty-seven minute lectures per quarter) it is likely that his remedial explanations will be too terse for those who need them. Finally, those who do not need the help will be doomed to the inevitable boredom and frustration resulting from not being able to get to the subject
matter of the course. In spite of these disadvantages, there is strong evidence (Collagan, 1969) that it is better to build remedial help into a course than to make the false assumption that students will be able to understand higher level concepts without the prerequisite skills (Okey, 1970).

The need for providing remedial help is increasing rapidly, largely due to the fact that universities are recruiting and admitting larger portions of students inadequately prepared by previous standards (Mitzel, 1970). In his address to the new graduates at the Summer Quarter, 1972, Commencement Exercises at The Ohio State University, Roger Heyns predicted that the nature of the university population will soon change to become much more heterogeneous (Heyns, 1972), including many more students having weak backgrounds. City University of New York, which launched an open-admissions policy in September, 1970, now finds, for example, that "... between 25 and 30 percent of its freshman students are underprepared" (Sanders, 1972, p. 34). It is obvious that chemistry departments wishing to maintain a quality level of instruction without failing an unacceptable proportion of the students will have to make some provision for remedial help. The overall problem is to find some method of providing remedial help to those who need it in a way which not only
will be effective, but also will not require time which should be devoted to instruction in chemistry.

**What Kind of Help and How Can It Be Provided**

The most effective instruction is that which has been individualized by basing it upon an analysis of what skills and understandings a student possesses in order to make it possible to teach him precisely those he needs. This type of instruction is also the least time consuming, since no time is unnecessarily allocated to trying to teach him what he already knows. Until recently, however, truly individualized instruction has not been feasible because of the physical impossibility for a teacher to provide such instruction for more than a very few students simultaneously (Baker, 1970). Mager and Clark (1963, p. 74) suggested nearly ten years ago that

...it is timely to begin thinking about curriculum generating machines. These devices would be designed to detect what the student already knows, compare this body of knowledge with that required by the objectives of the program, and then generate a curriculum for the student. The result would be a saving in student time equal to the time it would take to teach him what he already knows relating to the instructional objectives, minus the time required to detect the state of his knowledge; boredom would also be reduced.

The development of the highspeed electronic computer has finally made it possible, if not practical, to implement such a proposal.
Computers and Individualized Instruction

The first large scale applications of the computer to the problem of individualization (Suppes, 1969; Bitzer and Skaperdas, 1971) have utilized the computer in an interactive sense, with each student sitting at a terminal communicating with the computer. Unfortunately, on-line conversational systems are very expensive to operate, and even strong advocates admit that it will take some time before CAI is really practical (Seidel, 1969). In addition, the overwhelming preoccupation with interactive CAI has served to retard efforts to develop other approaches (Baker, 1971).

One recent development which offers great promise is using the computer to manage individualized instruction. Zinn (1967, p. 626) points out

Management applications can be implemented on a large scale sooner than tutorial uses of computers by individual students, and at much less expense per unit of instruction accomplished. Furthermore, knowledge about assessment of performance and sequencing of material in management systems will contribute to effective implementation of conversation tutorial uses of computers by students.

It is clear that many of the attributes of on-line CAI, including the ability to diagnose and provide individualized instruction, can also be built into a batch-processing system. Up to now, however, CBIM (computer based instructional management) systems have been
designed to prescribe instruction to be carried out by other means, rather than to act as direct agents of instruction (Baker, 1971). A review of the research, on the other hand, reveals no reason why the CBIM system should not be extended to act as a direct agent of instruction. There is no conclusive evidence that the two main differences between a batch-processing and an on-line system, namely feedback interval and amount of interaction between feedback intervals, favor on-line systems (More, 1969). Also, the economic and technological barriers holding back on-line systems are virtually nonexistent in the case of batch-processing systems. No expensive terminals are needed, no special rooms need to be used, and administrative overhead costs are much lower. A cost analysis for providing diagnostic testing and individualized feedback via on-line (Christopher, 1972) versus batch-processing (Deem, 1972) procedures was carried out at The Ohio State University by the writer. The analysis revealed that to administer a diagnostic pretest, to have the responses punched into holerith cards by optical scanning, and to use the computer (IBM 370/165) to provide individualized feedback for three hundred students (a normal lecture section) would cost between twenty-five and thirty-five dollars. This would include the cost of the examination papers and processing expenses of
four cents per sheet, and approximately twenty dollars in computer costs (Deem, 1972). To do the same thing with on-line CAI facilities at The Ohio State University would cost approximately four dollars per student per hour (includes central processing unit costs, terminal rental plus some service costs), or twelve hundred dollars per hour for three hundred students. While it may be argued that if efficient procedures were used in conjunction with the on-line system, a full hour might not be required for each student, it is easy to see that it would be impossible to compete with the batch-processing approach even in an ideal case.

To summarize, then,

1. A significant proportion of students cannot succeed in learning chemistry because of deficiencies in prerequisite skills and understandings. This proportion will increase sharply in the near future.

2. The remedial instruction must be provided fast and effectively. To achieve this means diagnosis and individualization of instruction. The computer appears to offer the most reasonable way to provide truly individualized instruction efficiently.
3. Individualization of instruction can be achieved completely by on-line computer systems, but it is prohibitively expensive, meaning that it cannot be used generally on a large scale for some time.

4. A batch processing system can be implemented very economically using available technology. The differences between a batch-processing system and an on-line CAI system, namely feedback interval and amount of information between intervals, do not necessarily favor on-line systems.

Based on this evidence, it was decided that a batch processing system for providing computerized remedial help for general chemistry students would be developed.

Identification of Subject Matter for the Remedial Help System

After finding a potentially useful and economically feasible way of using the computer to provide remedial instruction, the next problem was to identify those skills and understandings most critical to success in chemistry but which not all students possess. While the literature revealed that many other factors have importance, it was found that a mastery of certain mathematics skills appears to be absolutely necessary (Denny, 1971; Adams, 1964; Cronbach, 1967). Therefore, the system was designed to provide Computerized Help with Essential Mathematics Required in Chemistry (CHEMRIC).
CHEMRIC consists of a diagnostic pretest and a PL/1 program which is used first to analyze student responses to the pretest, and then to print feedback consisting of individualized explanations and problems for each student.

The Diagnostic Pretest

A search of the relevant literature was very helpful in making decisions about the diagnostic pretest. It pointed out the need for individualization of instruction, and also helped to identify both the subject matter (mathematics) and the specific mathematics skills (Denny, 1971) important for general chemistry. In addition, the literature was useful in selecting an appropriate format for the pretest. While a multiple-choice format appeared to be the most reasonable, the literature seemed to suggest that a standard objective test (in which a student is given a problem to work and several answers to the problem, from which he must select one) might not be the best type of pretest to use. There is evidence that a self-evaluative approach (in which a student would be given a problem to work, and then asked to indicate whether or not he felt he needed help with that type problem) might be superior, with respect both to validity and to motivation (Mager and Clark, 1963). This question is
directly related to the issue in instructional theory of how much voice a student should have in making instructional decisions. There are those who are convinced that the programmer (teacher) is in the best position to decide (Suppes, 1969; Stolurow, 1961), while others insist that the adult learner should make these decisions (Mager and Clark, 1963; Campbell and Chapman, 1965). A study comparing the relative effectiveness of using a self-evaluative diagnostic pretest versus an objective diagnostic pretest was designed to obtain evidence to help decide which format to use in the CHEMRIC system, and at the same time, to contribute toward the resolution of an important issue in instructional theory.

The CHEMRIC Feedback

The literature revealed that the most effective kind of feedback would have the following characteristics:

1. Provision of both knowledge of results and corrective explanations (Gilman, 1969a).

2. Easy to read and comprehend (Collagan, 1969; Nobel, 1969)

3. Careful use of mathematical symbols (Students must understand meanings) (Scandura, 1967).

4. Explanations as short as possible without sacrificing clarity (Swets, et al., 1964; Gilman, 1969a).

The programmer made every effort to follow these guidelines in preparing CHEMRIC.

Motivation

Ideally, of course, students would make the best use of the CHEMRIC materials without requiring any extrinsic reinforcement. Some educators feel that if the materials are intrinsically interesting and meaningful, "... the need for obviously extrinsic devices will be slight or non-existent" (Wingo, Max G., in Mouly, 1971, p. 330). Others are somewhat less idealistic. Consider, for example, this comment:

The most important characteristic of a favorable learning situation is a strong ego-involved drive on the part of the learner to acquire the various socially approved behavior patterns with which the school is concerned (Cook, 1950, p. 339).

or this:

No matter how excellent the quality of the material, the student will not learn it well unless he is provided an incentive for doing it (Sullivan, Baker, and Schutz, 1967, p. 169).

Reviewing the results of studies dealing with motivation was quite helpful in suggesting some general principles, i.e., praise is usually
more effective than blame, but it also led to the conclusion that there are very few all-encompassing, simple rules which will always work. The effect, for example, of a particular incentive may vary considerably with different individuals, and even with the same individuals under different conditions (Bower, et al., 1970; Premack, 1970). Although the interactions are complex, the fact that the presence or absence of an incentive has often been associated with the presence or absence of learning (Cohen, 1967; Nesselroad and Vargas, 1970) would seem by itself to justify the need for further research in this area. The particular situation in which the CHEMRIC system has been implemented has a number of attributes which make it a good vehicle for supporting incentive research, including good population size and ease of data collection. In addition, because courses similar to the one in which CHEMRIC is used are offered by hundreds of colleges and universities, the results should be quite generalizable.

Summary

A system such as CHEMRIC should be capable of providing individualized instruction which is effective, efficient with respect to time, and economically feasible. To optimize its effectiveness, it was felt that research should be carried out to:
1. Determine if the explanations in the feedback were appropriate and understandable;

2. Determine the need for providing an extrinsic incentive for using the materials; and

3. Determine whether a self-evaluative type diagnostic pretest or a standard objective type would be more beneficial.
STATEMENT OF THE PROBLEM

The research in this study was of two types, evaluative and experimental. The purpose was to improve CHEMRIC, to evaluate its operation and to add new knowledge relevant to computer related instructional theory through the examination and manipulation of certain key variables thought to be important in determining the effectiveness of such a system.

1. Evaluative Research

The first problem was to evaluate the CHEMRIC diagnostic pretest and the information generated through its use. The aim was to provide more complete and precise information about the mathematical competencies of entering college chemistry students.

The second evaluative problem was to determine whether there was a relationship between performance on the CHEMRIC pretest items and performance on related first midquarter examination items.

The third problem was to determine how the students felt about certain attributes of the CHEMRIC system; and also to find out if there was a relationship between their opinions and 1) their achievement in the course, or 2) the treatment situations into which they had been placed. The specific questions which were investigated include the following:
1. What are the relationships between student achievement and how students feel about the length, reading level, and comprehensibility of feedback, and usage of mathematical symbols in feedback?

2. What are the relationships between the amount of incentive a student indicates he would require and his achievement in the course; and whether or not he had been given an extrinsic incentive to work the CHEMRIC feedback problems?

3. What are the relationships between the student's ratings of their high school mathematics preparation and their performance on the CHEMRIC pretest and their achievement in chemistry?

4. What is the relationship between prediction of final course achievement and the type of CHEMRIC diagnostic pretest used in making the prediction?

2. Experimental Research

The main experimental problem was to determine whether varying either a) degree of student participation in deciding remedial instructional needs (DOSPIDRI N), or b) incentive conditions, would result in any difference in the effectiveness of the system. Specifically, the subproblems were:
1. To determine whether a self-evaluative diagnostic pretest or an objective pretest would lead to greater achievement in Chemistry 101.

2. To determine whether provision of an extrinsic incentive to the students for using the CHEMRIC materials would lead to greater achievement than if no extrinsic incentive were offered.

3. To determine whether or not there were interactive effects on achievement between the levels of the diagnostic pretest and levels of incentive.
ASSUMPTIONS, LIMITATIONS AND DELIMITATIONS

Assumptions

1. The responses to the descriptive questionnaire are an accurate source of information about the backgrounds of the students and they reflect the true attitudes of the students.

2. The mathematics skills identified as being important for success in chemistry (Denny, 1971) are necessary for success in Chemistry 101 at The Ohio State University.

3. The CHEMRIC system does not interact with the effects of varying student control or incentive conditions.

4. Results of research on varying the degree of student control and incentive conditions using CHEMRIC have relevance to general instructional theory.

5. Quantitative portions of the regular first midquarter and final examinations given in Chemistry 101 reflect the effect of CHEMRIC.

Limitations

1. The pretest could not contain more questions than could be answered comfortably in a period of forty-seven minutes.
2. The delay interval between the administration of the CHEMRIC diagnostic pretest and the return of the feedback had to be no less than twenty-four hours.

3. The study was limited to students enrolled in four of five lecture sections of Chemistry 101 during Autumn Quarter, 1972.

4. No control, other than the provision of incentive, could be exerted over the instructional environment, since the students used the information out of class.

Delimitations

1. The remedial help provided was limited to mathematics skills instruction.

2. Extrinsic incentives were limited to ten points out of one thousand total (one percent).

3. The manipulated independent variables were limited to a) provision of an extrinsic incentive and b) format type on the diagnostic pretest, either objective or self-evaluative.

4. The criterion variables were limited to performance on the quantitative and qualitative portions of the first midquarter examination and the final examination in the course.
DEFINITION OF TERMS

1. **Batch Processing**  This involves having a program, written in a language like COBOL, FORTRAN, or PL/1, on cards, disk, or tape, interact with data, also on cards, disk, or tape. Usually, a deck of cards containing job control language, the program, and data, is submitted to a central facility, where the information is processed by computer and the output printed or punched. A whole "batch" of information is processed as fast as the computer can handle it.

2. **CBIMS**  This is a Computer Based Instructional Management System. It consists of a) a diagnostic pretest given to students, which provides input information for b) a computer program, which analyzes the pretest responses, and c) prints out information designed to be used by either the teacher, the students, or both. The information is prescriptive, not instructive in a direct sense. That is, it a) tells the student whether or not he understands enough of the prerequisite material to continue, and b) prescribes activities for him to do in order to take care of his lack of understanding of certain material; but it does not directly provide the material. Instead, he is told to reread Chapter 2, view slides 1-8, work homework set 7, or something similar. The instructor is supplied detailed information
about how each student is doing, as well as information about
the class as a whole and the difficulty of the material.

3. **CHEMRIC** This is a batch-processing system, developed by
the author and others in the Chemistry Department of The Ohio
State University, which provides **Computerized** Help with
**Essential Mathematics Required In Chemistry.** Students take a
diagnostic pretest, the responses to which are scanned electroni-
cally at The Ohio State University Testing and Evaluation Center,
and punched into holeith cards. The cards are analyzed by
a **PL/1** program, written by Mr. Dennis Driggs and Mr. James
Eblin, which prints out two things for each student: a) concise
explanations of how to remedy his mathematics deficiencies; and
b) problems which demand the use of skills in which he was found
to be poorly prepared. The **CHEMRIC** system is similar to
CBIMS, except that it not only diagnoses and prescribes, but also,
like CAI, it provides the individualized instructional material in
the feedback itself.

4. **DOSPIDRIN** **Degree of Student Participation In Deciding
Remedial Instruction Needs.** This is one of the experimental
independent variables **studied.** The effect of the two
different levels of this variable (the use of the objective pretest
versus the use of the self-evaluative CHEMRIC pretest) were measured. The objective form utilizes a standard multiple-choice format on which the student is given a problem and asked to select one of four or five constructed responses to the problem. The self-evaluative form also utilizes a multiple-choice format, but the number of constructed responses to each question is only two: After being asked to try to work a particular problem, the student indicates either that he can do it or that he could use help with that type of problem.

5. **Extrinsic Incentive** This is a reward for performance which is not an integral part of the instructional activity which the student is supposed to be doing. Examples of extrinsic incentives are course grades and points.

6. **Feedback** This consists of information a student receives from a computer, after the computer has analyzed his response or responses. It may consist of anything from a simple "yes, no, or OK" to several pages of output.

7. **Intrinsic Incentive** This is reinforcement which is built into the instructional activity itself. Knowledge of results may be considered to be an intrinsic incentive.

8. **On-line CAI** On-line CAI includes drill, author-controlled tutorial and dialogue tutorial modes. The student sits at a
terminal and types responses to a computer which analyzes what
the student inputs and then responds, in a tutorial manner.

HYPOTHESES

Evaluative Research Hypotheses

1. There is no relationship between performance on selected
   items on the CHEMRIC diagnostic pretest and performance
   on related items on the first midquarter examinations in a
   chemistry course.

2. There is no relationship between student opinion of the
   length of the CHEMRIC explanations and mathematical
   proficiency or achievement in Chemistry.

3. There is no relationship between student opinion of the
   reading level of the CHEMRIC explanations and mathematical
   proficiency or achievement in Chemistry.

4. There is no relationship between student opinion of the
   comprehensibility of CHEMRIC explanations and mathematical
   proficiency or achievement in Chemistry.

5. There is no relationship between student opinion concerning the
   comprehensibility of the mathematical symbols in the CHEMRIC
   explanations and mathematical proficiency or achievement in
   Chemistry.
6. There is no relationship between the amount of incentive students indicate they would need to work the CHEMRIC problems and their mathematical proficiency or achievement in Chemistry.

7. There is no relationship between the amount of incentive students indicate they would need to work the CHEMRIC problems and whether or not they had been given an incentive to work the problems.

8. There is no relationship between the students' rating of their high school mathematics preparation and their performance on the CHEMRIC pretest.

9. There is no relationship between the students' rating of their high school mathematics preparation and their achievement in Chemistry.

10. There is no difference in prediction of final numeric course grade by a self-evaluative pretest or an objective pretest.

Experimental Research Hypotheses

1. There are no significant differences in the effects of an objective diagnostic pretest and a self-evaluative diagnostic pretest on achievement as measured by:
a. the quantitative questions on the first midquarter examination given in a chemistry course,
b. the qualitative questions on the first midquarter examination given in a chemistry course,
c. the quantitative questions on the final examination given in a chemistry course,
d. the qualitative questions on the final examination given in a chemistry course.

2. There are no significant differences in the effects of an extrinsic incentive and no extrinsic incentive to work CHEMRIC problems on achievement as measured by:
   a. the quantitative questions on the first midquarter examination in a chemistry course,
   b. the qualitative questions on the first midquarter examination in a chemistry course,
   c. the quantitative questions on the final examination in a chemistry course,
   d. the qualitative questions on the final examination in a chemistry course.

3. There are no significant interactions in the effects of the type of pretest experience (self-evaluative/objective) and the
incentive conditions (incentive/no incentive) on achievement as measured by:

a. the quantitative questions on the first midquarter examination in a chemistry course,

b. the qualitative questions on the first midquarter examination in a chemistry course,

c. the quantitative questions on the final examination in a chemistry course,

d. the qualitative questions on the final examination in a chemistry course.
CHAPTER II

REVIEW OF THE LITERATURE

This study involved the manipulation of two variables, namely degree of student participation in decision-making and provision of incentive for performance in a computer based instructional context. The research was designed to have both general relevance and a more specific function. Since the variables being studied are common to a wide variety of learning situations, the results should have rather general implications. Also, they should contribute to the resolution of two unresolved issues in the theory of instruction: the first relating to responsibility a student should have in the selection of the information he will receive; the second concerning the need for providing extrinsic incentives. The specific function of the research, on the other hand, was to provide information which could be used to improve the effectiveness of CHEMRIC (Computerized Help with Essential Mathematics Required in Chemistry), a system designed to provide general college chemistry remedial mathematics instruction.

In order to understand and utilize the results of this study properly beyond the specific context in which it was carried out, it
is necessary to be very familiar with the nature and function of each component of the CHEMRIC system as well as the decision-making process accompanying its design and development.

The first portion of the review will be rather general, discussing the need for individualized instruction, and with it, the need for diagnosis. The potential of the computer to diagnose and provide individualized instruction will be considered, and the instructional effectiveness and economic factors associated with different ways of using computers will be compared. Special attention will be directed to the possibility of combining the effective instructional characteristics of interactive computer assisted instruction (CAI) with the more favorable economic attributes of computer managed instruction.

The second portion of the review will be more specific, considering how each component of CHEMRIC was designed in order to maximize its effectiveness. This close examination of the system will provide the foundation for the research, since the need for more information about student participation in decision-making and also about the effect of incentive on performance will be established.

BACKGROUND

The development of the CHEMRIC system was in response to a need for some way to provide remedial help for general chemistry
students who enter the course deficient in the competencies necessary for coping successfully with the subject matter. From the beginning it was recognized that for such a system to be satisfactory it would have to be:

1. Effective. Alternative approaches should be evaluated with respect to their potential to meet the need.
2. Efficient with respect to time. Time is not available within the course to allocate to remedial instruction.
3. Economically and technologically feasible. It should be possible to allow all the students to utilize the facility immediately with available money and equipment.

**INDIVIDUALIZED INSTRUCTION**

The criteria of effectiveness and time efficiency suggested individualized instruction, which appears to have an advantage over group instruction in that it can permit students to spend all of their time on their own specific problems, without having to waste it on material they understand. While there remain those who argue against the individualization of instruction (Gentile, 1967; Oettinger and Marks, 1969) the overwhelming majority of educators view it as an ideal -- something to be worked toward (Gagne, 1970; Okey, 1970; Mitzel, 1970). The fact that not everyone appears to be convinced of
the advantages of individualization may be due to the lack of consensus concerning what is meant by "individualization". In his examination of the literature, Mitzel (1970), for example, found five different concepts of individualization of instruction:

1. furnishing the learner with a large choice of instructional materials,
2. self-paced instruction,
3. the learner being able to work at time convenient to the learner,
4. instruction beginning at a point appropriate to the learner's past achievement
5. diagnosis and remediation of missing skills or knowledges.

It is obvious that these definitions are not necessarily orthogonal. In fact, there is no reason why one should not attempt to incorporate positive attributes of several of these ways of achieving individualization into the design of a particular system. With that in mind, it would be useful to consider each in more detail and in the context of the problem at hand -- maximizing the effectiveness of the CHEMRIC system.

1. **Furnishing the learner with a large choice of instructional materials**

   It would seem that certain materials would be suited better to some individuals and that entirely different materials would be more
effective with other individuals. Experience with multimedia approaches indicates that there is a problem, however, in that students do not necessarily choose the medium or media with which they might have the best results (Mitzel, 1970). The part the student should play in making decisions about what he should do and how he should do it has not been clearly established and there is a need for further research in this area.

2. Self-Paced instruction

Providing a student with the opportunity to proceed at his own rate is easiest to do with textual material, especially programmed books and computer assisted instruction, but most difficult when using large group lectures, films or television. A number of prominent educational psychologists, including Benjamin Bloom and John Carroll (Shulman, 1970, p. 48) have suggested that rate may be a variable of primary significance, in that it is entirely possible that what has previously been defined to be aptitude is actually a "measure of the rate at which a given student can master an instructional objective". If this is the case, it would help to explain the effectiveness of materials designed to permit rate individualization. In a study (Herriot, 1967) testing the position of Carroll and Bloom, it was found that students who had been categorized as "slow learners" were
able to achieve as well in SMSG mathematics as "average" students when they were given more time in which to work through the materials. With this in mind, the CHEMRIC system was designed so that, as much as possible, students would be given as much time as they needed to use the materials.

3. Choice of time to work

While there is no question that individuals work more efficiently and prefer to work at different times of the day, to permit much choice of time to work would ordinarily lead to unbearably high costs. In the case of the CHEMRIC system, however, except for when he takes the diagnostic pretest, the student may work at any time convenient to him (within the first week of classes).

4. Instruction beginning at a point appropriate to the learner's past achievement

Unfortunately, this concept of individualization often makes the invalid assumption that a student's level of attainment in prerequisite skills can be perceived along a single, linear continuum, when in actuality the situation is usually much more complex. Kilpatrick (1968, pp. 1-2) states:

A student's strengths disguise his weaknesses, and it is possible for two or more students having vastly different weaknesses to receive the same total score. It is unfortunate that students currently are customarily placed in beginning
college courses of English, mathematics, chemistry, and others via a single score on a single placement test. Regardless of the extent of validity of the particular test, a single score can give only a restricted viewpoint of one rather broad, undetailed aspect of an individual student's capability. As a result, instructional efforts are not necessarily brought to bear directly on the student's weaknesses, yet to be identified.

In order for the instruction really to begin at the "appropriate point" it must be based on a thorough diagnosis of the student's entering abilities and characteristics, which is Mitzel's fifth concept of individualization.

5. Diagnosis and remediation of missing skills or knowledges

Educational psychologists and theorists appear to be unanimous in their support of the need for diagnosis. Woodruff (1951, p. 355) wrote:

Failure to do such work (diagnosis) inevitably involves the teacher in many wasted minutes working with a "stupid" pupil when a little corrective work could often set the pupil on his own feet and enable him to go ahead with the group.

Robert Gagne (1970, p. 471) is convinced that

... a learning program for each child must take fully into account what he doesn't know how to do already. One must find out what prerequisites he has mastered -- not in a general sense, but in a very precise sense for each learner. Does this mean one must use 'diagnostic testing'? Yes, that's exactly what it means.

Daniel Ausubel placed this statement at the beginning of one of his textbooks (Shulman, 1970, p. 47):
If I had to reduce all of educational psychology to one principle, I would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly.

The work of Gagne and others has thoroughly substantiated the effectiveness of individualized instruction based on diagnosis (Okey, 1970).

With respect to the CHEMRIC system, it seemed clear that, in order to have it be maximally effective and, in addition, time conserving, it would have to provide individualized instruction based on a thorough diagnosis of the students' entering capabilities. It seemed obvious, however, that it would be impossible to implement truly individualized instruction without some kind of extra assistance. Baker describes what would happen if an ordinary classroom teacher would attempt it (Baker, 1971, p. 52).

A situation develops rather quickly in which each pupil is employing a different set of instructional materials, progressing at his own rate, and experiencing a unique set of successes and learning difficulties. In the center of this milieu is the classroom teacher who somehow must regulate this activity, diagnose each child's difficulties, and prescribe his activities for some future period of time.

Computers and Individualized Instruction

Fortunately, the educator now has a tool, the computer, which has the potential not only to help provide individualized instruction, but
also to gather very useful data at the same time. One prominent educational technologist feels that the computer is "...the most promising vehicle yet developed for the analytical experimental study of variables affecting human learning and for the incorporation of research findings into improved instruments for practical instruction" (Lumsdaine, 1962, p. 523). Armed with the tremendous storage and information-processing capabilities of the computer, the educator should now find it possible to use a more scientific approach in attempting to solve many of the basic unsolved problems and unresolved issues in the theory of instruction.

The decision to use the computer as a basic component of the CHEMRIC system was made quite early, but the decisions concerning exactly how it would be used were made only after reviewing a considerable amount of relevant literature. It soon became apparent that the exact manner and degree of involvement of the computer in the instructional process remains a subject of vigorous debate. There are the conservatives, like Georgia Sachs Adams (1964, p. 480), who cautions that "...the learning process and the dynamics of human motivation are so complex that it is undesirable, if not impossible, to match corrective procedures to learning problems in any rote or mechanical fashion", while there are others who can envision computers
acting as total replacements for teachers (Kopstein, 1970). For example, one prominent educator, after pointing to the fact that machines have already taken over many formerly human functions, stated:

It is not difficult to shift to the educational arena and to make predictions concerning the development of completely automated instructional systems—systems which can direct the learning processes leading to complex instructional objectives, successfully and without human intervention. (Kersh, 1964, p. 58)

The approaches to the educational use of computers are just as divergent, ranging from on-line computer-assisted instructional systems to simulation and gaming to diagnosis and instructional management (Zinn, 1967). In designing CHEMRIC, it was felt that it would be useful to consider extracting favorable attributes from several different approaches and then incorporating as many of them as possible into the design of CHEMRIC.

ON-LINE COMPUTER ASSISTED INSTRUCTION (CAI)

The first type of computer application to instruction which was considered was on-line conversational computer-assisted instruction (CAI). This idea may be traced back to the early work by Pressey (1946) in the middle twenties. His simple machines led to the highly sophisticated machines developed first by Pressey and then by
Lumsdaine for the armed forces (Lumsdaine, 1962). Interest in teaching machines increased dramatically about eighteen years ago when B. F. Skinner (1954) first advocated the use of machines for instruction. His teaching machines were simple, however, and it was found that packaging the material in the form of programmed textbooks was just as effective as the use of the machine.

It was not until 1959 that the computer was used for instruction (Rath, et al., 1959). During the 1960's, while there were some exceptions (simulation, gaming), most of the educational work with computers involved feasibility studies and developmental work in the area of computer assisted instruction (CAI), in which the computer was used to implement various types of programmed learning. The work at Stanford (Suppes, 1969) on the elementary school level; and the work at Florida State University (Dick, 1969), Simon Fraser University (Lower, 1970), and the University of Texas (Castleberry and Lagowski, 1970) on the university level are representative of what can be done with present technology. The work at Illinois (Alpert and Bitzer, 1970) involving all levels of instruction offers the most promise of being able to surmount the economic barriers.

Near the end of the last decade, successful experiences in applying CAI at many levels of instruction, coupled with the promise of imminent technological breakthroughs, led to a euphoric optimism
that Barrett (1968) called the "Computer Mentality". In 1966, Louis Bright, the research director of the U.S. Office of Education, predicted that computerized classrooms would be competitive with traditional instruction by 1969 or 1970; that, by 1976 technology would be able to "take over teaching subjects, the drill, the facts, and so on"; and that, by the end of the 1970's, each large school would have a computer and about 100 consoles (Janssen, 1966).

An increasing number of critics, however, (Oettinger, 1969; Darnowski, 1968; Grindstaff, 1968; Kopstein, 1968, 1970) feel that from ten to twenty years or more will be required before CAI will make a significant impact on education. While most of them will concede that CAI has shown promise, they counter that many of the claims made for CAI have been found to be either overstated or untrue (Locke and Engler, 1970). Several reviews of studies comparing programmed instruction with CAI, for example, conclude that neither method is superior (Holland, 1961; Stolurow and Davis, 1966). A study at Florida State University found programmed instruction superior to CAI in a study involving the teaching of eighth grade mathematics (Dick, 1969). A recent research effort in the Pittsburgh Public Schools (Confer, 1971) found CAI no better than conventional instruction in producing achievement outcomes. In
addition, a fatigue and frustration factor was observed with CAI, and it was found that CAI had no greater holding power than a non-CAI approach. Looking back at some of the promises made by proponents of training films, programmed instruction and educational television, Kanner (1968, p. 38) suggests "a moratorium on promises not supported by facts".

Possibly a more important problem with CAI is its cost. Present systems cost anywhere from $2.50 to $4.00 per hour per student to operate (Christopher, 1972; Sanders, 1972). To provide three or four thousand chemistry students (the number typically enrolled in large universities, such as The University of Illinois, The Ohio State University, or Michigan State University), with as little as one hour of instruction each, for example, would cost from $7500 to $16,000. Even the most optimistic estimates (Bitzer and Skaperdas, 1971) of future rate reductions would not convince everyone of the economic feasibility of on-line CAI, especially in the face of its somewhat questionable instructional effectiveness.

Seidel counters that it is both too early to evaluate CAI because it is still in the prototype stage and also inappropriate to compare it with traditional forms of instruction because the older model of education does not consider the degree of individualization possible with CAI (Seidel, 1968).
Thus, it appears that both critics and proponents agree that the earlier vision of the imminent takeover of classroom instruction by CAI was somewhat premature. Implementation of CAI on a large scale must wait for breakthroughs and development in:

1. The theory of instruction and the development and testing of related models;
2. Technological areas (cost, hardware);
3. Software (identification and remuneration of authors who can write effective programs, copyright problems, language difficulties).

While the instructional capabilities of on-line CAI were quite appealing, it was decided that it would not be feasible at this time to implement CHEMRIC as an on-line system.

ALTERNATIVES TO ON-LINE COMPUTER ASSISTED INSTRUCTION

In recent years, educators have considered several other potentially useful applications of the computer in addition to CAI. The capability of the computer to monitor student progress, for example, has been utilized in the development of the CRAM (Comprehensive Random Achievement Monitor) (Delay, 1967) system at Portland, Oregon, and the CAM (Comprehensive Achievement Monitor) system at
Massachusetts (Gorth and Wightman, 1969). The diagnostic capability of the computer has been applied very recently in the area of guidance and counseling (Roach, 1970).

The capability of the computer to manage instruction by using it for diagnosis, reporting, and providing instructional guidance was recognized early, but most of the early efforts were made with respect to CAI. Now, several institutions are in the process of developing large scale computer based instructional management systems (CBIMS), in which CAI is viewed as an important, but not the only, instructional vehicle (Baker, 1971).

**COMPUTER-BASED INSTRUCTIONAL MANAGEMENT SYSTEMS (CBIMS)**

In the CBIMS, the computer first evaluates a diagnostic pretest and then either prescribes individualized educational experiences for each student or supplies the teacher with enough information to make a presentation. After the student has gone through the specified tasks he is given a post test. If his performance is satisfactory (85 percent) with respect to specific objectives he is permitted to proceed to the next instructional unit. If not, he is prescribed remedial help. The teacher is provided with detailed and summarized reports which make it possible to evaluate both the students and instructional materials in
a scientific manner.

In many respects CBIM is similar to CAI. The basic difference is that CAI is a direct agent of instruction, while CBIM is an indirect agent, utilizing a variety of instructional techniques. A second important distinction is that, while CAI ordinarily relies on conversational computing using expensive terminals, CBIM can utilize batch processing, which is considerably more economical.

Many of the CBIM systems which have been developed are at the elementary school level, including System Development Corporation's IMS (Instructional Management System), which is used for reading instruction, Pittsburgh's IPI/MIS (Individually Prescribed Instruction Management and Information System), which manages an elementary school curriculum and Wisconsin's CMS (Computer Managed System), designed to handle elementary mathematics instruction. The system designed by Suppes at Stanford, while heavily biased toward the more traditional idea of CAI, incorporates many of the basic components of CBIM systems (Baker, 1971). Another CBIM system which leans heavily on CAI is at Florida State University, where most of the work is at the college level. They have developed materials at many levels and for a wide range of courses, from social work to chemistry and physics (Dick, 1969). The TIPS (Teaching Information Processing
System), developed at Wisconsin to handle instruction in introductory economics is an example of a smaller, but similar system (Baker, 1971). Project Plan (Program for Learning in Accordance with Needs), developed by The American Institute for Research is an example of a CBIM system designed to use the computer in a very minor sense (Baker, 1971). While plans are being made to use PLAN at all levels of instruction, this system is still in the early development stages. A group working in Stockholm, Sweden at the Royal Institute of Technology has used CBIM successfully for a course in electronics (Markesjo and Graham, 1970). While most of the CBIM groups have not yet had the opportunity for quantitative evaluation, reports of qualitative success are common. The Swedish group, for example, found that benefits accrued to the course developer, the teacher and the student.

Possibly the strongest argument for CBIM is that present technology not only can handle it, but can do it very economically. Thus, while ordinary CAI is constrained by economic and technological limitations, CBIM is limited only by unresolved problems in instructional theory.

**COMBINING CAI WITH CBIMS**

Although present CBIM systems are not designed to be direct agents of instruction in an interactive sense, there is no reason why one
could not combine some of the aspects of both CAI and CBIM in a useful manner. As a matter of fact, the success of batch programs in statistics and simulation shows that many of the characteristics of ordinary CAI can be built into a batch system. Zinn points out that "Some of the enthusiasm for conversational computing may be attributed to non-essential features: quick response and understandable diagnosis can be provided also in batch systems" (Zinn, 1970, p. 44).

**FEEDBACK -- DELAY OF KNOWLEDGE OF RESULTS**

Diagnosis, prescription and individualized instruction can be handled by either an interactive CAI system or a batch process system. One basic difference is that with batch processing there would be some delay in providing feedback whereas feedback would be immediate in the interactive system. Whether this difference is important or not appears to be an unresolved issue.

Belief in the necessity of immediate feedback finds most of its origin in the behavioristic theory advocated by B. F. Skinner (1971, p. 39) who has written:

> It can easily be demonstrated that, unless explicit mediating behavior has been set up, the lapse of only a few seconds between response and reinforcement destroys most of the effect. In a typical classroom, nevertheless, long periods of time customarily elapse... between the child's response and the teacher's reinforcement. In many cases... as much as 24 hours may intervene. It is surprising that this system has any effect whatsoever."
Although Skinner bases most of his theory on work with pigeons and rats, there is no question that his shaping techniques can be applied effectively to human beings. The power of immediate feedback has been demonstrated in a wide range of applications (Wilhelm, 1970). In an often cited study designed to measure the effect of immediate knowledge of quiz results in freshman chemistry, Angell (1949) found that students who obtained immediate knowledge of results on their quizzes performed significantly better (.01 level) on the final examination. Students in the experimental group used a panelboard which gave them knowledge of the correctness of their responses as rapidly as they punched their choices, whereas students in the control group received knowledge of results at the next recitation meeting. The results of a more recent study (Sullivan, Baker and Schultz, 1967), however, conflict somewhat with the findings of Angell. It was found that students, in this case Air Force ROTC cadets at Arizona State University, who received no knowledge of results performed better (.001 level of significance) on unit mastery tests than students who got immediate feedback. On the final examination, however, the difference in performance was not significant. The authors hypothesized that the two groups employed different learning strategies. They suggested that the feedback group probably used the
mastery tests as learning aides, whereas the no feedback group had to depend solely on the textbook and lectures. This might explain the higher scores on the mastery tests earned by the no feedback group, as well as the equal performance of the two groups on the final examination. It appears that, like many other educational variables, feedback is more complex than was recognized earlier. Gagne and Rohwer suggest (1969) that the need for knowledge of results may be related to age. Holland (1965) and Hilgard (Hilgard and Bower, 1966) feel that it could be a function of the cognitive level of the material. In general, however, providing knowledge of results has been found to be more effective than withholding the information (Gilman, 1969).

Recently, a number of investigators have been concerned with determining an optimal time interval between the response and feedback (Estes, 1969). Using a program designed to teach logic, Boersma (1966) compared the effect of immediate feedback with delayed feedback (8 seconds), finding no significant difference. In a series of studies with third graders, Brackbill and his coworkers (Brackbill, Wagner, and Wilson, 1964) have found a few second delay to be more effective than immediate feedback. Using educational psychology students at the University of California at Davis, Sassenrath and Yonge (1969) compared the effectiveness of immediate with 24-hour
delayed feedback with respect to immediate and delayed retention. They found no differences in immediate retention but a small, but significant, advantage for delayed feedback when delayed retention was the criterion. The authors cited four additional studies which had similar results with college students. They conclude that

> Although the differences in retention are usually not large in absolute amount, the psychological importance of the difference is that it is contrary to the accepted principle that immediate reinforcement, as opposed to delayed reinforcement, provides superior learning and, therefore, presumably superior retention." (p. 176)

After reviewing the literature comparing immediate with delayed feedback, More (1969) suggested that, while immediate feedback appears to be important in immediate retention, delayed feedback appears to lead to longer retention. He also pointed out that the apparent advantage of immediate knowledge of results observed by Angell (1949) may have been due to the fact that "the groups which received immediate (feedback), also received delayed (feedback) in the form of a discussion of the test along with the delayed (feedback) groups" (More, 1969, p. 339). More decided that it would be useful to identify the delay interval which would provide the greatest retention. In a study using more than six hundred eighth grade students and two types of subject matter, science and social studies, he compared the effects of immediate feedback and delays of 2-1/2 hours, 1 day and 4 days. His
findings were that, while delaying feedback was in every case more effective than providing immediate knowledge of results, the interval associated with maximum retention was one day.

From the results of these studies, it would appear that the fact that interactive CAI systems provide immediate feedback may not be an important advantage over systems which can only provide delayed knowledge of results.

With respect to the CHEMRIC system, the primary purpose of looking at the question of delayed versus immediate knowledge of results was to obtain evidence which would lend credence and support to the proposition that a batch-processing computerized instructional system might be as effective as on-line CAI, at least for some applications. It would have been interesting to carry out a research study comparing on-line with a batch processing approach, but because large-scale implementation of on-line CAI is not feasible at this time, the results would have only academic value; therefore, such a study was not carried out. The secondary purpose was to identify information which might be used to improve the effectiveness of CHEMRIC. The students using CHEMRIC took a diagnostic pretest, the results were analyzed, and then the students received feedback. Since More (1969) found a one-day delay interval most effective, it was decided that the CHEMRIC feedback should be returned to students.
on the day following the pretest.

**FEEDBACK -- AMOUNT OF INFORMATION BETWEEN FEEDBACK INTERVALS**

A second basic difference besides feedback interval is that, when using an interactive CAI system, the student is usually given feedback after each interaction, whereas, when involved with a batch-processing system, he is given feedback after a series of interactions. Research somewhat related to this problem has been carried out in studies designed to compare the effect of large versus small step size in programmed instruction. Findings, however, have been inconsistent, and not much has been done recently to resolve the issue (Edling, 1968).

In a study examining the effects of different ways of communicating information using filmstrips, Smith (1964) found that on immediate test of retention, feedback after individual frames was more effective than after either a sequence or a whole unit. On the other hand, the sequence method was found best in facilitating retention of information. It appears that the fact that CHEMRIC provides feedback after a sequence, rather than after each question is not a disadvantage and may in fact be an advantage.
CAN A SYSTEM LIKE CHEMRIC BE EFFECTIVE, EFFICIENT AND FEASIBLE?

The first portion of the review considered whether or not a system like CHEMRIC, using a batch processing approach to provide individualized instruction following diagnosis, is a reasonable proposition. Review of the relevant literature led to the following conclusions:

1. For a system to be maximally effective and efficient, it would have to offer individualized instruction.

2. Truly individualized instruction must be based on diagnosis.

3. The computer offers the most reasonable way to achieve diagnosis and individualized instruction.

4. Batch processing is economically feasible now while on-line CAI is not now and may not be so for many years.

5. The instructional effectiveness of on-line CAI and the economical advantages of computer managed instruction can be combined to produce a hybrid like CHEMRIC.

6. The value of immediate feedback in small amounts available from on-line CAI systems has not been clearly established; recent evidence indicates that a delay interval, such as would be necessitated by a batch system, may lead to greater retention than with immediate feedback.
In conclusion, it appears that, at least from a general viewpoint, a system having the attributes of CHEMRIC should have the potential to be effective, efficient and feasible.

The second portion of this review will examine the rationale for and function of each component of the CHEMRIC system, starting with the choice of the subject matter, then the diagnostic pretest, and finally considering the feedback, both in terms of its information aspects and with respect to motivation. Wash (1970, p. 18) notes that

> The learning system must provide for stimulus definition and control, reinforcers, feedback systems, and deductible consequences. Systematic consideration must be given to outcomes of each component of the learning experience, not just final 'learner condition'.

**CHOICE OF CHEMRIC SUBJECT MATTER**

One of the initial, and most important, problems faced in designing a system to provide remedial help to students entering general college chemistry without the prerequisite skills and understandings was to identify the precise nature of those skills and understandings. To do so, it was felt that it would be useful to review studies which have identified factors predicting success or failure in chemistry. It was found, however, that many of the best predictors, such as intelligence (IQ), high school grade point average, family background, and others, were not very useful in that there
would not appear to be anything one could do to change them (Mallinson, 1969). Another group of factors known to be important are affective characteristics, such as those which can be described using psychological inventories and semantic differential instruments (Milligan, 1968; Rothman, 1968; Saunders, 1969). Like the first set of factors, however, while they have potential use in adapting instruction to individual learners, they do not offer much help in selecting subject matter.

One factor identified by many writers as having primary importance is proficiency in mathematics skills. Adams (1964, p. 476), for example, states:

> Difficulties in arithmetic reasoning or in the higher processes of arithmetic computation are attributable, in part, to the fact that the basic arithmetic skills are not functioning at an automatic level. Difficulties in algebra, chemistry and physics, industrial arts, and other subjects may be due, in part, to deficiencies in arithmetic. Corrective instruction in the basic skills is necessary if the students are to get adequate return from their study time in the subjects in which these skills are constantly demanded.

That mathematics ability is of basic importance to the study of chemistry has been recognized for many years, as is evidenced by a study carried out in the General Division of the Department of Chemistry at The Ohio State University nearly thirty years ago (Garrett and Fawcett, 1945, pp 24-26) which was based on the proposition that
In chemistry specifically, this lack of proficiency is such a disturbing element that the student becomes discouraged, the quality of his work is affected, and low achievement or failure invariably follows. (p. 25)

As would be expected, research studies testing the predictive power of mathematics ability verify the importance of this factor. A correlation of 0.50 has been found, for example, between chemistry course grade and the SAT (Scholastic Aptitude Test) Mathematical Score (Sieveking and Larson, 1969). Proficiency in mathematical skills has also been related to success in similar courses, such as engineering (Van Erdewyk, 1967). Correlations ranging from 0.633 to 0.823 with scores on a mathematics skills test (Denny, 1971) with the 1969 ASC - NSTA (American Chemical Society - National Science Teachers Association) High School Chemistry Test further verify this relationship. Cronbach (1970, p. 382) reports that "the only differential prediction of course marks that is reasonably dependable at present comes from the special relation of quantitative reasoning to mathematics and some sciences . . .". Based on this evidence, it was decided that mathematics skills would comprise the subject matter of the CHEMRIC system.
THE DIAGNOSTIC PRETEST

1. Need for Precise Diagnosis

Earlier, in discussing the gross features of the CHEMRIC system, it was argued that individualized instruction, to be both efficient and effective, must be based on diagnosis. Diagnosis, of course, may operate at any of several different levels, depending upon both the characteristics of the item or construct under examination and the need or desire for specificity. The proficiency tests often used in the placement of students into science courses are an example of a rough kind of diagnosis. At The Ohio State University, for example, a student may enroll in Chemistry 121 only after he has scored at a certain level of proficiency on a mathematics placement examination. While this helps to ensure that the students will have the skills to cope with the mathematical parts of the course, it does not provide much of a basis for remedial work, since it says nothing about individual or group proficiency with respect to specific skills. Obviously, two students achieving at the same level on the pretest may differ drastically in terms of their individual problems (Gerard, 1967b; Kilpatrick, 1968). If remedial help is provided to students scoring below a certain level on a pretest, therefore, it is almost sure to be an inefficient procedure.

An example of a more specific type of diagnosis is used by most
CBIM systems (Baker, 1971). Unlike placement tests, which operate at the course level, the CBIM pretests typically function at the unit level. Diagnosis means simply the determination of a student's proficiency level with respect to a given set of behavioral objectives; if he can score 85 percent, he can move on to the next set of materials; if he cannot, he repeats the unit, perhaps using an alternate approach, until he can.

While the CBIM approach is quite efficient when used with material new to students, there is reason to believe that it would be neither most efficient nor most effective with subject matter such as that handled by CHEMRIC. This is material which students should have learned over a period of many years, but failed to do so. To tell students to go back and repeat all of their mathematics would, obviously, be neither fair, economical, nor efficient. Evidence from relevant research studies also suggests that the level of diagnosis should be much more specific than that offered by CBIM. Studies in the area of on-line CAI have found that students soon become bored with linear programs which do not allow them to branch past material they know (Grubb, 1967; Confer, 1971). Programs permitting considerable branching, on the other hand, such as one developed to teach introductory principles of computers (Shuford and Massengill, 1967) to college students, appear to have overcome the problem. In a
study involving high school geometry students, Melangaro (1967) compared the effectiveness (as measured by subsequent achievement) and training times associated with three instructional approaches; the first, which he called "Branching", adjusted instructional materials by utilizing data obtained from performance on the materials themselves; the second, "Prediction", utilized information gathered from a battery of pretests which measured both achievement in geometry and a number of intellectual abilities; and the third, "Linear", was individualized only with respect to rate, each student receiving the same linear program. When the criterion was achievement, the "Branching" strategy proved to be best and the "Linear" condition least effective with the "Prediction" approach falling between. While the difference between "Branching" and "Linear" was significant, the "Prediction" results were not significantly different from the effects attributed to either of the other treatments. When training times were compared, however, differences were all significant. "Branching" was found most efficient; then "Prediction"; and then "Linear". Both of these criteria, effectiveness and time efficiency, were very important considerations in the design of CHEMRIC, making the implications of this research very relevant. With this in mind, CHEMRIC was designed to diagnose at a very specific level. In addition to providing an overall score, CHEMRIC evaluates the abilities and deficiencies of
each student precisely, and then not only tells him what he could and
could not do, but also provides him with detailed, individualized
explanations and problems to solve.

2. **Designing Pretest to give both Efficiency and Accuracy of Information**

To contribute most, the information provided by the pretest must
be not only specific, but in a form which can be processed efficiently,
and, more importantly, the information must be accurate. Finally, in
addition to its diagnostic function, the pretest itself must be designed
to enhance the learning situation.

A consideration of different examination formats, including free
response (fill-in-the-blank, problem solving, short answer, essay) and
constructed response (true-false, multiple choice), soon makes it clear
that the multiple-choice format provides information in a form which
can be processed much more easily than that resulting from free-
response types. Whereas there is no fully automatic method of
processing free-response tests (except, in a limited way, using on-
line CAI), there are machines available which can score multiple
choice tests and punch the information into IBM cards simultaneously.
In addition, studies comparing multiple choice and free response
examinations indicate that, at least with respect to several reasonable
criteria, multiple choice tests can measure abilities with the same
validity as free-response tests. A very relevant study found, for
example, that grades in college mathematics courses could be predicted with equal reliability by examinations utilizing either free-response or multiple choice questions (Cronbach, 1970).

While multiple-choice tests have obvious advantages, they also have a number of potential limitations. Probably the most critical of these are associated with the problem of guessing. Obviously, a diagnostic pretest must be able to determine with great validity and precision just what a student knows and does not know. If it cannot do this, it will be impossible to prescribe the proper kind of learning experience for the student. It would seem that guessing could seriously impair the effectiveness of a system if it were not controlled. If a student happened to make a correct guess he would not only receive no corrective feedback but also he might be led to believe that he was able to do something he actually could not do. This same type of problem plagues the writers of highly branched programmed materials. By guessing the correct alternative, a student can be skipped past material he actually needs (Briggs, 1968). If, on the other hand, a student makes a simple error, such as a clerical error, he is burdened with instruction he does not need. Leslie Briggs suggests that branched materials might be made much more effective
...if accumulated historical data and series of responses made earlier in the program relevant to the next branching decision to be made can become the replacements for branching on the basis of a single test item. ... (Briggs, 1968, p. 165)

Also concerned with the problem of guessing have been the writers of aptitude and achievement examinations. Although it may be true that principles relating to these examinations should not be applied to diagnostic tests (Adams, 1964), it is worth noting that, if students are told to answer every question, their average test score may be expected to increase (Slakter, 1969), simply due to chance. In the case of CHEMRIC, while it would seem to be desirable to have the students work all the questions, if they were to guess correctly too often, it would be a real problem, since then they would not receive necessary help.

While guessing a correct answer can introduce problems, guessing an incorrect answer may be an even more serious detriment to learning. One learning theorist, Frank Logan, feels that the learner "learns to perform in whatever manner he practices." (Logan, 1970, p. 84). B. F. Skinner (1958, p. 970) states

> effective multiple-choice material must contain plausible wrong responses, which are out of place in the delicate process of shaping behavior because they strengthen unwanted forms.

Thus, Skinner would have the material designed so that the student
would always "come up with the right answer." In response, Pressey (1964, p. 368) states

The prediction is ventured that in a few years the rejection of the objective item by Skinnerian programmers will be seen as one of the most odd and preverse episodes of American psychology. The writer has no evidence that, with meaningful auto instructional matter wrong alternatives mislead or discriminative tasks aid only discriminative learning—or that, using such items they may not be few and incisive rather than many and dull-easy. As it is, programing may be saddled for ten years with voluminous, clumsy, thousand-frame, write-in programs soon to be discarded, but with one more mark against psychologists as theory-bound and impractical.

Experimental studies have not resolved the issue. While a review by Holland (1965) concludes that plausible incorrect responses interfere with learning, a study made by Karraker (1968) found that incorrect responses interfered only when the student was denied knowledge of results. Gilman (1969) found, in fact, that providing the correct answer following an incorrect response was the same kind of reinforcement as confirmation of a correct response. In a study involving educational psychology students, Gibson (1965) found when multiple choice questions were used for review that making incorrect choices during the learning situation had no apparent detrimental effect on learning when the criterion was performance on the regular course quizzes. Schramm (Karraker, 1968) suggests that the Skinnerian approach may be better for some learning tasks
and the multiple choice format better for others.

3. **Self-Evaluative Diagnostic Pretest Format**

One possible method of reducing guessing and improving validity on a diagnostic pretest might be to make the pretest self-evaluative rather than objective. A student could examine a problem, and rather than choosing one of several plausible constructed responses, simple indicate whether or not he felt he could do the problem. The format could remain multiple-choice, except that he would choose an answer like, "I could use some extra help with a problem like this," rather than selecting an answer for the problem itself. The burden of decision would then be shifted from the examination to the student; he, not the test, would decide whether or not he would receive help with a particular skill or concept. In a limited sense, he would be designing his own instruction. While it is not known exactly how much or in what ways the learner should become involved in decision making about selection of subject matter, it is strongly felt by some that student participation can be helpful. In reviewing the results of a series of studies involving individualized instruction of adults, Mager and Clark (1963) conclude that:

1. Adult learners enter new learning situations with different, but often considerable, amounts of knowledge relevant to what is to be learned.
2. The adult learner may "...be a better judge of what he needs to add to his current knowledge in order to reach some given set of objectives than is a textbook writer, instructor, or programmer." (p. 76)

3. Training time is usually reduced when the adult learner is involved in deciding what he needs to learn.

4. Allowing the student to have something to say about the instructional procedure seems to "...exert a strong and favorable influence upon his motivation." (p. 72)

5. "...while...further improvement in programming can be achieved by continued research with variables having to do with subject matter presentation, we suggest that greater improvements can be attained by focusing on variables relating to subject matter selection". (p. 76).

Campbell and Chapman (1965), based on their studies examining the effects of learner control of the instructional process of the elementary school level, feel that

The experts usually know more about the learning task, the subject matter, and what conditions favor learning generally. But for reasons concerning meaningfulness, self evaluation and motivation, giving the learner control may sometimes be more sound. (p. 1)

They are quick to point out, however, that

The learner may mistakenly overrate his own understanding
as a result of getting the wrong meaning. Furthermore, good self evaluation is not likely to improve learning unless S knows appropriate alternative study tactics and chooses among them wisely on the basis of his evaluation. (p. 1)

Mitzel (1970) reports that studies of the multimedia approach indicate that students do not necessarily choose the communication medium or combination of media which would enable them to do their best work.

As with most instructional variables, the optimal degree of learner participation in the instructional process appears to depend on a complex array of factors. In the case of CHEMRIC it seemed critically important that the pretest would provide valid information. While it was felt that a standard objective multiple choice test could handle the job quite well, the research evidence seemed to suggest that a self-evaluative approach might be even better. While, admittedly, providing feedback contingent on the self-evaluation of the student rather than basing it on objective performance on a multiple choice question is a small step toward learner controlled instruction, it might be a move in the right direction. It was decided that it would be very worthwhile to carry out a research study in order to help resolve the issue. The answer would have relevance for both the design of CHEMRIC and general instructional theory.
4. Choice of CHEMRIC Diagnostic Pretest Questions

A final, but critical, consideration when preparing the pretest involves the choice of questions. Although examining commercially available diagnostic tests, such as the Brueckner (1955) Diagnostic Tests and Self-Helps in Arithmetic is helpful, it is best to write questions which relate to skills necessary in the specific instructional situation. Recently, such a test was developed for use in ascertaining the presence of mathematic skills in potential chemistry students (Denny, 1971). Questions for the test, which is called the Mathematics Skill Test (MAST), were selected through analysis of chemistry texts copywrited 1960 to 1970. The analysis identified ten mathematics skills, including computation, parentheses, signed numbers, fractions, decimals, exponents, percent, equations, ratio and proportion, and graphs. That these MAST skills were necessary in chemistry was further validated by correlating performance on each skill with scores on the 1969 ACS - NSTA (American Chemical Society - National Science Teachers Association) High School Chemistry Test. The fact that the correlations ranged from 0.633 to 0.833 is an indication of the importance of these skills.

The CHEMRIC pretest uses twenty-five questions to measure a student's proficiency with respect to each of the MAST skills, examining each skill in some detail. For example, proficiency in
using parentheses is evaluated using three items, the first of which is a simple numerical problem; the second contains both units and numbers, but only the numerical portion is checked; and the third is similar to the second, except that only the units are examined. The CHEMRIC PL/1 computer program uses the combination of the responses to the three interrelated items to provide highly individualized feedback, in this case dealing with the use of parentheses.

CHEMRIC FEEDBACK -- INFORMATION ASPECTS

After diagnosing the weaknesses in a particular student's mathematical preparation, the system should provide feedback which will help the student improve his skills quickly and effectively. To design such a feedback system requires the consideration of many variables and possible approaches. Decisions must be made with respect to the type of response to elicit, the quantity and difficulty level of the feedback, the type of content in the explanations, and the sequence of information in the feedback.

1. Type of Response to Elicit

A recent review (Briggs, 1968) of learner variables and educational media concluded that both overt and covert responding have been shown to enhance the value of most instructional media. Seidel and Rotberg (1966) found in a computer programming course that it was more effective to have students apply rules than to write
the rules when the criterion involved application of the rules. Byers and Davidson (1967) found that requiring overt hypotheses aided students in concept formation. Stake and Sjogren (1964) found that making written responses facilitated learning in an experiment comparing various levels of learner activity. In a simple verbal learning study involving two-choice discriminations in adults, Carmean and Weir (1967) found that verbalizing the correct stimulus after each response facilitated learning. In a review of eight studies which attempted to assess the importance of overt or covert responding, Buckland (1967) found conflicting evidence. In a study designed to resolve the issue, she found that overt responding was better for high ability students but found no significant differences between the methods for low ability students. In designing CHEMRIC, it was felt that overt responding would probably be best for the students, so after explanations are given, the student is asked to work a series of problems.

Another important issue asks whether materials should be response centered or stimulus centered. One group of learning theorists, led by B. F. Skinner and J. G. Holland, contends that programs should be response centered (Holland, 1961). In this type of program, the student attempts the answer, and is then shown the correct answer. If the answer is correct, he is reinforced; if not, he is not reinforced.
For this type of program to be effective, it must allow the student to make very few errors. The feedback information in this situation is simply knowledge of the correct answer.

A second group of theorists feels that stimulus centered programs are more effective in communicating information (Crowder, 1962). In these programs, the student attempts an answer, and then receives feedback whether or not the answer is correct. The nature of the feedback is contingent upon the answer. A correct response usually receives a simple confirmation, but feedback for an incorrect response may range from a simple hint to a very extensive review section. While it would appear that branching programs should be more effective, studies comparing linear with branching programs show no significant differences. (Schoen, 1970; Briggs, 1968). Briggs points out that the reason for this might be due to "inadequate techniques employed in making the decisions to branch ahead or to backtrack." (pp. 164-165). It is suggested that branching should be based on more than the results of a single item. Following a study involving the teaching of general science concepts to university upperclassmen (Gilman, 1969a), it was concluded that branching programs can be made more effective by providing the learner with the correct answer and extensive information in feedback messages.
Although there was some question about the need for it, stimulus centered contingent feedback was built into CHEMRIC.

2. Quantity of feedback

If contingent feedback is selected, one must be concerned about the amount of information to include in the feedback. The success of linear programs which merely supply the correct answer leads one to think that conciseness might be a virtue. Work with information storage and retrieval processes has shown that the probability of forgetting increases as a function of the amount of information which must be processed (Posner and Rossman, 1965). Gilman's (1969b) experience with CAI at Pennsylvania State University seems to indicate that there can be either too little or too much information in feedback, and that the most effective amount is dependent upon both the nature of the subject matter and the predispositions of the students. He found giving correctional messages combined with knowledge of results to be much better than simply providing knowledge of results. CHEMRIC explanations are as short as the programmer could make them and still convey the message clearly.

3. Difficulty level of explanations

A third concern involves the difficulty of wording of explanations. In a study involving college physical science students, Collagan (1969) found that a programmed text written in simple English was
much more effective than an ordinary mathematics text. Other studies (Leith and Davis, 1968; Eigen and Feldhusen, 1967; Lankford, 1964; Noble, 1969) support the contention that, if all students are to benefit, the reading level must be set at an intentionally low level.

4. Nature of the Explanations

A fourth consideration involves the type of content to be included in the explanations. In a study utilizing a mathematics program with ninth and tenth grade students, Gagne and Brown (1961) compared the relative effectiveness of three different feedback strategies: rule and example (R + E), discovery (D), and guided discovery (G. D.). Rule and example was defined to be a rule accompanied by several examples; discovery, to be a question followed by a series of hints leading toward the correct answer; and guided discovery, to be a series of questions leading toward the same question asked first in the discovery approach.

Using transfer as the criterion, it was found that the most effective strategy was guided discovery, followed by discovery, and then rule and example. Kersh (1958), on the other hand, found that the use of discovery techniques to teach rules of addition to college students led to less satisfactory performance on
a test immediately after instruction than when the rules were given first, followed by examples. Related studies (Kersh, 1964; Kittell, 1957) have given conflicting results.

The success of the autoinstructional techniques developed by Pressey and his coworkers (Pressey, 1950) suggests that another type of feedback might be very effective. Simply, his technique is first to expose the student to a well organized, but substantial unit of instruction, and then to ask a number of questions designed to help the student associate the material. The technique of asking questions which lead the student toward conceptual understanding, is, of course, also a characteristic of Gagne's (Gagne and Brown, 1961) guided discovery approach. The beneficial effects resulting from asking questions have been observed in many instructional situations in addition to guided discovery or autoinstruction (Briggs, 1968). Gibson (1965), for example, found that supplying students with multiple choice reviews relating to the textbook and lecture material in an educational psychology course was a very effective technique. The positive effects of prequestions may be related to the theory and work of Daniel Ausubel and his "advance organizers" (Ausubel and Fitzgerald, 1962). Berlyne (1966, p. 128) explains the effect as follows:
... questions would generate epistemic curiosity, which would be relieved after subsequent exposure to the corresponding statements and internal rehearsal of them, and that reinforcement from the subsequent curiosity reduction would increase the likelihood of recall when the questions were presented again during the test phase.

5. **Sequence of Presentation**

The observation that both Ausubel's prequestions and Pressey's postquestions seem to facilitate learning leads to asking which placement is more beneficial. Merrill and Stolurow (1966) found in a programmed learning situation, that using a summary prior to giving questions was more effective than presenting a summary following each incorrect response. Another study (Peeck, 1969), examined the effects of pre- and postquestions on the retention of a passage of verbal material (about Greece) by a group of college students. It was found that prequestions tended to facilitate specific retention at the expense of general retention, while postquestions were better for general retention. In another study (Frase, 1967), on the other hand, it was found that asking questions after a prose passage facilitated both specific and general retention more than placing the questions before the passage. CHEMRIC takes advantage of both pre- and postquestions, since it uses both. It is hoped that the prequestions will help them to make certain they have understood the explanations.
6. Mathematical or Verbal Explanations

The fact that the subject matter in this study is mathematical introduces one additional problem: Should the feedback utilize mathematical or verbal symbols? In a study involving the use of computer assisted instruction with ninth graders, (Keats and Hansen, 1970) it was found that verbal definitions were more effective than numerical examples as corrective feedback. Using elementary education majors enrolled in a methods course in mathematics, Scandura (1967), on the other hand, found that, following pretraining in the use of the symbols, students learned symbolic statements faster than verbal statements. Once the verbal statements were learned, however, they were applied equally as well as the symbolic statements. CHEMRIC explanations contain both verbal and symbolic statements. While it is felt that the material is understandable, it would be useful to ask the students if they found the material clear.

FEEDBACK-MOTIVATIONAL EFFECTS

Selecting appropriate information and presenting it in a way so that an individual can relate it to his cognitive structure meaningfully and efficiently is a primary consideration in the process of communication. It is obvious, however, that no matter what
potential the materials have to communicate information, they will be of little use to an individual unless he is motivated sufficiently to use them.

It is the responsibility of the designer of the system to see to it that the students receive that motivation. John Gardner (1961, p. 94) wrote

The apathetic student, if he is at all affected by schooling, receives an education. To say that teachers must meet him more than halfway understates the case: They must block all exits and trap him into learning. They must be wonderfully inventive in catching his attention and holding it. They must be endlessly solicitous in counseling him, encouraging him, awakening him and disciplining him. Every professor has observed that Lounsbury once described as 'the infinite capacity of the undergraduate to resist the intrusion of knowledge!'.

Gardner's description of the duties of teachers may be applied directly to any agent of instruction, including automatic instructional systems. Building this capacity into an instructional system is complicated by the fact that each individual reacts differently to the stimuli presented by the instructional situation. Gagne and Rohwer (1969) point out that the effect of varying informational and incentive properties of feedback depends, in part, on predispositions of the learner.

Fearing (1954, p. 191) summarized the findings of a number of
studies on the communicative process as follows:

The data obtained from these researchers indicate that the need, values, and motives of the individual, whether conscious or unconscious, determine in large measure not only how he sees his world but also how he thinks about it. This means that the individual's preceptual response to a stimulus is dynamic, not passive. It is a process through which the individual comes to terms with his environment at a dynamic, creative level. He is actually seeking meaningful organization--meaningful, that is, in terms of his congruence with his existing interests, needs and motives.

It is apparent that the most effective instructional system will be one which will recognize and relate to not only cognitive but also affective predispositions dynamically, and on an individual basis.

Parameters relating to motivation may be divided into two groups:

1. Variable characteristics of learning situations, such as reinforcement conditions, and

2. Variable characteristics of individuals, such as self concept and anxiety.

Studies of interrelationships between these two groups of parameters indicate that there are various levels of interaction. Certain learning situation variables appear to have predictable effects on nearly all learners, whereas the effects of others have very limited generalizability. A review of motivational research concludes

Consistent relationships can sometimes be found in particular kinds of subsamples or for individuals
meeting rather limited selection criteria, but the extent to which the resulting generalizations can be made to apply across various kinds of samples seems tenuous at best. (Bower, Boyer, and Scheirer, 1970, p. 37)

It would seem reasonable to first identify those characteristics of the learning situation which have general applicability and to build them into the system in a way which will maximize their positive effect; and then to find those variables which have different effects on different individuals and to individualize the system with respect to them.

1. Variables Affecting Most Students in the Same Manner

A number of studies have been successful in identifying attributes and procedures which are effective in motivating most students.

In a review of the literature relating motivation to retention, Weiner (1966), for example, found a number of useful relationships, including:

a. High arousal during learning improves long-term retention.

b. Stress during recall interferes with retention.

c. Provision of incentives during stimulus input enhances subsequent recall.

d. Pleasant experiences tend to be remembered better than unpleasant events.
In a study having special relevance to the present one, it was found that immediate feedback was superior in causing perseverance on a task but delayed feedback was superior in producing learning (Guthrie, 1971). Several studies using CAI have yielded useful information. Majer (1968), for example, found that verbal reinforcement of a pleasing, personalized nature had a significant influence on learning. Schoen (1971) found that occasional inclusion of a student's first name had a beneficial effect. The results of one study, however, indicate that personalized feedback may not have beneficial results on all individuals. Stumpfig and Maehr (1970) found that high school students having an "abstract" conceptual structure showed no difference in motivation as a result of either personal or impersonal feedback. "Concrete" students, on the other hand, showed increased motivation under the personalized feedback condition. No studies could be located which found any detrimental effects attributable to personalized feedback.

After examining the general relationships important in motivating students it was concluded that, for CHEMRIC to work most effectively,

1. Students would be told of the importance of making the best use of the materials, in order to "arouse" them.
2. Students would be told that the pretest would not count toward their grade, so that they would not feel under stress.

3. If incentives were provided, they would be announced before the pretest, after the feedback explanations, and, again after the problems.

4. Feedback would be provided one day following the pretest, which should be short enough so that students would retain their interest but long enough for them to benefit from the improved retention resulting from delayed feedback.

5. Feedback would use informal language as much as possible, and the format would be as pleasant as possible. Plans would also be made to include the student's name occasionally.

2. Variables Affecting Each Student Differently

Some variables, such as incentives, have both general and individual aspects. While it is true, for example, that provision of incentives has been shown to have general facilitatory effects on learning (Weiner, 1966), it is also true that the effects of a particular incentive are generalizable to only rather specific instances and individuals. The work of Premack (1970) with the relative nature of reinforcement leads to the conclusion that, depending on the predispositions of the individual, what may be a reward in one case may be a punishment in another case. Thus, reinforcers must be
dealt with relationally, and not in an absolute sense. This is
definitely not to say, however, that, because their interactions are
complex, incentives should be ignored. What is important, however,
is that, in evaluating the results of studies examining the effectiveness
of particular incentives, the characteristics of the situation and
individuals involved must be considered.

A number of studies dealing with incentives have yielded results
useful in designing an instructional system. An experiment carried
out with previously unmotivated eighth graders in Baltimore indicated
that the learning styles and behavior of students could be modified
through the use of concrete reinforcement in the form of currency
exchangeable for sweets or special privileges (Nichols, 1970). In a
series of studies involving juvenile delinquents as subjects, Cohen
(1967) found that points, exchangeable for money, were very
effective incentives. Giving coupons exchangeable for a variety of
goods and services for attendance and achievement appeared to have
little effect on students in the Work Opportunity Center in Minneapolis
(Almen and Joseph, 1968). Using college students at the University of
Texas at Austin, Goodyear (1969) found that using points as praise for
satisfactory performance had no effect, but that using them for
punishment (deducting for unsatisfactory performance) produced
significant inhibitory results. Another study, this time using tenth
grade biology students, found that study behavior could be improved by giving points for productive behavior (Nesselroad and Vargas, 1970).

A large number of studies which examined the effects of verbal incentives in learning were reviewed by Kennedy and Willcutt (1964). Their conclusion was that praise appears to facilitate learning whereas blame seems to have an inhibitory effect. Other studies, however, have shown that the effect of praise or blame cannot be generalized to apply to all instances. A study involving Air Force trainees, for example, (Kimble, 1961) showed reproof to be more effective than praise in instruction in the use of the slide rule.

In a well documented paper on motivating students in CAI technical courses, Bond (1971) concludes that extrinsic rewards are most effective when the individual perceives them as both reliably obtainable and valuable in satisfying his needs.

It is clear from this sampling of the research that the effect of a particular incentive is dependent upon both the individuals involved and the context in which it is applied. While the complex nature of incentives and their interactions makes it difficult to establish simple rules concerning their use, the demonstrated fact that they can determine whether or not learning will take place suggests the need for more research in this area.
SUMMARY

In the first portion of this review it was concluded that a system having the attributes of CHEMRIC should have the potential for making a useful contribution within the constraints imposed by the context in which it would be implemented; that is, evidence was offered indicating that such a system could be effective, efficient with respect to time, and economical and technologically feasible.

In the second portion of the review, the components of CHEMRIC and issues relating to their design were discussed in greater detail. The idea was to provide a rationale for the decisions which were made and, in addition, to point out the need for research to resolve issues about which decisions could not be made.

The first topic discussed was the choice of remedial mathematics skills as the subject matter for CHEMRIC. This decision was supported by evidence indicating that proficiency in certain mathematics skills is strongly related to success in Chemistry.

The second topic was diagnostic pretest. First, it was argued that diagnosis should be at a high level of specificity in order to be most effective and efficient with respect to time. It not only should identify which students have problems but also should point out exactly what skills are missing in each case. While it was decided
that a multiple choice format would have a number of advantages, it was felt that there may be some serious validity problems associated with the standard objective test. Evidence was offered suggesting that a self-evaluative approach, in which the student would attempt a problem, and then indicate whether or not he felt he could use help with that type of problem, might be an improvement over using a standard objective test format. It was felt that research on this problem should be valuable not only with respect to the CHEMRIC system, but also to instructional theory in general.

The third topic discussed was feedback information. An evaluation of the results of the relevant research helped to establish the following guidelines, which were utilized as much as possible in building CHEMRIC:

1. Students should be given knowledge of results on the pretest and explanations contingent on their performance; and they should be asked to respond overtly to the material.

2. Neither too little nor too much information should be provided in the feedback. The proper amount varies with the nature of the subject matter and the backgrounds of the students.

3. The feedback information must be written in simple terms, and mathematical symbols should be used only when they are either understood or clearly defined.
4. Giving questions after explanatory material should lead to better learning, retention, and transfer of the information.

The fourth topic was motivation. The research provided a rather long list of relevant information, including:

1. To benefit from the materials, the student must be given sufficient incentive to use them. What is sufficient in one case may be insufficient in another. Important variables include the meaning and importance of the reward to the individual and the situation in which the learning is supposed to be taking place.

2. It is more effective to give the student his incentive during the time of learning than at the time of recall.

3. The more humanized the feedback, the more effective it will be.

4. Positive incentives are better than negative incentives.

Another important fact also became clear. The effect of a particular incentive may vary considerably with different individuals and situations. This suggested that research should be carried out to determine what kind of an incentive would work best for the students using CHEMRIC. The results of this research should have
implications for three important entities:

1. for the CHEMRIC system

2. for instructional situations similar in structure and student makeup to Chemistry 101. This is a very common type of course offering in colleges and universities throughout the nation.

3. for instructional theory in general, of which incentive theory is an important part.
The first portion of this chapter will discuss a pilot study and the remainder of the chapter will be concerned with the main evaluative and experimental study.

PILOT STUDY

The pilot study was carried out during Spring Quarter, 1972, using a single lecture section of Chemistry 101. There were three primary reasons for carrying out this study. The first was to test the operation and feasibility of CHEMRIC, since this was the initial implementation of the system. It was felt very important to identify any unanticipated logistics or programming problems before attempting to use the system with the large population involved later in the main study. The second reason was to use the experience to reveal the presence of and/or to provide information about theoretical problems which might be investigated in the main study. The third reason was to permit the carrying out of a study designed to measure the effect of CHEMRIC on students enrolled in Chemistry 101.

The pilot study lecture section was made up of twelve laboratory-recitation sections, half of which had been assigned by
the Registrar to meet on Monday, and the other half to meet on Tuesday of each week for laboratory. Students in the Monday laboratory group were assigned randomly to six different laboratory-recitation sections, and the students in the Tuesday group were also assigned randomly to six different laboratory-recitation sections. Two of the Tuesday laboratory sections and two of the Monday sections, 76 students, in all, were selected at random to participate in the pilot study as a control group. The remaining eight sections, containing a total of 143 students, served as the treatment group. All students took the CHEMRIC diagnostic pretest (objective format) on Monday of the first week, and feedback was distributed to the students in the eight treatment groups on the next day. Students in the control sections took the pretest but received no feedback.

The criteria chosen to decide whether or not receiving the CHEMRIC feedback had an effect on achievement were performance on (1) the quantitative questions on the first midquarter examination and on (2) the quantitative questions on the final examination in the course. To find out whether the students who had above average mathematics proficiency or those with below average proficiency benefitted more from the CHEMRIC feedback, the control and treatment groups were divided into an upper and lower half based on
the pretest score (above or below mean class performance on the pretest), and performance on the above criteria was compared.

**Pilot Study Hypotheses**

1. There are no significant differences in the effects of providing stimulus contingent feedback and not providing feedback on achievement of an entire lecture section as measured by the two criterion variables.

2. There are no significant differences in the effects of providing stimulus contingent feedback and not providing feedback on achievement of the lower stratum (stratified by pretest performance) of a lecture section as measured by the two criterion variables.

3. There are no significant differences in the effects of providing stimulus contingent feedback and not providing feedback on achievement of the upper stratum (stratified by pretest performance) of a lecture section as measured by the two criterion variables.

**Analysis and Results**

The MANOVA program was utilized as follows: 1) to test homogeneity of covariance (equality of regression coefficients for each cell); and 2) to carry out analyses of covariance on the effect
of feedback, using the CHEMRIC diagnostic pretest score as the covariate. Three analyses were carried out, corresponding respectively to the total lecture section, to the upper stratum (stratified by pretest performance), and to the lower stratum of the pilot lecture section.

Results for the tests of homogeneity of covariance are presented in Appendix G. Since none of the F ratios is sufficiently high to be considered significant, it may be assumed that the adjustments made using the technique of covariance were statistically sound.

Results of the analyses of covariance on the effect of feedback using pretest score as the covariate are summarized in Tables 1, 2 and 3.

As may be seen in Table 1, which considers the entire lecture section, students who received the feedback did slightly better than those who received no feedback, but the levels of significance (p < .334 for the first midquarter and p < .280 for the final examination) are not very convincing. When performance of students (Table 2) who had scored less than 17 points on the pretest (lower stratum) was compared, the group receiving no feedback achieved slightly better results on both criteria than the feedback groups. Neither difference
TABLE 1

TOTAL PILOT LECTURE SECTION ANCOVA OF EFFECT OF
FEEDBACK USING PRETEST SCORE AS COVARIATE

---

Cell Statistics

<table>
<thead>
<tr>
<th></th>
<th>First Midquarter Examination</th>
<th>Final Examination</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Feedback group</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>X</strong>&lt;sup&gt;a&lt;/sup&gt; = 6.388</td>
<td></td>
<td><strong>X</strong> = 14.826</td>
</tr>
<tr>
<td>S. D. = 2.081</td>
<td></td>
<td>S. D. = 4.051</td>
</tr>
<tr>
<td>N = 128</td>
<td></td>
<td>N = 128</td>
</tr>
<tr>
<td><strong>No feedback group</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>X</strong> = 6.101</td>
<td></td>
<td><strong>X</strong> = 14.213</td>
</tr>
<tr>
<td>S. D. = 1.962</td>
<td></td>
<td>S. D. = 3.346</td>
</tr>
<tr>
<td>N = 53</td>
<td></td>
<td>N = 53</td>
</tr>
</tbody>
</table>

---

Multivariate Test of Significance Using Wilks Lambda Criterion

<table>
<thead>
<tr>
<th>Test of Roots</th>
<th>F</th>
<th>DF HYP</th>
<th>DF ERR</th>
<th>P Less Than</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.817</td>
<td>2</td>
<td>177</td>
<td>0.444</td>
</tr>
</tbody>
</table>

---

Univariate F Tests

<table>
<thead>
<tr>
<th>Variable</th>
<th>F(1, 178)</th>
<th>Mean Square</th>
<th>P Less Than</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First Midquarter</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quantitative Items</td>
<td>0.939</td>
<td>3.036</td>
<td>0.334</td>
</tr>
<tr>
<td><strong>Final Examination</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quantitative Items</td>
<td>1.173</td>
<td>14.085</td>
<td>0.280</td>
</tr>
</tbody>
</table>

<sup>a</sup>Adjusted means.
TABLE 2
LOWER STRATUM OF PILOT LECTURE SECTION ANCOVA OF
THE EFFECT OF FEEDBACK USING PRETEST SCORE AS
COVARIATE

<table>
<thead>
<tr>
<th>Cell Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First Midquarter Examination</strong></td>
</tr>
<tr>
<td>Quantitative Items</td>
</tr>
<tr>
<td><strong>Feedback group</strong></td>
</tr>
<tr>
<td>$\bar{X} = 5.421$</td>
</tr>
<tr>
<td>S. D. = 1.939</td>
</tr>
<tr>
<td>N = 60</td>
</tr>
<tr>
<td><strong>No feedback group</strong></td>
</tr>
<tr>
<td>$\bar{X} = 5.526$</td>
</tr>
<tr>
<td>S. D. = 1.847</td>
</tr>
<tr>
<td>N = 30</td>
</tr>
</tbody>
</table>

Multivariate Test of Significance Using Wilks Lambda Criterion

<table>
<thead>
<tr>
<th>Test of Roots</th>
<th>F</th>
<th>DF HYP</th>
<th>DF ERR</th>
<th>P Less Than</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.060</td>
<td>2</td>
<td>86</td>
<td>0.941</td>
</tr>
</tbody>
</table>

Univariate F Tests

<table>
<thead>
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<th>Mean Square</th>
<th>P Less Than</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Midquarter Quantitative Items</td>
<td>0.056</td>
<td>0.201</td>
<td>0.814</td>
</tr>
<tr>
<td>Final Examination Quantitative Items</td>
<td>0.085</td>
<td>0.902</td>
<td>0.772</td>
</tr>
</tbody>
</table>

*a Adjusted means.*
TABLE 3

UPPER STRATUM OF PILOT LECTURE SECTION ANCOVA OF
THE EFFECT OF FEEDBACK USING PRETEST SCORE AS
COVARIATE

<table>
<thead>
<tr>
<th>Cell Statistics</th>
<th>First Midquarter Examination</th>
<th>Final Examination</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quantitative Items</td>
<td>Quantitative Items</td>
</tr>
<tr>
<td>Feedback</td>
<td>$\overline{X}^a = 7.255$</td>
<td>$\overline{X} = 16.370$</td>
</tr>
<tr>
<td>group</td>
<td>S.D. = 1.784</td>
<td>S.D. = 4.045</td>
</tr>
<tr>
<td>N = 68</td>
<td></td>
<td>N = 68</td>
</tr>
<tr>
<td>No Feedback</td>
<td>$\overline{X} = 6.811$</td>
<td>$\overline{X} = 15.081$</td>
</tr>
<tr>
<td>group</td>
<td>S.D. = 1.953</td>
<td>S.D. = 3.155</td>
</tr>
<tr>
<td>N = 23</td>
<td></td>
<td>N = 23</td>
</tr>
</tbody>
</table>

Multivariate Test of Significance Using Wilks Lambda Criterion

<table>
<thead>
<tr>
<th>Test of Roots</th>
<th>F</th>
<th>DF HYP</th>
<th>DF ERR</th>
<th>P Less Than</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.283</td>
<td>2</td>
<td>87</td>
<td>0.282</td>
</tr>
</tbody>
</table>

Univariate F Tests

<table>
<thead>
<tr>
<th>Variable</th>
<th>F(1, 88)</th>
<th>Mean Square</th>
<th>P Less Than</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Midquarter</td>
<td>1.394</td>
<td>3.394</td>
<td>0.241</td>
</tr>
<tr>
<td>Quantitative Items</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final Examination</td>
<td>2.151</td>
<td>28.531</td>
<td>0.146</td>
</tr>
<tr>
<td>Quantitative Items</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$^a$Adjusted means.
approached statistical significance, however (p < .814 for the first midquarter and p < .772 for the final examination). Results were quite different for the upper stratum of the lecture section, as shown in Table 3. Not only were the mean performances better for the feedback groups, but the differences approached meaningful statistical significance (p < .241 on the first midquarter and p < .146 on the final examination).

Conclusions

The lecturer and the teaching assistants commented favorably about the CHEMRIC system for several reasons. The lecturer appreciated both the information concerning the mathematics preparation of the class as a whole and the early identification of individual students having severe mathematics deficiencies. Teaching assistants found the feedback sheets very useful in helping students during office hours in that they not only identified specific problem areas, but also they provided core explanations and relevant exercises.

The results of the study suggested that the students having above average mathematics proficiency made fairly good use of the CHEMRIC feedback while the below average students, for whom the help had really been designed, did not appear to have used the information effectively.
**Resulting Action**

It was decided that a replicate study in which some students would receive no **CHEMRIC** feedback should not be carried out, for several reasons:

a. There was rather good evidence that at least some students were given an advantage by receiving the feedback. To deny certain students the opportunity of receiving this advantage, just for the sake of a study seemed to be unfair.

b. Although very few students in the group which received no feedback complained about it, it was felt that in a larger study this could become a serious problem, especially in light of the evidence from the pilot study.

c. The professors involved with the course were very reluctant to place some of their students in a situation (no feedback) which might be considered less favorable than that into which the remainder of their students had been placed.

It was felt that time could be more effectively spent on exploring ways of getting more of the students to benefit from the **CHEMRIC** system. Thus, it was decided to:

a. Revise the explanations to make them clearer and easier to read.
b. Investigate ways of motivating students to use materials, such as providing incentives.

c. Consider the use of other ways of finding out the specific needs of the students for help, perhaps asking them to help decide rather than leaving it entirely to the pretest.

POPULATION FOR THE MAIN STUDY

The population for the study consisted of four lecture sections of Chemistry 101, and the study was carried out during Autumn Quarter, 1972. Chemistry 101 at The Ohio State University is a course designed for nonscience majors; that is, students who do not intend to major in science, but who need some chemistry to satisfy distribution requirements or prerequisites for certain applied areas, such as agriculture, home economics, nursing, or allied medical sciences.

The Chemistry 101 course at The Ohio State University provides three different learning environments:

1. Lecture. There are three lectures per week given in a large lecture hall. All students enrolled in a given lecture section attend the same lectures; the number per lecture ranges from two hundred fifty to slightly over three hundred.
2. **Recitation.** Students in a lecture section are assigned to small recitation-laboratory groups by the University's Computer Assisted Scheduling (CAS) system. There is one recitation meeting per week, and it is led by a graduate teaching assistant. Each section contains about twenty-five students.

3. **Laboratory.** The same students assigned to a particular recitation section also meet together once each week for a three-hour laboratory session. The laboratory instructor may or may not be the same person as the recitation instructor. While all the recitation instructors are graduate students, approximately half of the laboratory instructors are advanced undergraduate teaching assistants.

A typical lecture section of three hundred students, then, will comprise twelve recitation-laboratory sections, each containing about twenty-five students.

Four lecture sections were used in the overall study, one of which was used for only the evaluative research. The remaining three lecture sections were involved in related, but different approaches to the testing of the research hypotheses. For convenience, the experimentation with the different lecture sections, A, B, and C, were treated as three separate substudies, A, B, and C, respectively.
TABLE 4

POPULATIONS OF LECTURE SECTIONS A, B, C AND D AT IMPORTANT POINTS DURING AUTUMN QUARTER, 1972

<table>
<thead>
<tr>
<th>Lecture section</th>
<th>No. Lab-Rec. Sections</th>
<th>No. students pretested</th>
<th>No. students at first midquarter</th>
<th>No. students at final</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>12</td>
<td>264</td>
<td>241</td>
<td>227</td>
</tr>
<tr>
<td>B</td>
<td>12</td>
<td>264</td>
<td>241</td>
<td>221</td>
</tr>
<tr>
<td>C</td>
<td>10</td>
<td>266</td>
<td>232</td>
<td>214</td>
</tr>
<tr>
<td>D</td>
<td>12</td>
<td>300</td>
<td>280</td>
<td>248</td>
</tr>
</tbody>
</table>

As much as possible, entire populations were utilized, exceptions being when data were missing for reasons such as withdrawal from the course or failure to take an examination when scheduled. The number of students in the different lecture sections decreased steadily during the quarter as is shown in Table 4. The populations described by lecture sections A, B, and C were utilized in all portions of the research; Lecture Section D was not used in the experimental portion of the research except to gather information concerning possible confounding variables.
OVERALL DESIGN STRUCTURE

1. **Lecture Section A**

   Two variables, incentive and Degree Of Student Participation In Deciding Remedial Instructional Needs (DOSPIDRIN) were varied, giving rise to four treatment groups.

<table>
<thead>
<tr>
<th>INCENTIVE CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incentive</td>
</tr>
<tr>
<td>------------</td>
</tr>
<tr>
<td><strong>DOSPIDRIN</strong></td>
</tr>
<tr>
<td>Self-Evaluative</td>
</tr>
<tr>
<td>Objective</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

2. **Lecture Section B**

   One variable, DOSPIDRIN, was varied, while the other, incentive, was held constant. All students received an incentive.

<table>
<thead>
<tr>
<th>INCENTIVE CONDITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incentive</td>
</tr>
<tr>
<td><strong>DOSPIDRIN</strong></td>
</tr>
<tr>
<td>Self-Evaluative</td>
</tr>
<tr>
<td>Objective</td>
</tr>
</tbody>
</table>

3. **Lecture Section C**

   One variable, DOSPIDRIN, was varied while the other, incentive was held constant. No incentive (extrinsic) was offered.

<table>
<thead>
<tr>
<th>INCENTIVE CONDITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Incentive</td>
</tr>
<tr>
<td><strong>DOSPIDRIN</strong></td>
</tr>
<tr>
<td>Self-Evaluative</td>
</tr>
<tr>
<td>Objective</td>
</tr>
</tbody>
</table>
4. Lecture Section D

All students in this lecture section were treated in the same way, i.e., no variables were manipulated. All students received the incentive and used the objective form of the CHEMRIC pretest.

\[ N = 300 \]

EVALUATIVE RESEARCH

All students in Lecture Sections A, B, C and D were administered either the self-evaluative or the objective form of the CHEMRIC diagnostic pretest on Thursday, September 28, 1972.

The CHEMRIC diagnostic pretest consists of twenty-five questions designed to measure proficiency with respect to ten mathematics skills. The importance and relevance of these skills, which include computation, parentheses, signed numbers, fractions, decimals, exponents, ratio and proportion and graphs, have been established by both reason (Adams, 1964; Cronbach, 1970) and research (Denny, 1971; Garrett and Fawcett, 1945).

The pretest was taken on answer sheets which were optically scanned; responses were automatically punched into holerith cards. These data were used in two ways: to design individualized instructional feedback; and to provide information about individual students and each class as a whole.
Two types of pretests were used: a self-evaluative pretest and an objective pretest. Because different portions of the total population (Lecture Sections A, B, C, and D) were placed under different incentive conditions and utilized different types of pretests, the data were gathered and treated according to lecture section and treatment, following the same design as for the experimental research (see Experimental Research). This means that for Lecture Section A, four groups were involved, each containing approximately sixty-five students and each corresponding to a different experimental treatment. Lecture Section B comprised two groups of approximately one hundred thirty, and Lecture Section C was made up of two groups of approximately one hundred thirty-five students. Lecture Section D, in which all students used the objective pretest and also received an incentive for working the CHEMRIC problems, contained three hundred students at the start of the quarter.

All students in Lecture Sections A, B, C, and D were asked to complete a questionnaire sometime during the week of December 4 through December 8, 1972. The questionnaire was designed to gather information about the feedback, the incentive conditions, and the students' ratings of their entering mathematics capabilities.
Responses to the questionnaire items were compared with the scores on the CHEMRIC pretest, to find out if there were any significant relationships. Also, the two forms of the CHEMRIC diagnostic pretest were compared with respect to predicting the final numeric grade earned by each student in the course. The results were analyzed by lecture section and also by experimental treatment group (see Experimental Research).

**EXPERIMENTAL RESEARCH**

1. **Design**

   a. **Independent Variables**

      The effect of manipulating two variables was examined, the variables being:

      1) **Incentive**

      This independent variable was assigned two values or levels, one corresponding to an *incentive* condition (Incentive 1) and the other to a *no-incentive* (Incentive 2) condition. Students working under the Incentive 1 condition were offered up to ten points (out of 1000 in the course) to work and turn in the problems contained in the CHEMRIC feedback. Those working under the Incentive 2 condition were simply told that it would be helpful for them to work the problems and that additional help would be available from their
recitation instructors. The specific statements are contained in Appendix C.

2) **DOSPIDRIN** (Degree of Student Participation In Deciding Remedial Instructional Needs).

This independent variable was manipulated through the use of two kinds of CHEMRIC diagnostic pretests: an ordinary objective multiple-choice test where the student was given a problem and asked to select the best one from four or five plausible constructed responses; and, a self-evaluative pretest on which the student was asked to try to work a problem and then to indicate whether or not he could use help with that type of problem. The objective test called for one level of student participation, **DOSPIDRIN 2**, where decisions were made primarily by the system. An increased degree of participation, **DOSPIDRIN 1**, was demanded by the self-evaluative test, in that both decision-making and the accompanying burden of validity were shifted from the test to the student; it was he, not the test, who had to evaluate his competencies and decide upon the need for the remedial help.

The two levels of each variable considered led to the following four combinations:
b. Dependent (criterion) variables

Effects of the manipulated variables were compared through the use of the first midquarter and final examinations written by the lecturers in charge of each of the respective lecture sections. The items on each examination were separated into two groups, the first being those which were qualitative in nature, the second being those which were quantitative in nature (involved mathematical manipulation). Thus, for the three lecture sections, A, B, and C, there was a total of six criterion instruments. Performance on these instruments constituted the criterion variables.

As may be seen in Tables 5, 6, and 7, the instruments varied considerably in terms of number of items, variance, discriminative power, difficulty and reliability. With the single exception of the qualitative items on the first midquarter examination in Lecture Section B (KR20 = 0.231; KR21 = 0.104), the reliabilities of the instruments appear fairly good. More significantly, the reliabilities of the quantitative instruments are consistently higher than those of
TABLE 5
CRITERION INSTRUMENTS
DESCRIPTIVE STATISTICS FOR THE QUALITATIVE AND QUANTITATIVE PORTIONS
OF THE FIRST MIDQUARTER EXAMINATION AND FINAL EXAMINATION FOR LECTURE
SECTION A

First Midquarter Examination

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Final Examination

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<td>0.751</td>
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### TABLE 6

**CRITERION INSTRUMENTS**

**DESCRIPTIVE STATISTICS FOR THE QUALITATIVE AND QUANTITATIVE PORTIONS OF THE FIRST MIDQUARTER EXAMINATION AND FINAL EXAMINATION FOR LECTURE SECTION B**

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<th>Std. Dev.</th>
<th>Mean Dis.</th>
<th>Mean Diff.</th>
<th>KR20</th>
<th>KR21</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>Std. Err.</th>
<th>Mean</th>
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#### Final Examination

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TABLE 7
CRITERION INSTRUMENTS
DESCRIPTIVE STATISTICS FOR THE QUALITATIVE AND QUANTITATIVE PORTIONS
OF THE FIRST MIDQUARTER EXAMINATION AND FINAL EXAMINATION FOR LECTURE
SECTION C

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</table>
the qualitative instruments.

c. Compromise Design

Students from all four lecture sections, A, B, C, and D were assigned to their individual recitation groups by The Ohio State University Computer Assisted Scheduling System. The program operates as follows.

1) Initially, students choose a particular recitation section from a list in the Master Schedule of Classes. Although the rooms and times are given, no information is given concerning who will be lecturing or teaching laboratories or recitations in the courses.

2) The information is input into the computer, whereupon,

3) The program fills each request on a "first-come-first-served" basis until one of the sections, usually the top one on the list, fills to 80 percent capacity.

4) The following students are assigned to the next open section until that one fills.

5) The pattern repeats until all sections are 80 percent filled, whereupon,

6) The program assigns the remaining 20 percent at random to the different available sections.
Since it was not certain that such a procedure would result in a random distribution of confounding variables throughout all sections, it was felt necessary either: to offer evidence showing the statistical equivalence of the groups with respect to certain important variables; or to gather and utilize data for the purpose of matching or equating the different groups; or to use a design which would not demand random assignment. It was hoped that the first of the three would be the case. Two approaches were used to obtain evidence:

1) At the beginning of the term, everyone in Lecture Section D was given the same treatment (i.e., no variables were manipulated). Performance on the CHEMRIC pretest from section to section was compared. All students were offered an incentive (Incentive 1) and all students were given the same degree of participation in designing their CHEMRIC feedback. As may be seen from the overall design structure, one-fourth of Lecture Section A, as well as half of Lecture Section B, were under testing conditions comparable to those for Lecture Section D. Furthermore, each of the other testing conditions was assigned to one treatment group in a minimum of two lecture sections. Pretest performance was compared between all groups under equivalent testing conditions. It was felt that if pretest
performance could be shown to have no significant difference (at
\( p < .05 \)) between laboratory-recitation groups corresponding to each
of the four treatment conditions, the generalizability of the results
would be strengthened, and at the same time, evidence for
randomization would be provided.

2) The second approach used to demonstrate the equivalence
of groups before the treatment was to give students in all of the
lecture sections a questionnaire designed to yield information about
several potentially confounding variables and then check to see if the
variables were distributed randomly in the population. It is known
that family or cultural background (Terrell and Wyer, 1966) is a
strong determiner of success. Since there would seem to be a
rather strong relationship between the location of a high school and
the family backgrounds of the students (it would be reasonable to
assume that, for example, students in a rural school might have
different backgrounds from students in a large urban high school),
one item on the questionnaire was designed to find out whether the
student graduated from a rural, small town, suburban, urban-
medium sized city, or urban-big city school. Another item asked
the student how many students were in the high school from which he
graduated. Barker and Gump (Bower, et al. 1970, p. 40) found that
students in large schools feel less needed than those in smaller schools and that this a "profound" effect on academic motivation. Three other items, including two on mathematics preparation and one on science background were included on the questionnaire. While the relevance of these three items would appear to be obvious, a number of studies have also confirmed the relationships (Mallinson, 1969; Van Erdewyk, 1967). As in the first approach, responses of students in equivalent treatment groups were compared both within lecture sections and from lecture section to lecture section. It was felt that if it could be shown that all of these potentially confounding variables appeared to have been distributed at random throughout the different treatment groups, it could be assumed that The Ohio State University Computer Assisted Scheduling System assigned the students in a manner which led to random distribution of important instruction and learning variables and characteristics.

d. Specific design features of substudies A, B and C

As was indicated earlier (see Overall Design Structure), in substudy A the twelve laboratory-recitation sections were assigned to four treatment groups, corresponding to two levels of incentive and two levels of DOSPIDRIN. In Substudy B, all students received an incentive (Incentive condition 1), but there were two levels of
DOSPIDRIN; consequently, each of the twelve laboratory-recitation sections was assigned to one of two treatment groups. Substudy C was similar to substudy B, except that no students in Lecture Section C received an incentive (Incentive condition 2); therefore, each of the ten laboratory-recitation sections was assigned to one of two treatment groups, one corresponding to each level of DOSPIDRIN.

In each substudy, both the assignment of instructors to laboratory-recitation sections and the assignment of the laboratory-recitation section to specific treatment groups were made using randomizing techniques.

e. Sequence of events

Thursday and Friday, September 28 and 29, 1972, every student enrolled in Chemistry 101 (i.e., in Lecture Sections A, B, C and D) was administered one of the four experimental treatments, according to the design discussed above. On Thursday all the students took either the self-evaluative or objective form of the CHEMRIC pretest and on Friday they all received their feedback. Some students were offered an incentive for working the problems in the feedback; others were not.

Monday, October 30, 1972, the First Midquarter Examinations were administered to all Chemistry 101 students. Each lecture
section took an examination written by the professor assigned to that section.

Tuesday or Thursday, December 5 or 7, 1972, all Chemistry 101 students were asked to fill out the CHEMRIC questionnaire, a ten item instrument.

Tuesday, December 12, 1972, all Chemistry 101 students took Final Examinations, each examination having been prepared by the professor in charge of a particular lecture section.
## TABLE 8
### DESIGN SUMMARY

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<th>Random Assignment to Treatments</th>
<th>First MQ Exams</th>
<th>CHEMRIC Questionnaire&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Final Exams</th>
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<th>4, 8, 11</th>
<th>67&lt;sup&gt;d&lt;/sup&gt;</th>
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<td></td>
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<td>1, 5, 6, 8, 9</td>
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<td></td>
<td>Obj. 1 - 12</td>
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<td></td>
<td></td>
<td></td>
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<tr>
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<td></td>
<td>300</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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a. Laboratory-Recitation Section Numbers.

b. Does not include those students who withdrew from the course or received an Incomplete in the course.

c. Number of students in a lecture section.

d. Number of students in a treatment group.
CHAPTER IV

STATISTICAL ANALYSIS AND RESULTS

The results of the study will be presented in two sections. First, the evaluative research will be considered, then the experimental research.

EVALUATIVE RESEARCH

1. CHEMRIC Pretest Performance

One main purpose of this portion of the study was to utilize responses to the CHEMRIC diagnostic pretest to evaluate the proficiency of entering Chemistry 101 students with respect to a specific set of mathematics skills known (Garrett and Fawcett, 1945; Denny, 1971) to be important in the study of Chemistry. An item analysis program written by Mr. Dennis Driggs under the supervision of this researcher was used to analyze the student response data. This program calculates and tabulates summary test statistics such as mean, mode, median, number of students, and standard deviation; and analyzes items. It also prints out an alphabetical listing of student responses, a graph of the total scores, and a listing from high to low. The item analysis tabulates the response
made to each constructed response and calculates percentage and average credit given for each item. Mean performance (fraction who got the item correct) of students on each item under different treatment conditions (self-evaluative pretest versus objective pretest; incentive of ten points to work feedback problems versus no incentive) is given in Appendix F. Table 9 summarizes total mean performance on the two forms of the pretests in all four lecture sections.

It is useful to compare item-by-item performance on the two types of pretest. On ten of the twenty-five items (2, 4, 7, 11, 13, 19, 20, 21, 23, and 25) objective performance was not much different from the results of self-evaluation. Of the remaining fifteen, self-evaluation gave considerably higher means on four items (1, 6, 17 and 24) and, perhaps surprisingly, objective performance was significantly higher on eleven items (3, 5, 8, 9, 10, 12, 14, 15, 16, 18 and 22). It would seem that, more often than not, students tended to underestimate their abilities rather than to overestimate them. This is reflected somewhat in the total scores, which are slightly lower for the self-evaluative form (see Table 9). It should be pointed out that, if the effects of random guessing on the objective form could have been eliminated, the results might have shown a different, even opposite, trend.
<table>
<thead>
<tr>
<th>Lecture Section</th>
<th>Pretest Form</th>
<th>Incentive Condition</th>
<th>N</th>
<th>Mean Score$^a$</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Self-Evaluative</td>
<td>Incentive</td>
<td>67</td>
<td>15.0</td>
<td>4.7</td>
</tr>
<tr>
<td>A</td>
<td>Self-Evaluative</td>
<td>No Incentive</td>
<td>66</td>
<td>12.9</td>
<td>4.0</td>
</tr>
<tr>
<td>A</td>
<td>Objective</td>
<td>Incentive</td>
<td>64</td>
<td>14.9</td>
<td>4.9</td>
</tr>
<tr>
<td>A</td>
<td>Objective</td>
<td>No Incentive</td>
<td>67</td>
<td>15.9</td>
<td>3.9</td>
</tr>
<tr>
<td>B</td>
<td>Self-Evaluative</td>
<td>Incentive</td>
<td>130</td>
<td>13.1</td>
<td>6.0</td>
</tr>
<tr>
<td>B</td>
<td>Objective</td>
<td>Incentive</td>
<td>134</td>
<td>14.9</td>
<td>4.9</td>
</tr>
<tr>
<td>C</td>
<td>Self-Evaluative</td>
<td>No Incentive</td>
<td>148</td>
<td>13.4</td>
<td>4.9</td>
</tr>
<tr>
<td>C</td>
<td>Objective</td>
<td>No Incentive</td>
<td>118</td>
<td>14.5</td>
<td>4.8</td>
</tr>
<tr>
<td>C</td>
<td>Objective</td>
<td>Incentive</td>
<td>300</td>
<td>15.6</td>
<td>4.8</td>
</tr>
</tbody>
</table>

$^a$Out of 25 points total.
Items which gave students the greatest trouble on the objective form were numbers seventeen (16 percent mean performance), twenty-one (19 percent mean performance) and twenty-four (23 percent mean performance). Question seventeen is somewhat complex in that it involves multiplication and division of decimals, operations within parentheses and proper handling of units. Students who used the self-evaluative form appear to have greatly overestimated, assuming that the objective results were valid, their ability to handle the item, in that 73 percent indicated that they "very seldom have any trouble with simplifying expressions like this". Item number twenty-one asks the student to convert a base ten logarithm into an equivalent expression. While this skill is very important to the study of pH and other basic chemical concepts, it is clear that entering students do not have it. The 19 percent objective performance is what might be expected from random guessing; in fact, 4.31 percent answered "A", 28.71 percent chose "B", 19 percent selected "C" (the correct answer), 7.89 percent picked "D", 17.7 percent marked "E", and 22.25 percent left the response blank. With respect to this skill, the self-evaluative mean is probably more valid, being 11 percent. Problem twenty-four asks the student to read a two-dimensional graph. Again, it would appear
that random guessing was involved. The self-evaluative mean was somewhat higher (30 percent) than the performance on the objective instrument (23 percent), but it is clear that this is another weak spot in the preparation of entering students. The other two questions about graphs reveal a general weakness in the whole area. Performance on item eight, which asks the student to write the equation for a straight line when given the slope and intercept, was only 53 percent; and on the self-evaluative form only 14 percent said they could do it. Item sixteen, which asks the student to find the slope of a straight line from given X and Y data, gave slightly better, but still poor results; 58 percent on the objective form and 36 percent on the self-evaluative form got it correct (or indicated proficiency).

Manipulations involving units appears to be another problem area. Only 41 percent could divide fractions with units (item eleven); on the self-evaluative form even fewer, 26 percent, said they could do it. Performance on item three (71 percent) suggests that the problem is not so much with dividing fractions as with what to do with the units. While item three is almost identical to item eleven, the constructed responses to item three hold units constant; responses to item eleven hold the numeric portion constant, varying only the units. The same trend holds for items 10 (73 percent, checking
<table>
<thead>
<tr>
<th>Item Number</th>
<th>Objective Form</th>
<th>Self-Evaluative Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>67</td>
<td>92</td>
</tr>
<tr>
<td>2</td>
<td>78</td>
<td>96</td>
</tr>
<tr>
<td>3</td>
<td>71</td>
<td>25</td>
</tr>
<tr>
<td>4</td>
<td>80</td>
<td>85</td>
</tr>
<tr>
<td>5</td>
<td>67</td>
<td>42</td>
</tr>
<tr>
<td>6</td>
<td>53</td>
<td>68</td>
</tr>
<tr>
<td>7</td>
<td>68</td>
<td>53</td>
</tr>
<tr>
<td>8</td>
<td>53</td>
<td>14</td>
</tr>
<tr>
<td>9</td>
<td>74</td>
<td>33</td>
</tr>
<tr>
<td>10</td>
<td>73</td>
<td>29</td>
</tr>
<tr>
<td>11</td>
<td>41</td>
<td>26</td>
</tr>
<tr>
<td>12</td>
<td>73</td>
<td>48</td>
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<tr>
<td>13</td>
<td>83</td>
<td>77</td>
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<td>14</td>
<td>80</td>
<td>31</td>
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<td>15</td>
<td>61</td>
<td>30</td>
</tr>
<tr>
<td>16</td>
<td>58</td>
<td>36</td>
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<td>17</td>
<td>16</td>
<td>73</td>
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<td>18</td>
<td>64</td>
<td>37</td>
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<td>19</td>
<td>72</td>
<td>77</td>
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<td>20</td>
<td>67</td>
<td>75</td>
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<tr>
<td>21</td>
<td>19</td>
<td>11</td>
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<tr>
<td>22</td>
<td>55</td>
<td>33</td>
</tr>
<tr>
<td>23</td>
<td>45</td>
<td>42</td>
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<tr>
<td>24</td>
<td>23</td>
<td>30</td>
</tr>
<tr>
<td>25</td>
<td>79</td>
<td>88</td>
</tr>
</tbody>
</table>

*aObjective Form  
*bSelf-Evaluative Form
numeric part only), 17 (16 percent, checking units only), and 18 (64 percent, checking units only); that is, units seem to cause more problems than numbers.

Algebraic manipulations also seem to give students trouble, as evidenced by objective test performance on items 7 (60 percent), 15 (61 percent), and 23 (45 percent). Corresponding means of 53 percent, 30 percent and 42 percent on the self-evaluative form suggest that the students themselves are aware of their limitations. The weak performance in this area is especially disturbing because these skills are utilized considerably in developing many of the important conceptual schemes in chemistry.

Operations with decimals and exponents appear to cause very few students serious trouble, as performance on items utilizing these skills was consistently high. One exception was item six (53 percent) which involves multiplication of decimals and exponents. Examination of the responses, however, indicates that the problem was that nearly forty percent of the students forgot to add one to the exponent when they shifted the decimal point one place to the left; thus, the mistake may possibly have been more a result of carelessness than misunderstanding.
2. Items on CHEMRIC Pretests and Related Items on First Midquarter Examinations

To determine whether or not there was a relationship, phi correlations were carried out between performance on selected items on the CHEMRIC diagnostic pretests and performance on related items on the first midquarter examinations. For two reasons it was decided to interpret the results of the correlations for only Lecture Sections B and C, namely, the examinations had twelve items in common, permitting comparisons across lecture sections; and the sizes of the treatment groups were large (more than one hundred in each), providing a favorable situation with respect to statistical interpretations.

The CHEMRIC pretest items chosen were two pairs (7, 15 and 9, 17) of items, each pair relating to the same skill. These pairs were chosen because they related to more midquarter examination items than did the other pretest items.

Pretest items seven and fifteen (see Appendix B) were designed to measure the ability to manipulate an algebraic equation. There were eleven items on the midquarter examinations (same items on both examinations) which required an algebraic manipulation (see Appendix D). The results (see Table 11) show very
### TABLE 11

**PHI CORRELATIONS**<sup>a</sup> **RELATING PRETEST PERFORMANCE TO FIRST MIDQUARTER EXAMINATION**<sup>b</sup> **PERFORMANCE ON ITEMS INVOLVING MANIPULATION OF ALGEBRAIC EXPRESSIONS**

<table>
<thead>
<tr>
<th>Pretest Item 7 and Related First Midquarter Exam Items</th>
<th>Pretest Item 15 and Related First Midquarter Exam Items</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lecture Section B</strong></td>
<td><strong>Lecture Section C</strong></td>
</tr>
<tr>
<td>MQ&lt;sup&gt;b&lt;/sup&gt; Item</td>
<td>Self/ Ob/</td>
</tr>
<tr>
<td>N=113</td>
<td>Inc</td>
</tr>
<tr>
<td>2</td>
<td>.10</td>
</tr>
<tr>
<td>7</td>
<td>.21</td>
</tr>
<tr>
<td>8</td>
<td>.11</td>
</tr>
<tr>
<td>9</td>
<td>.18</td>
</tr>
<tr>
<td>10</td>
<td>.40*</td>
</tr>
<tr>
<td>11</td>
<td>.22</td>
</tr>
<tr>
<td>17</td>
<td>.12</td>
</tr>
</tbody>
</table>

<sup>a</sup> Correlations are significant at the .05 level.

<sup>b</sup> MQ = Manipulation of equations.
Table 11 (continued)

<table>
<thead>
<tr>
<th>MQ</th>
<th>Lecture Section B</th>
<th>Lecture Section C</th>
<th>Lecture Section B</th>
<th>Lecture Section C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item</td>
<td>Self/Inc N=113</td>
<td>Ob/Inc N=104</td>
<td>Self/NoInc N=113</td>
<td>Ob/NoInc N=101</td>
</tr>
<tr>
<td>18</td>
<td>.08</td>
<td>-.04</td>
<td>9</td>
<td>.16</td>
</tr>
<tr>
<td>19</td>
<td>.18</td>
<td>.15</td>
<td>10</td>
<td>.19</td>
</tr>
<tr>
<td>20</td>
<td>-.06</td>
<td>-.07</td>
<td>11</td>
<td>-.05</td>
</tr>
<tr>
<td>21</td>
<td>.15</td>
<td>.03</td>
<td>12</td>
<td>.08</td>
</tr>
</tbody>
</table>

---

*a Correlations rounded to two places

*b Examination Items 2, 7, 8, ..., 21 for Lecture Section B correspond respectively to Items 1, 3, 4, ..., 12 for Lecture Section C

*c See Appendix D for examinations

*p < .01
TABLE 12

PHI CORRELATIONS\textsuperscript{a} RELATING PRETEST PERFORMANCE TO FIRST MIDQUARTER EXAMINATION\textsuperscript{c} PERFORMANCE ON ITEMS INVOLVING ORDER OF MATHEMATICAL OPERATIONS

<table>
<thead>
<tr>
<th>Pretest Item 9 and Related First Midquarter Exam Items</th>
<th>Lecture Section B</th>
<th>Lecture Section C</th>
<th>Lecture Section B</th>
<th>Lecture Section C</th>
</tr>
</thead>
<tbody>
<tr>
<td>MQ\textsuperscript{b}</td>
<td>Self/Ob</td>
<td>Inc</td>
<td>MQ</td>
<td>Self/Ob</td>
</tr>
<tr>
<td>Item</td>
<td>Inc</td>
<td>NoInc</td>
<td>Item</td>
<td>NoInc</td>
</tr>
<tr>
<td>N=113</td>
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<td>N=113</td>
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<td>.14</td>
</tr>
<tr>
<td>9</td>
<td>.25*</td>
<td>.22</td>
<td>5</td>
<td>.01</td>
</tr>
<tr>
<td>10</td>
<td>.25*</td>
<td>.07</td>
<td>6</td>
<td>.10</td>
</tr>
<tr>
<td>11</td>
<td>.06</td>
<td>.20</td>
<td>7</td>
<td>.20</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Correlations rounded to two places
\textsuperscript{b}Examination Items 2, 8, 9, 10 and 11 for Lecture Section B correspond respectively to Items 1, 4, 5, 6 and 7 for Lecture Section C.
\textsuperscript{c}See Appendix D for examinations.

\*p < .01
little, if any relationship between performance on the pretest items and related midquarter examination items.

Pretest items seven and fifteen (see Appendix B) were designed to measure the ability to properly order operations in problems involving several different operations (multiplication, addition, division). Five items on the midquarter examinations were found which involved this skill. Again, the results (see Table 12) would seem to show little relationship between performance on the pretest items and on the related midquarter examination items.

3. CHEMRIC Questionnaire

The purpose of this portion of the study was to determine the extent of relationship between population characteristics, characteristics of the experimental treatments, and performance in the course. Correlations were carried out using the BMD03D (Dixon, 1970) when data were incomplete and the BMD02D when data were complete.

a. Feedback characteristics versus CHEMRIC pretest performance and final numeric course grade

Items six, seven, eight and nine on the CHEMRIC Questionnaire (see summary Table 13 and complete table in Appendix F) relate to student opinion of the length, the reading level, the
### Table 13

**Overall Summary** of Chemric Questionnaire Results

For Items Evaluating Attributes of Chemric Feedback

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Topic</th>
<th>Percentage Response</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Length of explanations</td>
<td>too short</td>
<td>2</td>
<td>10</td>
<td>76</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>too long</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Reading level of explanations</td>
<td>too easy</td>
<td>1</td>
<td>25</td>
<td>65</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>too difficult</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Comprehensibility of explanations</td>
<td>superior</td>
<td>10</td>
<td>25</td>
<td>49</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>poor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Usage of Mathematical Symbols</td>
<td>very clear</td>
<td>25</td>
<td>52</td>
<td>20</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>not understood</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*aSee Appendix F for complete table.

*bSee Appendix E for Questionnaire.*
comprehensibility, and the usage of mathematical symbols in the feedback explanations. Responses were analyzed using the Driggs Chemistry Department Item Analysis Program (see Appendix F). Correlations were also carried out to relate responses to each of the questionnaire items to performance on the CHEMRIC pretests and to the final numeric course grade. Results of the correlations are presented in Tables 14 and 15.

1) Length of the average CHEMRIC explanation

More than seventy-five percent of the students felt that the length of the average explanation was about right; approximately twelve percent felt it was not quite long enough; but they were balanced by an equal number who said it was too long. See Table 13.

When the student opinion of length of explanations was correlated with CHEMRIC pretest performance, it was found that, while only one correlation was significant at $p < .05$ (Lecture Section C, objective, no incentive), 7 of 9 were negative. This implied that the students who needed the explanations most felt that they were too short. See Table 14.

When opinion of the length of explanations was correlated with the final course grade, no correlations were found to be significant at $p < .05$, and this time five of the correlations were positive and
TABLE 14

CORRELATIONS OF CHEMRIC QUESTIONNAIRE ITEMS WITH CHEMRIC PRETEST PERFORMANCE

<table>
<thead>
<tr>
<th>Lecture Section</th>
<th>Treatment</th>
<th>A Self/Inc</th>
<th>A Self/NoInc</th>
<th>A Ob/Inc</th>
<th>A Ob/NoInc</th>
<th>B Self/Inc</th>
<th>B Ob/Inc</th>
<th>C Self/Ob</th>
<th>C Ob/NoInc</th>
<th>D Ob/Inc</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>53</td>
<td>44</td>
<td>56</td>
<td>45</td>
<td>104</td>
<td>89</td>
<td>106</td>
<td>92</td>
<td>227</td>
</tr>
<tr>
<td>Item 5 (Math)</td>
<td></td>
<td>.490**</td>
<td>.485**</td>
<td>.682**</td>
<td>.613**</td>
<td>.550**</td>
<td>.556**</td>
<td>.555**</td>
<td>.652**</td>
<td>.666**</td>
</tr>
<tr>
<td>Item 6 (Length)</td>
<td></td>
<td>-.146</td>
<td>-.092</td>
<td>-.102</td>
<td>-.196</td>
<td>-.100</td>
<td>-.025</td>
<td>-.004</td>
<td>-.207*</td>
<td>-.095</td>
</tr>
<tr>
<td>Item 7 (Rd. Lev.)</td>
<td></td>
<td>.286</td>
<td>.411**</td>
<td>.143</td>
<td>.241</td>
<td>.126</td>
<td>.007</td>
<td>.205</td>
<td>.166</td>
<td>.150*</td>
</tr>
<tr>
<td>Item 8 (Comp.)</td>
<td></td>
<td>.277*</td>
<td>.193</td>
<td>.158</td>
<td>.288</td>
<td>.179</td>
<td>.239*</td>
<td>.243*</td>
<td>.161</td>
<td>.205**</td>
</tr>
<tr>
<td>Item 9 (Symb.)</td>
<td></td>
<td>.415**</td>
<td>.294*</td>
<td>.527**</td>
<td>.397**</td>
<td>.410**</td>
<td>.367**</td>
<td>.402**</td>
<td>.394**</td>
<td>.403**</td>
</tr>
<tr>
<td>Item 10 (Inc.)</td>
<td></td>
<td>.074</td>
<td>.059</td>
<td>.081</td>
<td>.173</td>
<td>-.103</td>
<td>-.308**</td>
<td>.176</td>
<td>-.044</td>
<td>.022</td>
</tr>
</tbody>
</table>

* p < .05

**p < .01
### TABLE 15

**CORRELATIONS OF CHEMRIC QUESTIONNAIRE ITEMS WITH FINAL NUMERIC COURSE GRADES**

<table>
<thead>
<tr>
<th>Lecture Section Treatment</th>
<th>A Self/Inc</th>
<th>A Self/NoInc</th>
<th>A Ob/Inc</th>
<th>A Ob/NoInc</th>
<th>B Self/Inc</th>
<th>B Ob/Inc</th>
<th>C Self/NoInc</th>
<th>C Ob/Inc</th>
<th>D Ob/Inc</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>53</td>
<td>44</td>
<td>56</td>
<td>45</td>
<td>104</td>
<td>89</td>
<td>106</td>
<td>92</td>
<td>227</td>
</tr>
<tr>
<td>Item 5 (Math)</td>
<td>.648**</td>
<td>.439**</td>
<td>.424**</td>
<td>.491**</td>
<td>.404**</td>
<td>.433**</td>
<td>.430**</td>
<td>.671**</td>
<td>.503**</td>
</tr>
<tr>
<td>Item 6 (Length)</td>
<td>.138</td>
<td>-.179</td>
<td>.023</td>
<td>.020</td>
<td>-.052</td>
<td>-.029</td>
<td>.182</td>
<td>-.089</td>
<td>.065</td>
</tr>
<tr>
<td>Item 7 (Rd. Lev)</td>
<td>.103</td>
<td>-.041</td>
<td>.167</td>
<td>.342*</td>
<td>.149</td>
<td>-.021</td>
<td>.065</td>
<td>.096</td>
<td>.067</td>
</tr>
<tr>
<td>Item 8 (Comp.)</td>
<td>.106</td>
<td>-.005</td>
<td>.045</td>
<td>.179</td>
<td>.303**</td>
<td>.260*</td>
<td>.176</td>
<td>.158</td>
<td>.161*</td>
</tr>
<tr>
<td>Item 9 (Symb.)</td>
<td>.258</td>
<td>.189</td>
<td>.216</td>
<td>.229</td>
<td>.227*</td>
<td>.160</td>
<td>.264**</td>
<td>.392*</td>
<td>.271**</td>
</tr>
<tr>
<td>Item 10 (Inc.)</td>
<td>.135</td>
<td>.136</td>
<td>.020</td>
<td>-.054</td>
<td>.071</td>
<td>.240*</td>
<td>.298**</td>
<td>.118</td>
<td>.151*</td>
</tr>
</tbody>
</table>

*p < .05

**p < .01
four were negative. This suggests that the large number of negative correlations with pretest results was due more to chance than to anything else. See Table 15.

2) Reading Level of the CHEMRIC Explanations

As may be seen in Table 13, approximately sixty-five percent of the students felt that the reading level of the explanations was "about right"; more than a fourth felt they were "very easy"; and only about nine percent thought they were either "slightly too hard" or "much too difficult".

The correlations (see Table 14) relating the students' opinions of the reading level to pretest performance were all positive, one being significant at \( p < 0.01 \) and three more (out of nine) at \( p < 0.05 \). The correlations with the final numeric grade were not as strong (see Table 15), two being slightly negative and only one of the positive correlations being significant at \( p < 0.05 \). The overall finding is what would be expected; that is, the better students found the reading level to be easier than the poorer students.

3) Comprehensibility of Feedback

About half of the students felt the explanations were understandable; more than a third rated them above average or superior; only about sixteen percent felt the explanations were below average
Correlations between positive ratings of the comprehensibility of the explanations and performance on the CHEMRIC pretest and with final numeric grade were rather strong, showing that the better students found the explanations easier to understand than did the poorer students. Out of eighteen correlations, seventeen were positive, two were significant at the $p < .01$ level and another five were significant at $p < .05$; several others approached significance at the $p < .05$ level. See Tables 14 and 15.

4) **Usage of Mathematical Symbols**

About one-fourth of the students indicated that they always understood the symbols, and another half of them said they usually did. Only twenty percent indicated partial understanding, and less than three percent said they had real trouble.

As would be expected, the correlations between the students' understanding of the mathematical symbols and achievement were very strong, both with respect to the pretest performance and with respect to the final numeric course grade. When correlated with pretest performance, eight of nine correlations were significant at the $p < .01$ level, while the ninth was significant at the $p < .05$ level. While the correlations with the final numeric course grade
were not as strong, the presence of a relationship seems clear.

b. Incentive conditions

Item ten on the CHEMRIC Questionnaire (see Appendix E) asked the students how much incentive they would have to receive to work the CHEMRIC feedback problems. Constructed responses a, b, c, d, and e correspond to decreasing amounts of credit. The Ohio State University Chemistry Department Item Analysis Program was used to tabulate how students in each lecture section, and each treatment group within each lecture section responded to that question.

As may be seen in Appendix F, nearly seventy percent of the students indicated that they would have done the CHEMRIC problems "for my own good, even if no credit were given." Another twenty percent thought they would have needed ten points, and only about ten percent indicated a need for more than ten points.

Three correlations dealing with Item ten were computed, the first two relating response to Item ten to CHEMRIC pretest performance and final numeric course grade, respectively. See Tables 14 and 15. The results indicate no consistent relationship between expressed need for incentive and course achievement.

The third correlation was carried out to determine if responses
to Item ten were related to whether or not the students in Lecture Section A had received an extrinsic incentive to work the CHEMRIC problems. Students who had been given the incentive were designated by the number "one" and students who had not been given the extrinsic incentive were labeled "zero." The BMD03D (Dixon, 1970) was used to carry out the point biserial correlation.

Correlations for both the group which had used the self-evaluative pretest ($r_{pb} = 0.065$) and the group which had used the objective pretest ($r_{pb} = 0.139$) were positive, but neither correlation was significant at the $p < .05$ level. To have been significant at $p < .05$, the point biserial correlation coefficient would have had to have exceeded 0.195.

c. Students' Rating of Mathematics Preparation

Item five on the CHEMRIC questionnaire asks the students to rate their mathematics background with respect to their experience in Chemistry 101. These responses were correlated (Pearson Product-Moment) with both (1) their performance on the CHEMRIC pretest, and (2) their achievement in Chemistry 101 as measured by the total number of points earned in the course (out of 1000), again using the BMD03D. See Tables 14 and 15.

Not surprisingly, the students' self ratings of their
mathematics proficiency upon entering Chemistry 101 correlated very highly with both pretest performance and final numeric course grade. The reason the high correlations were expected is that the ratings were obtained near the end of the course. Correlations with respect to the pretest ranged from 0.433 to 0.682 and, with respect to the final grade, from 0.404 to 0.671.

3. Prediction of Final Course Grades by Pretest Scores

As may be seen in Table 16, prediction of the final course grade was consistently better using the objective pretest format. Correlations for the self-evaluative form ranged from 0.162 to 0.503, whereas for the objective form they ranged from 0.417 to 0.575. The differences (Hays, 1963) were not highly significant, however, as is seen in Table 17.

EXPERIMENTAL RESEARCH

The experimental research had four parts, the first relating to the assignment of subjects to experimental treatment groups; and the remaining three dealing with experimental research carried out on Lecture Sections A, B, and C, respectively.

1. Testing Possibility of Non-Random Assignment

As was indicated earlier, while the experimenter had control over the assignment of laboratory-recitation sections to treatment
TABLE 16
CORRELATIONS BETWEEN CHEMRIC PRETEST SCORES
AND FINAL NUMERIC COURSE GRADES

<table>
<thead>
<tr>
<th>Lecture Section</th>
<th>Treatment</th>
<th>N</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Self/Inc</td>
<td>53</td>
<td>0.334*</td>
</tr>
<tr>
<td>A</td>
<td>Self/NoInc</td>
<td>44</td>
<td>0.162</td>
</tr>
<tr>
<td>A</td>
<td>Ob/Inc</td>
<td>56</td>
<td>0.533**</td>
</tr>
<tr>
<td>A</td>
<td>Ob/NoInc</td>
<td>45</td>
<td>0.417**</td>
</tr>
<tr>
<td>B</td>
<td>Self/Inc</td>
<td>104</td>
<td>0.301**</td>
</tr>
<tr>
<td>B</td>
<td>Ob/Inc</td>
<td>90</td>
<td>0.502**</td>
</tr>
<tr>
<td>C</td>
<td>Self/NoInc</td>
<td>107</td>
<td>0.503**</td>
</tr>
<tr>
<td>C</td>
<td>Ob/NoInc</td>
<td>93</td>
<td>0.575**</td>
</tr>
<tr>
<td>D</td>
<td>Ob/Inc</td>
<td>230</td>
<td>0.533**</td>
</tr>
</tbody>
</table>

*p < .05

**p < .01
TABLE 17
DIFFERENCES BETWEEN SELF-EVALUATIVE AND OBJECTIVE CHEMRIC PRETEST FORMS IN PREDICTING FINAL NUMERIC COURSE GRADES

<table>
<thead>
<tr>
<th>Comparison Groups</th>
<th>N</th>
<th>R</th>
<th>Z_{Group}</th>
<th>Z_{Ratio}</th>
<th>P less than</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture Section A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self/Inc</td>
<td>53</td>
<td>0.334</td>
<td>0.347</td>
<td>1.25</td>
<td>0.21</td>
</tr>
<tr>
<td>Ob/Inc</td>
<td>56</td>
<td>0.533</td>
<td>0.594</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lecture Section A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self/NoInc</td>
<td>44</td>
<td>0.162</td>
<td>0.163</td>
<td>1.28</td>
<td>0.20</td>
</tr>
<tr>
<td>Ob/NoInc</td>
<td>45</td>
<td>0.417</td>
<td>0.444</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lecture Section B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self/Inc</td>
<td>104</td>
<td>0.301</td>
<td>0.310</td>
<td>1.66</td>
<td>0.09</td>
</tr>
<tr>
<td>Ob/Inc</td>
<td>90</td>
<td>0.502</td>
<td>0.552</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lecture Section C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self/Inc</td>
<td>107</td>
<td>0.503</td>
<td>0.553</td>
<td>0.708</td>
<td>0.47</td>
</tr>
<tr>
<td>Ob/Inc</td>
<td>93</td>
<td>0.575</td>
<td>0.655</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
groups, he did not have control over the assignment of individual subjects to the different laboratory-recitation sections. Since the experimenter wished to use experimental designs and parametric statistics it was felt important to provide evidence showing that the assignments made outside of his control had resulted in a situation not statistically different from that which would have resulted from random assignments.

Two approaches were used to determine whether or not the Ohio State University Computer Assisted Scheduling System had assigned students to laboratory-recitation sections in a manner which had resulted in random distribution of confounding variables (see Chapter IV).

The first approach was to utilize analysis of variance to compare CHEMRIC pretest performance between all sections under equivalent treatment conditions; that is, all those who used the same form of the pretest and had the same incentive conditions were compared. The results are summarized in Table 18. None of the F ratios is significant at $p < .05$. This evidence indicates that the ability to perform on the pretest, which was shown earlier to correlate strongly with final numeric course grade (see Table 16) was distributed rather evenly throughout the different laboratory-recitation sections.
### TABLE 18

ANOVA OF CHEMRIC PRETEST SCORES FOR LABORATORY-RECITATION SECTIONS UNDER SPECIFIED TREATMENT CONDITIONS

<table>
<thead>
<tr>
<th>Treatment Condition</th>
<th>Number of Sections</th>
<th>Degrees of Freedom Between</th>
<th>Degrees of Freedom Within</th>
<th>Total</th>
<th>F Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self/Inc</td>
<td>9</td>
<td>8</td>
<td>188</td>
<td>196</td>
<td>0.8509</td>
</tr>
<tr>
<td>Self/NoInc</td>
<td>8</td>
<td>7</td>
<td>196</td>
<td>203</td>
<td>1.6651</td>
</tr>
<tr>
<td>Obj/Inc</td>
<td>21</td>
<td>20</td>
<td>476</td>
<td>496</td>
<td>1.5036</td>
</tr>
<tr>
<td>Obj/NoInc</td>
<td>8</td>
<td>7</td>
<td>177</td>
<td>184</td>
<td>1.2840</td>
</tr>
</tbody>
</table>
The second approach was to carry out analyses of variance comparing responses on the first four items on the CHEMRIC Questionnaire for students in all of the different laboratory-recitation sections. Results are presented in Table 19.

**TABLE 19**

**ANOVA FOR THE FIRST FOUR CHEMRIC QUESTIONNAIRE ITEMS**

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Item</th>
<th>Degrees of Freedom</th>
<th>F Ratio $^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>High School Size</td>
<td>33 574 607</td>
<td>0.8091</td>
</tr>
<tr>
<td>2</td>
<td>High School Location</td>
<td>33 574 607</td>
<td>1.0556</td>
</tr>
<tr>
<td>3</td>
<td>Mathematics Taken</td>
<td>33 574 607</td>
<td>0.6246</td>
</tr>
<tr>
<td>4</td>
<td>Physical Science Taken</td>
<td>33 574 607</td>
<td>1.2390</td>
</tr>
</tbody>
</table>

$^a$To have been significant at $p < .10$, the F ratio would have had to have been greater than 1.33.

The fact that none of these F ratios is significant at $p < .05$, or even $p < .10$, provides additional evidence that potentially confounding variables had an even distribution throughout the population.

Finally, it should be pointed out that treatment groups were made
up by randomly assigning several laboratory-recitation sections to each of them (see Overall Design Structure). Therefore, even if significant differences between the smaller sections had been present, chances are that such differences would have been reduced or eliminated by the process of assigning sections to treatment groups. For this reason and the other evidence offered above, it was felt that an assumption of random distribution of potentially confounding variables was justified, and that the use of parametric statistics would be appropriate.

2. **Substudy A--Lecture Section A**

To evaluate the direct and interactive effects of the two manipulated variables, DOSPIDRIN and incentive, two-way analysis of variance on each of the four criterion variables was carried out. The results are presented in Tables 20, 21, 22 and 23. The F ratios for performance on the qualitative portion of neither examination (First Midquarter nor Final) approached significance. As might be expected, differences, while not highly significant, were found in the effects on the quantitative portions. Groups which had used the self-evaluative CHEMRIC pretest exhibited higher mean performance on both criteria; the differences were not highly significant, however, corresponding to only \( p < .10 \) for both the first midquarter and the
TABLE 20
CELL MEANS AND STANDARD DEVIATIONS, PLOT OF CELL MEANS, AND ANOVA OF THE EFFECTS OF THE LEVELS OF DOSPIDRIN AND INCENTIVE ON THE QUANTITATIVE PORTION OF THE FIRST MIDQUARTER EXAMINATION FOR LECTURE SECTION A

<table>
<thead>
<tr>
<th></th>
<th>Incentive</th>
<th>No Incentive</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Self-Evaluative</strong></td>
<td>( \bar{X} = 9.86 )</td>
<td>( \bar{X} = 9.90 )</td>
</tr>
<tr>
<td><strong>S. D.</strong></td>
<td>2.84</td>
<td>2.45</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>59</td>
<td>60</td>
</tr>
<tr>
<td><strong>Objective</strong></td>
<td>( \bar{X} = 9.34 )</td>
<td>( \bar{X} = 9.26 )</td>
</tr>
<tr>
<td><strong>S. D.</strong></td>
<td>2.53</td>
<td>2.90</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>65</td>
<td>57</td>
</tr>
</tbody>
</table>

Plot of Cell Means

\( \text{No Incentive} \)

\( \text{Incentive} \)

\( \text{Self-Evaluative} \)

\( \text{Objective} \)

\( \text{Inc} \)

\( \text{NoInc} \)
Table 20 (continued)

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>F Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOSPIDRIN</td>
<td>20.318</td>
<td>1</td>
<td>2.823*</td>
</tr>
<tr>
<td>Incentive</td>
<td>0.024</td>
<td>1</td>
<td>0.003</td>
</tr>
<tr>
<td>Interaction</td>
<td>0.185</td>
<td>1</td>
<td>0.026</td>
</tr>
<tr>
<td>Error</td>
<td>1705.922</td>
<td>237</td>
<td></td>
</tr>
</tbody>
</table>

*p < .10
TABLE 21

CELL MEANS AND STANDARD DEVIATIONS, PLOT OF CELL MEANS, AND ANOVA OF THE EFFECTS OF THE LEVELS OF DOSPIDRIN AND INCENTIVE ON THE QUALITATIVE QUESTIONS ON THE FIRST MIDQUARTER EXAMINATION FOR LECTURE SECTION A

<table>
<thead>
<tr>
<th>Cell Statistics</th>
<th>Incentive</th>
<th>No Incentive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-Evaluative</td>
<td>( \bar{X} = 9.49 )</td>
<td>( \bar{X} = 9.65 )</td>
</tr>
<tr>
<td>Pretest</td>
<td>( \text{S. D.} = 2.44 )</td>
<td>( \text{S. D.} = 2.69 )</td>
</tr>
<tr>
<td>Pretest</td>
<td>( N = 59 )</td>
<td>( N = 60 )</td>
</tr>
<tr>
<td>Objective</td>
<td>( \bar{X} = 9.55 )</td>
<td>( \bar{X} = 9.32 )</td>
</tr>
<tr>
<td>Pretest</td>
<td>( \text{S. D.} = 2.26 )</td>
<td>( \text{S. D.} = 2.52 )</td>
</tr>
<tr>
<td>Pretest</td>
<td>( N = 65 )</td>
<td>( N = 57 )</td>
</tr>
</tbody>
</table>

Plot of Cell Means

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>F Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOSPIDRIN</td>
<td>1.111</td>
<td>1</td>
<td>0.1810</td>
</tr>
<tr>
<td>Incentive</td>
<td>0.095</td>
<td>1</td>
<td>0.0155</td>
</tr>
<tr>
<td>Interaction</td>
<td>2.363</td>
<td>1</td>
<td>0.3849</td>
</tr>
<tr>
<td>Error</td>
<td>1454.733</td>
<td>237</td>
<td></td>
</tr>
</tbody>
</table>
TABLE 22

CELL MEANS AND STANDARD DEVIATIONS, PLOT OF CELL MEANS; AND ANOVA OF THE EFFECTS OF THE LEVELS OF DOSPIDRIN AND INCENTIVE ON THE QUANTITATIVE QUESTIONS ON THE FINAL EXAMINATION FOR LECTURE SECTION A

<table>
<thead>
<tr>
<th>Cell Statistics</th>
<th>Incentive</th>
<th>No Incentive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-Evaluative Pretest</td>
<td>X = 15.54</td>
<td>X = 14.23</td>
</tr>
<tr>
<td></td>
<td>S. D. = 4.69</td>
<td>S. D. = 3.47</td>
</tr>
<tr>
<td></td>
<td>N = 56</td>
<td>N = 56</td>
</tr>
<tr>
<td>Objective Pretest</td>
<td>X = 13.74</td>
<td>X = 14.08</td>
</tr>
<tr>
<td></td>
<td>S. D. = 4.39</td>
<td>S. D. = 4.64</td>
</tr>
<tr>
<td></td>
<td>N = 62</td>
<td>N = 52</td>
</tr>
</tbody>
</table>

Plot of Cell Means

<table>
<thead>
<tr>
<th>Source</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>F Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOSPIDRIN</td>
<td>53.446</td>
<td>1</td>
<td>2.859*</td>
</tr>
<tr>
<td>Incentive</td>
<td>13.200</td>
<td>1</td>
<td>0.706</td>
</tr>
<tr>
<td>Interaction</td>
<td>37.776</td>
<td>1</td>
<td>2.021</td>
</tr>
<tr>
<td>Error</td>
<td>4149.474</td>
<td>222</td>
<td></td>
</tr>
</tbody>
</table>

*p < .10
### TABLE 23

**CELL MEANS AND STANDARD DEVIATIONS, PLOT OF CELL MEANS, AND ANOVA OF THE EFFECTS OF THE LEVELS OF DOSPIDRIN AND INCENTIVE ON THE QUALITATIVE QUESTIONS ON THE FINAL EXAMINATION FOR LECTURE SECTION A**

<table>
<thead>
<tr>
<th>Cell Statistics</th>
<th>Incentive</th>
<th>No Incentive</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Self-</strong></td>
<td>$\bar{X} = 17.59$</td>
<td>$\bar{X} = 17.11$</td>
</tr>
<tr>
<td>Evaluative</td>
<td>$S.D. = 4.03$</td>
<td>$S.D. = 3.18$</td>
</tr>
<tr>
<td>Pretest</td>
<td>$N = 56$</td>
<td>$N = 56$</td>
</tr>
<tr>
<td><strong>Objective</strong></td>
<td>$\bar{X} = 17.15$</td>
<td>$\bar{X} = 17.46$</td>
</tr>
<tr>
<td>Pretest</td>
<td>$S.D. = 3.71$</td>
<td>$S.D. = 4.44$</td>
</tr>
<tr>
<td></td>
<td>$N = 62$</td>
<td>$N = 52$</td>
</tr>
</tbody>
</table>

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**Plot of Cell Means**

17.8
17.6
17.4
17.2
17.0

**Source** | **Sum of Squares** | **DF** | **F Ratio** |
---|-------------------|-------|-------------|
DOSPIDRIN | 0.11328           | 1     | 0.00763     |
Incentive | 0.38661           | 1     | 0.02603     |
Interaction| 8.97140           | 1     | 0.60398     |
Error     | 3297.52734        | 222   |             |
final examination. Incentive appeared to have little if any effect on any of the criteria; and, with only one of the four criteria was an interactive effect of any kind noted. On the quantitative portion of the final examination the F ratio for the interactive effect of incentive and DOSPIDRIN was 2.021; to have been significant at $p < .10$ the F ratio would have to have been greater than 2.73. Thus, the results of this substudy indicate a slight superiority for the self-evaluative pretest with respect to its effect on performance on quantitative examination items, no effect of incentive, and very little, if any, interactive effect between incentive and DOSPIDRIN.

3. **Substudy B—Lecture Section B**

This study was in some respects a replicate of Substudy A, the difference being that, instead of two manipulated variables, there was only one, DOSPIDRIN. Instead of manipulating incentive, as in Substudy A, all students in Lecture Section B were offered an incentive of ten points to work the CHEMRIC feedback problems.

To evaluate the effect of the two levels of DOSPIDRIN (use of self-evaluative CHEMRIC diagnostic pretest versus use of the objective form) on achievement, one way analyses of variance (using the BMDOIV) were carried out on the four criterion variables. As is clear from the results presented in Tables 24, 25, 26 and 27, none of the F ratios even approach significance. Thus the
TABLE 24

CELL MEANS AND STANDARD DEVIATIONS, AND ANOVA OF THE EFFECT OF DOSPIDRIN ON THE QUANTITATIVE PORTION OF THE FIRST MIDQUARTER EXAMINATION FOR LECTURE SECTION B (INCENTIVE GIVEN TO ALL)

<table>
<thead>
<tr>
<th>Cell Statistics</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Self-Evaluative</strong></td>
<td><strong>Objective</strong></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td>Pretest</td>
<td></td>
</tr>
<tr>
<td>$\bar{X} = 14.26$</td>
<td>$\bar{X} = 14.69$</td>
<td></td>
</tr>
<tr>
<td>S. D. = 4.70</td>
<td>S. D. = 4.84</td>
<td></td>
</tr>
<tr>
<td>N = 134</td>
<td>N = 117</td>
<td></td>
</tr>
</tbody>
</table>

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Analysis of Variance

<table>
<thead>
<tr>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Square</th>
<th>F Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between groups</td>
<td>11.609</td>
<td>1</td>
<td>11.609</td>
</tr>
<tr>
<td>Within Groups</td>
<td>5654.750</td>
<td>249</td>
<td>22.710</td>
</tr>
<tr>
<td>Total</td>
<td>5666.356</td>
<td>250</td>
<td></td>
</tr>
</tbody>
</table>
TABLE 25

CELL MEANS AND STANDARD DEVIATIONS, AND ANOVA OF THE EFFECT OF DOSPIDRIN ON THE QUALITATIVE PORTION OF THE FIRST MIDQUARTER EXAMINATION FOR LECTURE SECTION B (INCENTIVE GIVEN TO ALL)

<table>
<thead>
<tr>
<th>Cell Statistics</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Self-Evaluative</strong></td>
<td>$\bar{X}$ = 3.179</td>
<td>S. D. = 1.348</td>
<td>N = 134</td>
</tr>
<tr>
<td><strong>Pretest</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Objective</strong></td>
<td>$\bar{X}$ = 3.137</td>
<td>S. D. = 1.426</td>
<td>N = 117</td>
</tr>
<tr>
<td><strong>Pretest</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Analysis of Variance

<table>
<thead>
<tr>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Squares</th>
<th>F Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Between Groups</strong></td>
<td>0.112</td>
<td>1</td>
<td>0.112</td>
</tr>
<tr>
<td><strong>Within Groups</strong></td>
<td>477.511</td>
<td>249</td>
<td>1.918</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>477.623</td>
<td>250</td>
<td></td>
</tr>
</tbody>
</table>
TABLE 26

CELL MEANS AND STANDARD DEVIATIONS, AND ANOVA OF THE EFFECT OF DOSPIDRIN ON THE QUANTITATIVE PORTION OF THE FINAL EXAMINATION FOR LECTURE SECTION B (INCENTIVE GIVEN TO ALL)

<table>
<thead>
<tr>
<th>Cell Statistics</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Self-Evaluative</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td>$\bar{X} = 14.655$</td>
<td>$S. D. = 4.999$</td>
<td>$N = 116$</td>
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</tr>
<tr>
<td>Objective</td>
<td>$\bar{X} = 14.857$</td>
<td>$S. D. = 4.734$</td>
<td>$N = 105$</td>
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</tr>
</tbody>
</table>

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### Analysis of Variance

<table>
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<tr>
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<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Squares</th>
<th>F Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>2.248</td>
<td>1</td>
<td>2.248</td>
<td>0.946</td>
</tr>
<tr>
<td>Within Groups</td>
<td>5205.039</td>
<td>219</td>
<td>23.767</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>5207.285</td>
<td>220</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TABLE 27

CELL MEANS AND STANDARD DEVIATIONS, AND ANOVA OF THE EFFECT OF DOSPIDRIN ON THE QUALITATIVE PORTION OF THE FINAL EXAMINATION FOR LECTURE SECTION B (INCENTIVE GIVEN TO ALL)

<table>
<thead>
<tr>
<th>Cell Statistics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-Evaluative</td>
<td>$\bar{X} = 12.704$</td>
</tr>
<tr>
<td>Pretest</td>
<td>S. D. = 3.482</td>
</tr>
<tr>
<td></td>
<td>N = 115</td>
</tr>
<tr>
<td>Objective</td>
<td>$\bar{X} = 12.857$</td>
</tr>
<tr>
<td>Pretest</td>
<td>S. D. = 3.498</td>
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<tr>
<td></td>
<td>N = 105</td>
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</tbody>
</table>

Analysis of Variance

<table>
<thead>
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<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Square</th>
<th>F Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>1.281</td>
<td>1</td>
<td>1.281</td>
<td>0.1052</td>
</tr>
<tr>
<td>Within Groups</td>
<td>2654.788</td>
<td>218</td>
<td>12.178</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2656.070</td>
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</tbody>
</table>

---

Cell Means and Standard Deviations, and ANOVA of the Effect of Dospidrin on the Qualitative Portion of the Final Examination for Lecture Section B (Incentive Given to All)
inescapable conclusion of this substudy is that varying the type of pretest experience had no statistically meaningful effect on either qualitative or quantitative performance on either the first mid-quarter or final examination.

4. Substudy C--Lecture Section C

Like Substudy B, this study replicated, in a sense, a portion of Substudy A, and, also like Substudy B, the manipulated variable was DOSPIDRIN. The difference was that, in Substudy B all students received an incentive, whereas in Substudy C no student received the ten point extrinsic incentive to work the CHEMRIC feedback problems.

Analyses of variance were carried out on the four criterion variables, and the results are presented in Tables 28, 29, 30 and 31. In each case the students who had used the self-evaluative form of the CHEMRIC pretest performed at a slightly higher level than those who had used the objective form. The difference, however, was significant at $p < .05$ in only one case (qualitative items on the First Midquarter Examination). The difference observed between the groups on the quantitative items on the Final Examination approached statistical significance ($p < .20$). Thus while the results are more satisfying than those for Substudy B, they are by no means definitive.
TABLE 28
CELL MEANS AND STANDARD DEVIATIONS, AND ANOVA OF
THE EFFECT OF DOSPIDRIN ON THE QUANTITATIVE PORTION
OF THE FIRST MIDQUARTER EXAMINATION FOR LECTURE
SECTION C (NO INCENTIVE GIVEN)

<table>
<thead>
<tr>
<th></th>
<th>Self-Evaluative</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pretest</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\overline{X}$ = 12.92</td>
<td>S. D. = 3.87</td>
<td>$N = 118$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Objective</td>
<td>Pretest</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\overline{X}$ = 12.37</td>
<td>S. D. = 4.07</td>
<td>$N = 115$</td>
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Analysis of Variance

<table>
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<th>F Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>17.606</td>
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<td>17.606</td>
<td>1.115</td>
</tr>
<tr>
<td>Within Groups</td>
<td>3647.213</td>
<td>231</td>
<td>15.789</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3664.819</td>
<td>232</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TABLE 29

CELL MEANS AND STANDARD DEVIATIONS, AND ANOVA OF THE EFFECT OF DOSPIDRIN ON THE QUALITATIVE PORTION OF THE FIRST MIDQUARTER EXAMINATION FOR LECTURE SECTION C (NO INCENTIVE GIVEN)

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Self-Evaluative</strong></td>
<td><strong>Objective</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Pretest</strong></td>
<td><strong>Pretest</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>X = 6.966</strong></td>
<td><strong>X = 6.426</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>S. D. = 1.956</strong></td>
<td><strong>S. D. = 2.136</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>N = 117</strong></td>
<td><strong>N = 115</strong></td>
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Analysis of Variance

<table>
<thead>
<tr>
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<th>Mean Square</th>
<th>F Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>16.894</td>
<td>1</td>
<td>16.894</td>
<td>4.031*</td>
</tr>
<tr>
<td>Within Groups</td>
<td>963.9695</td>
<td>230</td>
<td>4.191</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>980.864</td>
<td>231</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p < .05
TABLE 30
CELL MEANS AND STANDARD DEVIATIONS, AND ANOVA OF
THE EFFECT OF DOSPIDRIN ON THE QUANTITATIVE PORTION
OF THE FINAL EXAMINATION FOR LECTURE SECTION C
(NO INCENTIVE GIVEN)

<table>
<thead>
<tr>
<th></th>
<th>Cell Statistics</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>X</strong> = 8.974</td>
<td><strong>X</strong> = 8.307</td>
</tr>
<tr>
<td>Self-Evaluative</td>
<td></td>
<td>S. D. = 3.121</td>
<td>S. D. = 3.367</td>
</tr>
<tr>
<td>Pretest</td>
<td></td>
<td>N = 113</td>
<td>N = 101</td>
</tr>
<tr>
<td>Objective</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretest</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analysis of Variance

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Square</th>
<th>F Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>23,693</td>
<td>1</td>
<td>23.693</td>
<td>2.2581*</td>
</tr>
<tr>
<td>Within Groups</td>
<td>2224.383</td>
<td>212</td>
<td>10.492</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2248.075</td>
<td>213</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* *p < .2
# TABLE 31

**CELL MEANS AND STANDARD DEVIATIONS, AND ANOVA OF THE EFFECT OF DOSPIDRIN ON THE QUALITATIVE PORTION OF THE FINAL EXAMINATION FOR LECTURE SECTION C (NO INCENTIVE GIVEN)**

<table>
<thead>
<tr>
<th>Cell Statistics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Self-Evaluative</strong></td>
<td><strong>Pretest</strong></td>
</tr>
<tr>
<td>$\overline{X}$</td>
<td>17.814</td>
</tr>
<tr>
<td>S. D.</td>
<td>4.242</td>
</tr>
<tr>
<td>N</td>
<td>113</td>
</tr>
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</table>

### Analysis of Variance

<table>
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<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Square</th>
<th>F Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Between Groups</strong></td>
<td>10.228</td>
<td>1</td>
<td>10.228</td>
</tr>
<tr>
<td><strong>Within Groups</strong></td>
<td>3730.774</td>
<td>212</td>
<td>17.598</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>3741.001</td>
<td>213</td>
<td></td>
</tr>
</tbody>
</table>
5. **Summary of Experimental Research**

The experimental research was designed to measure effects of manipulating two variables, one involving incentive conditions, the other involving the approach used to gather the information necessary for individualizing instruction (self-evaluation versus objective performance). The overall experimental study included three substudies, namely A, B, and C, each involving one lecture section of Chemistry 101 at The Ohio State University.

Substudy A, in which both independent variables were manipulated, examined both direct and interactive effects of the two variables, finding a slight superiority for self-evaluation, no differences relating to incentives, and no important interactive effects. The confidence level for none of the differences was sufficiently high to rule out the possibility that the differences had occurred by chance.

Substudy B involved varying DOSPIDRIN while holding the other independent variable, incentive, constant. All students got the incentive. The analyses of variance showed no statistically significant superiority for the use of either type of pretest experience with respect to any of the chosen criteria. While the results of this substudy do not refute the findings in Substudy A, neither do they support them.
Substudy C, in which no students received an incentive, yielded results supportive of those of Substudy A, but still not highly significant. Again the self-evaluative approach seemed to be related to higher achievement, but, surprisingly, the most highly significant difference occurred when the criterion was performance on the qualitative, not quantitative, portion of the Final Examination.
CHAPTER V

SUMMARY, CONCLUSIONS, IMPLICATIONS
AND RECOMMENDATIONS

SUMMARY

This study was related to the development and improvement of a system designed to provide Computerized Help with Essential Mathematics Required In Chemistry (CHEMRIC) which was conceived of and implemented by this researcher in the Department of Chemistry at The Ohio State University. The CHEMRIC system consists of 1) a diagnostic pretest used in obtaining information about the mathematics skills proficiencies and deficiencies of each student; and 2) a batch processing computer program designed to analyze the data gathered by the pretest and to provide feedback consisting of individualized explanations and related homework exercises for each student.

The study took place during Spring Quarter, 1972, and Autumn Quarter, 1972, at The Ohio State University. Spring Quarter was used to conduct a pilot study, which had three purposes:
1. To implement the **CHEMRIC** system for the first time, checking for errors and testing feasibility;

2. To help to reveal problem areas which could be examined further in the main study; and

3. To conduct an experimental study designed to test the effectiveness of the system.

The main study, which included both evaluative and experimental research, was carried out during Autumn Quarter, 1972. The evaluative research examined attributes of and relationships between the **CHEMRIC** system and the population involved in the study. The experimental research involved the manipulation of two variables which were thought to relate directly to the effectiveness of the system.

The population for the pilot study included all students enrolled in Chemistry 101 Spring Quarter, 1972, which was one lecture section. The main study utilized four of the five lecture sections of Chemistry 101 offered during Autumn Quarter, 1972. Each lecture section contained between 250 and 300 students.

**The Pilot Study**

The pilot study (see Chapter III) found that, contrary to the original purpose of the system, the students having better than
average mathematical proficiency benefitted more from CHEMRIC than did the below average students. Perhaps this should not be surprising, since related studies in the area of programmed instruction have had similar results. A study by Noble (1969a), for example, which involved teaching mathematics to elementary students using a teaching machine to present programmed materials, found that

...older more intelligent children who were better readers, scored more highly on mathematical attainment tests both before and after programmed instruction and adopted faster speeds of progress through the program. (p. 117)

The reason the results were not anticipated in this case is that the amount of explanatory information provided by CHEMRIC is inversely proportional to the score on the pretest, that is, a student who misses only one pretest item receives only one explanation, whereas a student who misses many items receives a great deal of explanatory feedback and many problems to work. What seems to have happened is that students who got two or three explanations managed to erase their deficiencies whereas students who received much information were able to get very little help from it. This result would be consistent with the findings of Possner and Rossman (1965), who have found a direct relationship between the probability
of forgetting and the amount of information which must be processed. If this is true, perhaps different types and amounts of remedial help should be provided to students at different levels of mathematics proficiency.

As a result of the pilot study and a review of the relevant literature, it was decided to revise the explanations in the CHEMRIC feedback to make them clearer and easier to read, and also to investigate ways of getting more students to benefit from the materials, such as providing incentives or involving the students to a greater degree in the operation of the system.

The Main Study

Of the four lecture sections of Chemistry 101 utilized in this study, all were used for the evaluative research, while only three were used in the manipulative portion of the experimental research. All students utilized the CHEMRIC system at the beginning of the term and filled out an evaluative questionnaire at the end of the term, but the manipulated and criterion variables were different for each lecture section.

The evaluative research had two purposes, which were

1. To describe the mathematical proficiencies and deficiencies of entering Chemistry 101 students;
2. To utilize student opinion to evaluate certain attributes of the CHEMRIC system and to relate the opinions to specific characteristics and segments of the population.

The experimental research was designed to evaluate the effect on achievement of manipulating two variables:

1. Incentive--one treatment was to provide a ten point extrinsic incentive to work the CHEMRIC feedback problems; the opposite treatment condition was to not provide the incentive.

2. DOSPIDRIN (Degree of Student Participation in Deciding Remedial Instruction Needs)--one treatment involved use of a self-evaluative form of the CHEMRIC diagnostic pretest, on which a student would try a problem and then decide himself whether or not he needed help with that type of problem; the opposite treatment involved use of an objective form of the pretest, on which a student would attempt a problem and then select one of four or five constructed responses.

Thus, each manipulated variable had two levels, corresponding to incentive/no incentive and self-evaluative/objective. In Substudy A, which utilized Lecture Section A, there were four treatment conditions, one corresponding to each of the four combinations resulting from crossing the two levels of the two variables. In Substudy B and Substudy C the only variable manipulated was
DOSPIDRIN. In Substudy B all students received the incentive of ten points; in Substudy C no students received the incentive. Thus, in both Substudy B and Substudy C there were only two treatment groups, each corresponding to a different level of DOSPIDRIN.

The criterion variables for each substudy were performance on four instruments, including the quantitative and the qualitative portion of the First Midquarter Examination and the Final Examination given to each lecture section. Because each professor wrote his own examinations the criteria varied somewhat from substudy to substudy (see Appendix D).

CONCLUSIONS AND IMPLICATIONS OF EVALUATIVE RESEARCH

CHEMRIC Diagnostic Pretest Information

The two forms (objective and self-evaluative) of the CHEMRIC diagnostic pretest had a number of similarities as well as important differences. The items on each form were identical, but the constructed responses were considerably different (see Appendix B). The objective form asked the student to work a problem and then to select the best one of four or five listed "answers"; the self-evaluative form asked him to work the same problem, and then to indicate whether or not he needed help with that type of problem. The CHEMRIC PL/1 program treated an incorrect response on the
objective form in the same manner as an expressed need for help on the self-evaluative form; a correct objective response was treated in the same way as an expression of no need for help. Thus, in one case (on the self-evaluative form) it was the decision made by the student which caused the program to provide an explanation; in the other case (on the objective form) the decision was made on the basis of whether or not the student had selected a correct response.

Analysis of the data resulting from the administration of the two forms of the pretest yielded a number of useful general observations, among them:

1. Item by item comparisons of results on the two forms reveal considerable differences between objective performance and self-evaluation (see Table 10); these differences may be real or may have resulted from either random guessing on the objective form or invalid evaluations on the self-evaluative form.

2. More often than not the self-evaluative mean (based on the number of students indicating proficiency) for an item was considerably lower than was the mean (based on the number of students getting the item correct) for the corresponding objective item. Again, this may have been due to either guessing or invalid self-evaluation.
3. Items which appeared to result in random guessing (even distribution of selection of each constructed response) on the objective format usually had low means on the self-evaluative form.

The considerable apparent discrepancy between the way in which students evaluated their own proficiencies and the way in which they performed on the objective pretest indicates that there may be a validity problem with either one approach or the other, or perhaps both. Considering the magnitude of the item-by-item differences, it is surprising that the means for total performance on the objective form were even close to the means of indicated proficiency on the self-evaluative form (see Table 9). It might be worth considering a combined objective-self-evaluative format on which a student could either choose an objective response or indicate he needed help. Since the feedback produced by CHEMRIC depends solely on the responses to the pretest, it is crucially important that the information be as accurate as possible. This study was not able to determine which approach, self-evaluation or objective performance, provides more valid information, but it did show that the information produced by the two approaches is considerably different.
The pretest data also revealed (see Table 10) useful information about the mathematical proficiencies and deficiencies of entering Chemistry 101 students, including:

1. Problems incorporating several different kinds of manipulations seem to give the greatest difficulty.
2. Simple concepts involving logarithms are not widely understood by these students.
3. The use of graphs is another weak area.
4. Manipulations of units seem to be more difficult than similar operations on numbers.
5. Many students cannot handle simple algebraic manipulations.
6. Most students are quite proficient with respect to operations involving decimals and exponents.

While some studies (Denny, 1971) have identified certain mathematical skills necessary for success in chemistry and others have shown that general mathematics ability (Garrett and Fawcett, 1945; Cronbach, 1970) is important in chemistry, this researcher could find no source of information which identified the existing competency levels of entering college chemistry students with respect to specific mathematics skills. This information should be of use to instructors of courses similar to Chemistry 101 at
The Ohio State University, as well as to persons involved with mathematics instruction at the secondary level.

**Performance on Selected Pretest Items and Related Midquarter Examination Items**

The hypothesis that there is no relationship between performance on selected items on the CHEMRIC diagnostic pretest and performance on related First Midquarter Examination items is not rejected. Although there were a number of correlations significant at $p < .01$ (see Tables 11 and 12), it would appear that they were more a result of chance occurrence than indicative of a strong relationship, in that correlations which were significant for one lecture section were seldom significant for the other lecture section, even under nearly identical conditions.

There are several possible explanations for the lack of relationship between item-by-item pretest and midquarter examination performance. One is that the pretest items were designed to measure very specific mathematical skills while the midquarter examination items were designed to measure both mathematical skills proficiency and knowledge of chemistry. Thus, the correlations may have been confounded by the extraneous information in the midquarter examination data.
A second possible explanation for the low correlations is that, if CHEMRIC had made an effect, low correlations are what would be expected. The primary function of CHEMRIC, after all, is not to predict failure, but to identify problems and to remedy the situation. Thus, the absence of a relationship between item-by-item pretest performance and performance on related midquarter examination items may indicate that CHEMRIC did have the desired effect.

CHEMRIC Questionnaire Information and Relationships

a. Student opinion of CHEMRIC feedback

1. Most students (75 percent) felt that the length of the CHEMRIC explanations was about right. The hypothesis that there is no relationship between student opinion of the length of the CHEMRIC explanations and mathematics proficiency or achievement in chemistry cannot be rejected on the basis of correlations with pretest performance or numerical course grade. There was some indication, however, that the poorer students found the explanations too short (see Tables 14 and 15). This is quite interesting in light of the results of the pilot study (see Chapter III, Tables 2 and 3) which indicated that the students who received a relatively large amount of CHEMRIC feedback benefitted less from the system than the
students who received a smaller amount of information.

2. More than 90 percent of the students found the reading level of the explanations to be either appropriate or too easy. The hypothesis that there is no relationship between student opinion of the reading level of the CHEMRIC explanations and mathematics proficiency or achievement in chemistry is not rejected. It should be pointed out, however, that there was a consistent, although not usually significant, positive relationship between opinion of the "easiness" of the reading level and achievement with respect to both the pretest and the final numeric course grade. The importance of setting the reading level of materials at a low level (Leith and Davis, 1968; Eigen and Feldhusen, 1964; Lankford, 1964; Noble, 1969a) was recognized before and during the development of CHEMRIC. Although there was a slight indication that some of the poorer students may have found the reading level too high, it would appear that it is sufficiently low.

3. More than 80 percent of the students rated the comprehensibility of the explanations average or above. The hypothesis that there is no relationship between student opinion of the comprehensibility of CHEMRIC explanations and mathematics proficiency or achievement is not rejected, but there was some indication that
the better students found the explanations easier to understand than did the students who scored lower on the pretest. The fact that comprehensibility was rated considerably lower than was reading level indicates that the explanations should be clarified somewhat. It was hoped that the meaningfulness of the explanations would be enhanced through the use of prequestions (Ausubel and Fitzgerald, 1962; Berlyne, 1966), postquestions (Pressey, 1950), and examples (Kersh, 1958). Perhaps one problem was that many students did not always understand the mathematical symbols used in the explanations.

4. Almost all students indicated that "usually" they understood the mathematical symbols in the explanations. Only about a fourth, however, said they "always" understood their meaning. The hypothesis that there is no relationship between student opinion concerning the comprehensibility of the mathematical symbols used in the explanations and mathematics proficiency or achievement in chemistry is rejected. Eight of nine correlations with pretest score were significant at $p < .01$, the ninth at $p < .05$. Two of nine correlations with the final numerical course grade were significant at $p < .01$, two more at $p < .05$, and several others approached statistical significance. Expressed understanding of mathematical symbols in explanations relates positively to mathematics
proficiency and to achievement in chemistry. The fact that students having the greatest need for remedial help had trouble understanding the mathematics symbols used in the explanations means that the explanations should be revised or some other provision should be made for those students to get the necessary information (Scandura, 1967).

b. Incentive conditions

Nearly seventy percent of the students indicated that they would have worked the CHEMRIC feedback problems even without an extrinsic incentive. Only ten percent felt that they would have needed more than a ten point incentive. The hypothesis that there is no relationship between the amount of incentive students estimate they would need to work the problems and mathematics proficiency or achievement is not rejected. No consistent relationship could be found between expressed need for incentive and mathematics ability or achievement. This indicates that neither the poorer nor the better students have a greater need for extrinsic incentives.

The hypothesis that there is no relationship between the amount of incentive students indicate they would need to work the CHEMRIC problems and whether or not they had received an incentive is not rejected. Students who had received the incentive had a slightly
greater tendency to say they would not have needed it than those who had not received the incentive, but the correlation was not significant at a high level of confidence.

In the early planning stages of this study one question which was raised concerned how much of an extrinsic incentive would be required to make a difference. A review of the relevant literature was helpful only to the extent of indicating that the effect of incentives varies with the situation and the subjects (Bower, Boyer, and Sheirer, 1970). Under certain circumstances and with certain individuals specific extrinsic incentives have been shown to have predictable positive effects (Cohen, 1967; Nichols, 1970; Nesselroad and Vargas, 1970), but in other situations (Almen and Joseph, 1968; Goodyear, 1969; Kimble, 1961) the same or similar incentives have been shown to have little or no effect. The situation in which CHEMRIC was used would appear to be one in which extrinsic incentive is not important. Perhaps a greater incentive would have made a difference, but the results of the questionnaire seem to support the choice of a ten point incentive, in that less than ten percent of the students indicated that they would have needed a greater incentive. The fact that nearly seventy percent said they would have used the CHEMRIC feedback with no incentive at all
might be interpreted as an indication of approval of the system.

c. Students' Rating of Mathematics Preparation

The hypothesis that there is no relationship between the students' rating of their high school mathematics preparation and their CHEMRIC pretest score is rejected (see Table 14). Of nine correlations, eight are significant at $p < .01$, and the ninth is significant at $p < .05$. The hypothesis that there is no relationship between the students' rating of their high school mathematics preparation and their final numerical course grade is not rejected. It would appear that a relationship may exist but not have been detected, however, in that while only four of nine correlations (see Table 15) are significant at $p < .05$, all nine are positive and approach significant levels.

The high correlations between the students' self ratings of their mathematics background with pretest scores might be attributed to the fact that they had knowledge of their pretest scores. The fact that the correlations with the final numerical course grade were not as high as those with the pretest might be attributed to the confounding influence of the many variables other than mathematics preparation which entered into the determination of the final grade in the course.
Prediction of Final Course Grades by Pretest Scores

The hypothesis that there is no difference in the prediction of final course grades by a self-evaluative pretest and an objective pretest is not rejected, although the objective pretests rather consistently gave higher correlations. All but one of the nine correlations (see Table 16) were significant, the only exception involving the group in Lecture Section A who used the self-evaluative form and received no incentive.

The results, although not statistically significant, indicate that objective pretest scores are better predictors (see Tables 16 and 17) of final course grades than are self-evaluative pretest scores. There are at least two possible explanations for this:

1. Perhaps the students who used the self-evaluative form could not do a good job of evaluating their mathematics proficiencies and deficiencies or were not honest.

2. Perhaps the students who used the self-evaluative form were more affected by CHEMERIC: in a sense, a lower correlation for the self-evaluative form could indicate that more of these students had benefitted from CHEMERIC than those who had used the objective form. This explanation would receive support from the experimental research, in which the self-evaluative approach was associated with
CONCLUSIONS AND IMPLICATIONS OF THE EXPERIMENTAL RESEARCH

Hypothesis I

The hypothesis that there are no significant differences in the effects of an objective diagnostic pretest and a self-evaluative diagnostic pretest on achievement is not rejected. In Substudy A (see Tables 20 and 22) differences, while not sufficiently significant ($p < .10$) for rejection of the null hypothesis, were found favoring the use of the self-evaluative form when the criteria were performance on the quantitative portions of both the First Midquarter Examination and the Final Examination. Coupled with the fact that the self-evaluative pretest scores correlated less well with final numeric course grade (see Table 17) than did the objective pretest scores, this finding may have more meaning. If it is true that the self-evaluative approach was superior to the objective approach, this evidence would support those (Mager and Clark, 1963; Campbell and Chapman, 1965; Smith, 1971) who advocate an increased role for students in instructional decision-making. Substudy B (see Tables 24 and 26) neither supported nor refuted the findings of Substudy A. The results of Substudy C (see Tables 28 and 30) gave differences slightly better achievement.
approaching statistical significance, but even weaker than those observed in Substudy A. It should be noted, however, that, in the three substudies, whenever differences were statistically significant, or came close to significance, the self-evaluative approach was favored.

**Hypothesis II**

The hypothesis that there are no significant differences in the effects of an extrinsic incentive and no extrinsic incentive to work \textbf{CHEMRIC} problems on achievement is not rejected. No evidence was found indicating any effect of incentive to work the \textbf{CHEMRIC} problems on either qualitative or quantitative achievement in Chemistry. The fact that incentive could not be shown to have any effect is surprising. If the questionnaire finding that seventy percent of the students said they would have needed no incentive to use \textbf{CHEMRIC} is a true reflection of the students' attitudes, this would help to explain the lack of effect. Although this finding might be thought to conflict with the results of many studies (Nichols, 1970; Cohen, 1967; Nesselroad and Vargas, 1970) which found incentives to have significant positive effects, it should be noted that other studies (Sullivan, Baker and Schutz, 1967; Almen and Joseph, 1968) have found little or even negative (Kimble, 1961) effects. The work
of Premack (1970) with the relative nature of reinforcement suggests that the use of a common incentive (ten points) for all students may have resulted in different effects on different individuals. Thus, some students may have done better, but their increases may have been offset by others who were affected negatively. It appears that the conclusion of Bower, Boyer and Scheirer (1970) that the effect of incentives may be generalized only to very specific situations and individuals, may be true. The situation in which CHEMRIC was used seems to be one where the presence or absence of extrinsic incentive is irrelevant.

**Hypothesis III**

The hypothesis that there are no significant interactions in the effects of the type of pretest experience (self-evaluative/objective) and the incentive conditions (incentive/no incentive) on achievement is not rejected. In Substudy A, a possibility of interaction was observed on the quantitative questions on the Final Examination, but no interactive effects were observed elsewhere.

**RECOMMENDATIONS FOR FUTURE STUDY**

1. The different patterns of responses to the two forms of the CHEMRIC pretest (see Table 10) and the higher correlations between the objective form and the final course grade (see Table 16)
suggest the need for further research to determine the relative validity of a self-evaluative and an objective pretest, with respect to describing students' actual proficiencies and deficiencies.

2. A third form of the CHEMRIC diagnostic pretest, incorporating both objective and self-evaluative features, should be prepared, and the responses to it compared to those resulting from the other two forms.

3. The pilot study found that students having above average proficiency in mathematics benefitted more from CHEMRIC than did those having below average proficiency. It is recommended that further studies comparing the effects of CHEMRIC on these and other strata of the population be carried out.

4. The review of the literature revealed that inclusion of a student's first name in the feedback should have a positive effect (Schoen, 1971). This feature was not incorporated into CHEMRIC at the time of the study, but was put in at a later date. It might be worthwhile to examine the effect, if any, of including the first name.

5. This study did not examine the effect of CHEMRIC on professors or teaching assistants, except in an informal fashion. It would be useful to find out how it was used by and how valuable it was for the teaching staff.
6. Since it has been demonstrated that a system like CHEMRIC can be implemented at a very low cost (approximately ten cents per student) it would seem reasonable to consider the use of such a system to provide feedback for quizzes or midquarter examinations in the course.
APPENDIX A

1. CHEMRIC PL/1 PROGRAM LISTING
2. CHEMRIC PL/1 PROGRAM FLOWCHART
3. CHEMRIC SAMPLE PRINTOUT FOR STUDENT
ANNIE: /* by EBLIN FOR MARCUS TO PROVIDE FEEDBACK TO PHSUPERSONS */
/* CORE USAGE IS OPTIMIZED BY ALLOCATION OF CORE FOR EACH */
/* MESSAGE AS IT IS READ IN. */
PROC OPTIONS(MAIN):
DECLARE ARROW(100)POINTER;
DECLARE BLANKCARD CHARACTER(72)STATIC INITIAL(' ');
DECLARE ENDING CHARACTER(1000)VARYING;
DECLARE HEADER CHARACTER(1000)VARYING;
DECLARE INPUT CHARACTER(72);
DECLARE KEY CHARACTER(72);
DECLARE LINE CHARACTER(72)STATIC INITIAL(' ');
DECLARE MESSAGE CHARACTER(3000) VARYING;
DECLARE MIDDLE CHARACTER(1000)VARYING;
DECLARE RESPONSE CHARACTER(LL_REFER(L)) INITIAL(' ');
DECLARE SCORECARD CHARACTER(17);
DECLARE TEXT CHARACTER(17);
ON CONVERSION C NCHAR='6';
ON ENDFILE(SYSIN)BEGIN;
EXECUTION TERMINATED NORMALLY BY END OF FILE ON SYSIN*;
READ RESPONSE=0;
READ_RESPONSE:
RESPONSE_NUMBER=RESPONSE_NUMBER+1;
GET EDIT(KEY)(COLUMN(1), A(3))COPY;
IF KEY='**' THEN GO TO READ_KEYCARD;
MESSAGE=MESSAGE || INPUT;
END:
GET EDIT(INPUT)(COLUMN(1), A(72))COPY;
IF INPUT=BLANKCARD THEN GO TO GETMAIN;
MESSAGE=MESSAGE || INPUT;
GO TO LOOP1;
GETMAIN:
  LL=LENGTH(MESSAGE);
  ALLOCATE REPLY;
  ARROW(RESPONSE_NUMBER)=PNTR;
  RESPONSE=MESSAGE;
  GO TO READ_RESPONSE;
READ_KEYCARD:
  GET EDIT(KEYCARD)(COLUMN(1),A(17),25 A(1));
  PUT EDIT(KEYCARD)(COLUMN(1),A(17),25 A(1));
NITTY GRITTY:
  GET EDIT(SCORECARD)(COLUMN(1),A(17),25 A(1));
  PUT PAGE EDIT(SCORECARD)(A);
  PUT EDIT(LINE2)(COLUMN(1),A(72));
  DO I=1 TO 25:
    IF KEYANSWERS(I)+ANSWERS(I)=5 THEN R_W(I)="R"; ELSE R_W(I)="W";
  END;
  PUT EDIT((R_W(I) DO I=1 TO 24))COLUMN(1),24 (X(2),A(1));
  PUT EDIT(LINE4)(COLUMN(1),A(2));
  PUT EDIT(R_W(25))(COLUMN(1),X(1),A(1));
  PNTR=ARRROW(R_W);
  HEADER=PNTR->RESPONSE;
  PUT SKIP LIST(HEADER);
LOOP2:
  DO I=1 TO 6;
    J=I+8;
    K=J+8;
    NERROR=1;
    IF R_W(I)="R" THEN NERROR=NERROR+4;
    IF R_W(J)="R" THEN NERROR=NERROR+2;
    IF R_W(K)="R" THEN NERROR=NERROR+1;
    RESPONSE_NUMBER=(I-1)+*4+NERROR;
    PNTR=ARRROW(RESPONSE_NUMBER);
    MESSAGE=PNTR->RESPONSE;
    PUT SKIP LIST(MESSAGE);
  END LOOP2;
  IF R_W(25)="W" THEN RESPONSE_NUMBER=65;
  ELSE RESPONSE_NUMBER=66;
  PNTR=ARRROW(RESPONSE_NUMBER);
  MESSAGE=PNTR->RESPONSE;
  PUT SKIP LIST(MESSAGE);
  PNTR=ARRROW(93);
  MIDDLE=PNTR->RESPONSE;
```plaintext
PUT SKIP LIST(MIDDLE);
LOOP3:
DO I = 1 TO 25;
IF R_W(1)='R' THEN GO TO NEXT_QUESTION;
RESPONSE_NUMBER=I+66;
PNTR=ARRW(RESPONSE_NUMBER);
MESSAGE=PNTR->RESPONSE;
PUT SKIP LIST(MESSAGE);
NEXT_QUESTION:
END LOOP3;
PNTR=ARRW(94);
ENDING=PNTR->RESPONSE;
PUT SKIP LIST(ENDING);
GO TO NITTY GRITTY;
END_OF_PROC;
END;
```
CHEMRIC PROGRAM FLOWCHART

VARIABLES

1. RSPNS - Counter used to number items (subscripted variables) in arrays.

2. KEY - Array of correct answers to pretest.

3. KEYCARD - Card containing KEY information

4. INPUT - Card deck comprising all of the SETs.

5. BLANK CARD - Delimiter between SETs.

6. MESSAGE - Concatenation of INPUT into SETS

7. SET - Array of 66 MESSAGES

8. STUDENT CARD - Card containing identification and pretest responses for an individual student.

9. LINE 2 - Character string of digits (1-24) corresponding to pretest item numbers.

10. KEY ANS - Correct answer to particular pretest item (given on KEY)

11. STUDENT ANS - Student's answer to particular item on pretest. If \( \text{KEY ANS} + \text{STUDENT ANS} = 5 \), answer is judged correct by program.

12. ANS - Array containing evaluated student answers.

13. NERROR - Binary-based counter used to determine which SETs will be printed out for a given student.

14. HEADING, MIDDLE, ENDING - Messages printed out in the feedback for all students, supposedly from the professor.
STUDENT-CARD

STUDENT-CARD

ANSWER NO. (LINE 2)

\( I = 1 \)

\( I = I + 1 \)

\( I \leq 25 \)

NO

\( I = 1, 24 \)

ANS \((I)\) — RITE

YES

TEST — KEY-ANS + STUDENT-ANS

ANS \((I)\) — RONG

NO

125

(LINE 4)

ANS(25)

HEADING

III
\begin{align*}
I &= 1 \\
I &= I + 1 \\
I \leq 8 &\quad \text{NO} \\
&\quad \text{IV} \\
\text{YES} \\
J &= I + 8 \\
K &= J + 8 \\
\text{NERROR} &= 1 \\
\text{ANS}(I) &= \text{RITE} \\
\text{NO} \\
\text{ANS}(I) &= \text{RITE} \\
\text{NO} \\
\text{ANS}(I) &= \text{RITE} \\
\text{NO} \\
\text{NERROR} &= \text{NERROR} + 1 \\
&\quad \text{YES} \\
\text{NERROR} &= \text{NERROR} + 2 \\
&\quad \text{YES} \\
\text{NERROR} &= \text{NERROR} + 4 \\
&\quad \text{YES} \\
\text{NERROR} &= \text{NERROR} + 4 \\
&\quad \text{NO} \\
\text{NUM} &= \frac{I-1 \times 8 + \text{NERROR}}{} \\
\text{SET(NUM)} \\
2
\end{align*}
ANS(25): RITE

Y E S

NUM ← 66

NUM ← 65

SET(NUM)

MIDDLE

I = 1
I = I + 1

I ≤ 25

ANS(I): RITE

PROBLEM(I)

ENDING

EOD

STOP

PROBLEM(I)

STOP

I = 1

I = I + 1

I ≤ 25

YES

NO
DEAR CHEMISTRY STUDENT,

THE PRETEST YOU TOOK RECENTLY HAS BEEN ANALYZED AND WE HAVE IDENTIFIED A NUMBER OF WEAKNESSES IN YOUR MATHEMATICAL PREPARATION. IT SHOULD BE POSSIBLE, HOWEVER, TO TAKE CARE OF YOUR DEFICIENCIES IF YOU WILL GO THROUGH THE FOLLOWING EXPLANATIONS AND TRY TO SOLVE THE PROBLEMS GIVEN.

YOU SEEM TO KNOW THE PROPER ORDER IN WHICH TO EVALUATE MATHEMATICAL EXPRESSIONS, BUT YOU HAVE TROUBLE WHEN UNITS ARE INTRODUCED. REMEMBER THAT UNITS ARE MULTIPLIED AND DIVIDED IN THE SAME WAY AS NUMBERS. FOR EXAMPLE, (2CM)(2CM)=4CM^2. CONSIDER THIS EXAMPLE:

\[ \frac{10 \text{ grams}}{5 \text{ moles}} = ? \]

\[ \frac{2 \text{ grams}}{5 \text{ moles}} \]

TO DIVIDE GRAMS BY GRAMS/MOLE, SIMPLY INVERT THE DIVISOR (GRAMS/MOLE), AND MULTIPLY.

\[ \text{THIS GIVES } \frac{2 \text{ grams}}{5 \text{ moles}} \times \frac{5 \text{ moles}}{2 \text{ grams}} = \text{5 moles} \]

THIS GIVES GRAMS/MOLE, WHICH GIVES MOLES FOR THE UNITS.

GRAMS

THUS, THE ORIGINAL EXPRESSION FINALLY SIMPLIFIES TO 5 MOLES.

YOU SHOULD REVIEW YOUR MULTIPLICATION OF FRACTIONS. SUPRISINGLY, YOU SEEMED TO HAVE NO TROUBLE WITH ADDITION OF FRACTIONS, WHICH I WOULD HAVE EXPECTED TO CAUSE YOU MORE TROUBLE THAN MULTIPLICATION.

IN MULTIPLYING FRACTIONS, FIRST CANCEL AS MUCH AS POSSIBLE, AND THEN MULTIPLY ACROSS THE NUMERATORS AND DENOMINATORS OF THE REDUCED FRACTIONS.

\[ \frac{21 \text{ cal}}{8 \text{ grams}} \times \frac{32 \text{ grams}}{1 \text{ ml}} \]

THERE IS THE SETUP, FOR EXAMPLE, CAN BE REDUCED TO

\[ \frac{3 \text{ cal}}{3 \text{ ml}} \times \frac{1 \text{ ml}}{1 \text{ ml}} \]

THE REASON FOR THIS IS THAT \( \frac{3}{3} = 1 \) AND \( \frac{1}{1} = 1 \). ALSO

\[ \frac{3 \text{ cal}}{1 \text{ ml}} \times \frac{1 \text{ ml}}{1 \text{ ml}} = \frac{3 \text{ cal}}{1 \text{ ml}} \]

THE UNITS CANCEL JUST AS IF THEY WERE NUMBERS. THE FINAL ANSWER IS

\[ \frac{3 \text{ cal}}{1 \text{ ml}} \]

IT IS OF COURSE

\[ \frac{3 \text{ cal}}{4 \text{ ml}} \]

BE SURE TO REVIEW DIVISION OF FRACTIONS. TO DIVIDE ONE FRACTION BY ANOTHER, THE BOTTOM FRACTION IS INVERTED, AND THEN THE FRACTIONS ARE MULTIPLIED AS USUAL. IN THIS PROBLEM

\[ \frac{2 \text{ grams}}{3 \text{ ml}} \]

\[ \frac{2 \text{ grams}}{3 \text{ ml}} \]

THE BOTTOM FRACTION IS INVERTED TO GIVE

\[ \frac{3 \text{ ml}}{2 \text{ grams}} \]

\[ \frac{3 \text{ ml}}{2 \text{ grams}} \]

THEN THE UNITS ARE CANCELLED AND THE MULTIPLICATION CARRIED OUT TO GIVE \( \frac{10}{9} \), WHICH IS EQUAL TO 1 1/9.

ALSO, BE SURE YOU CAN CONVERT A FRACTION TO PERCENT. TO DO THIS, DIVIDE THE NUMERATOR (TOP) BY THE DENOMINATOR (BOTTOM), AND MULTIPLY BY 100. FOR EXAMPLE, TO CONVERT 5/9 TO PERCENT, DIVIDE 5 BY 9 TO GET 0.555.

THEN, MULTIPLY BY 100, GIVING 62.5 PERCENT.
WHILE YOU APPEAR TO UNDERSTAND MULTIPLICATION OF DECIMALS AND HAVE LITTLE TROUBLE WITH DIVISION ITSELF, YOU SHOULD PRACTICE PLACEMENT OF THE DECIMAL POINT IN DIVISION OF DECIMALS.

TO FIND THE DECIMAL POINT IN A DIVISION PROBLEM,
FIRST MOVE THE POINT OVER ENOUGH PLACES IN THE DIVISOR TO MAKE IT A WHOLE NUMBER, AND THEN MOVE THE POINT OVER IN THE DIVIDEND THE SAME NUMBER OF PLACES. THIS WILL LOCATE THE DECIMAL POINT IN THE ANSWER. FOR EXAMPLE, IN DIVIDING 0.003627 BY 0.0001, FIRST CHANGE THE PROBLEM TO DIVIDING 362.7 BY 1000. THE ANSWER WILL WORK OUT TO BE 0.437.

NOTE THE USE OF ZERO AS A PLACEHOLDER (THE ANSWER IS NOT 0.43).

YOU MUST LEARN HOW TO EXPRESS DECIMALS IN SCIENTIFIC NOTATION AND ALSO HOW TO CONVERT FROM SCIENTIFIC NOTATION TO A DECIMAL. REMEMBER THAT (10 X 10 X 10) = 1000, AND 1/(10 X 10 X 10) = 0.001. ALSO, RECALL THAT MOVING A DECIMAL POINT 2 PLACES TO THE RIGHT IS THE SAME AS MULTIPLYING BY 10 X 10. IN ADDITION, MOVING THE POINT 2 PLACES TO THE LEFT IS THE SAME AS MULTIPLYING BY 1/10 X 10. IF WE MOVE THE DECIMAL POINT TWO PLACES TO THE LEFT AND ALSO MULTIPLY BY 10 X 10, THE VALUE OF THE NUMBER IS UNCHANGED. CONSIDER THESE EXAMPLES:

\[ 2.53 \times 10^2 = 253, \quad 2.53 \times 10^1 = 25.3, \quad 0.0253 = 2.53 \times 10^{-1}, \quad \text{AND} \quad 0.00253 = 2.53 \times 10^{-2}. \]

65,187 = 6.518 \times 10^4. YOU SHOULD ALSO LEARN HOW TO CONVERT FROM LOGARITHMIC NOTATION TO EXPONENTIAL NOTATION. THE BASE 10 LOG OF A NUMBER IS THE POWER TO WHICH 10 MUST BE RAISED TO GIVE THE NUMBER. Thus

\[ \log_{10} 100 = 2, \quad \text{AND} \quad \log_{10} 1000 = 3. \]

MULTIPLYING AND DIVIDING EXPRESSIONS CONTAINING NUMBERS WRITTEN IN SCIENTIFIC NOTATION Seems TO CAUSE YOU A GREAT DEAL OF TROUBLE. THE KEY THING TO REMEMBER IS THAT IN MULTIPLICATION, EXPONENTS ARE ADDED, AND THAT IN DIVISION, EXPONENTS ARE SUBTRACTED. FOR EXAMPLE,

\[ 12 \times 10^3 \times 10^2 = 12 \times 10^5 \]

BUT 12 X 10/10 X 10 = 12 X 10, THE SAME RULES APPLY WHEN MULTIPLYING FRACTIONS CONTAINING EXPONENTS.

EXCEPT THAT IT IS VALUABLE TO REMEMBER TO DO AS MUCH CANCELLATION AS POSSIBLE AT THE BEGINNING. THIS EXPRESSION:

\[ 23 \]

16.02 X 10 \text{ MOLECULES/2.24 X 10 LITERS}/(5.0 LITERS/5.0 X 10 ML) = ?

FOR EXAMPLE, CAN BE REDUCED TO

\[ \frac{23}{1} \]

16.02 \text{ MOLECULES/2.24 X 10 LITERS}/(10 /10 X 10)

WHICH BECOMES 2.7 X 10 \text{ MOLECULES/ML}. THE DECIMAL PORTION EQUALS

\[ (23-1-3) = 10 \]

2.7 AND THE EXPONENTIAL PORTION EQUALS 10.
It is very important that you improve your ability to manipulate simple algebraic equations. Summarize the material, and we will be done.

Sides by sides, giving PV = NR since the NR

Cancel the expression would give

\[ P \times V = N \times R \]

You should also be able to handle a problem such as this:

Pressure \( P = \frac{F}{A} \) ft/sq. in.

Temperature \( T = \frac{F}{A} + \frac{A}{10} \) ft/sq. in.

Potential \( E = \frac{V}{A} \) ft/sq. in.

Substituting in:

\[ P \times V = N \times R \]

Explain from the fact that \( F \) and \( A \) are equal, each other.

How and \( \Delta P = \frac{F}{A} \), multiplication of both sides by \( V \) will give

I think that you are having trouble with graphs. Look at this one:

\[ \Delta X = \Delta Y \]

The value of \( X \) when \( Y = 0 \) (the y-intercept)

**Note:** The slope \( m \) of a straight line

If \( m = \frac{\Delta Y}{\Delta X} \) then \( X = 0 \) and \( A \), i.e., \( Y = 1 \) or \( X \).

\[ \Delta Y = \Delta X \]

It appears that you know something about operations with negative numbers. Since you have been doing this, you will be returned to the margin. If somehow you felt I needed to go back...
THE ABOVE EXPLANATIONS SHOULD HELP YOU TO SOLVE THE FOLLOWING EXERCISES.
WORK OUT EACH PROBLEM USING THE INFORMATION GIVEN ABOVE.

IF THE EXPLANATIONS ARE NOT SUFFICIENT, FEEL FREE TO MEET WITH YOUR
RECITATION INSTRUCTOR, WHO WILL BE PLEASED TO HELP YOU.

NEXT WEEK THURSDAY, OCTOBER 5, 1972, TURN IN THE WORKED OUT PROBLEMS,
ALONG WITH THE QUESTIONS, TO EITHER YOUR LABORATORY OR RECITATION
INSTRUCTOR.

YOUR RECITATION INSTRUCTOR WILL GIVE YOU UP TO TEN POINTS FOR MAKING
A GOOD EFFORT.

A SAMPLE OF IRON HAD A MASS OF (7/4) KG. THE ATOMIC WEIGHT OF IRON
IS 55 17/20 GRAMS/MOLE. HOW MANY MOLES OF IRON ARE PRESENT IN THE
SAMPLE?

EXPRESS IN SCIENTIFIC NOTATION:

0.00000005341 GRAMS = ?

MULTIPLY:

(5.69 X 10^-3 ML) (12.44 X 10 GRAMS/ML) = ?

SOLVE THE FOLLOWING EQUATION FOR #: PV = NRT : N = ?

THREE DATA POINTS OBTAINED FROM A STRAIGHT LINE GRAPH HAD THE COORDINATES LISTED AT THE RIGHT. USING THIS
INFORMATION, OBTAIN THE SLOPE, Y-INTERCEPT, AND
EQUATION FOR THE LINE.

63.456 GRAMS - (0.6909 X 62.9261 GRAMS) = ?

(SIMPLIFY THIS EXPRESSION:
(300 DEG.K)(1740 TORR)(25 LITERS) = ?

(1760 TORR)(1296 DEG.K)

(17/4) MOL = ?

(21 5/8) MOLES/LITER

(SIMPLIFY THIS EXPRESSION:
12.3 ML X 2.54 MOLES/LITER = ?

0.9996 MOLES/LITER

-27

(7.0 X 10^-6 ERG-SEC) (7.0 X 10^-6 CM/SEC) = ?

2.1 X 10^-5 CM^2
IF 2.0000 LITERS OF A LIQUID HAVE A MASS OF 6.4000 GRAMS, WHAT WILL BE THE MASS OF 5.6000 LITERS OF THE LIQUID?

TWO MEASUREMENTS OF THE MASS AND VOLUME OF A SOLID SAMPLE GAVE THE FOLLOWING DATA: SAMPLE 1, MASS = 18 GRAMS, VOLUME = 6 ML.; SAMPLE 2, MASS = 27 GRAMS, VOLUME = 9 ML. WRITE A STRAIGHT LINE EQUATION CORRESPONDING TO THIS DATA. PLACE THE MASS MEASUREMENTS ON THE y-AXIS AND VOLUME MEASUREMENTS ON THE x-AXIS.

SIMPLIFY THIS EXPRESSION:
82 + 31(27 - 21)12/3 = ?

SIMPLIFY THIS EXPRESSION:
1.000 LITERS 2.44 ML. x = ? 1.000 WOLF

1.000 X 10 ML. 22.41 LITERS

SUPPOSE THAT IN THE LABORATORY YOU FOUND THE MOLAR VOLUME OF OXYGEN TO BE 21.8 LITERS, WHILE THE ACTUAL VALUE IS 22.4 LITERS. WHAT IS THE PERCENT ERROR IN YOUR MEASUREMENT?

THE PH OF A WATER SOLUTION IS A MEASURE OF THE DEGREE OF ACIDITY. IT IS APPROXIMATELY EQUAL TO -LOG [H+] IN THE SOLUTION.

IF THE H+ CONCENTRATION IN A SOLUTION IS 10 MOLES/LITER, WHAT IS THE PH OF THE WATER SOLUTION?

735 TORR 100 ML.

760 TORR/ATOMS 1000 ML./LITER = R SOLVE FOR R.

(10045 MOLES/298 DEG. K)

GIVEN: P V = NRT AND P V = NRT

FIND AN EXPRESSION RELATING P, V, AND T TO P, V, AND T.

USING A "SOLUBILITY VS. TEMPERATURE GRAPH" (P. 107 IN THE CHEM 121 LAB MANUAL OR P. 176 IN THE CHEM 101 TEXTBOOK), DETERMINE THE SOLUBILITY OF POTASSIUM NITRATE IN WATER AT A TEMPERATURE OF 60 DEGREES CELSIUS.

BE SURE TO WORK OUT THE ABOVE PROBLEMS AND TURN THEM IN NEXT WEEK THURSDAY FOR UP TO TEN POINTS CREDIT. WORK OUT THE ABOVE PROBLEMS AS SOON AS POSSIBLE. YOUR RECITATION INSTRUCTOR WILL BE HAPPY TO MEET WITH YOU IF YOU NEED EXTRA HELP.

SINCERELY YOURS,

YOUR CHEMISTRY PROFESSOR
APPENDIX B

1. SELF-EVALUATIVE FORM OF THE DIAGNOSTIC PRETEST

2. OBJECTIVE FORM OF THE DIAGNOSTIC PRETEST
1. Simplify: \[ 2 + 3(3 \times 10) = ? \]
   
   a) I am not completely sure about how to simplify an expression containing parentheses.
   
   b) I know how to simplify this kind of expression.

2. Add: \[ \frac{5}{9} + \frac{8}{27} + \frac{7}{18} = ? \]
   
   a) I could use some help with adding fractions.
   
   b) I would have no problem with solving this.

3. Divide: \[ \frac{\frac{1}{3} \text{ cal}}{\frac{1}{6} \text{ cal/°C}} = ? \]
   
   a) I am not completely sure about what the answer would be.
   
   b) I don't need any help with dividing fractions and keeping the units straight.

4. Multiply: \[ (0.020000) (777.770) = ? \]
   
   a) I am not absolutely sure about how to multiply numbers containing a decimal point.
   
   b) I understand how to multiply numbers containing decimal points completely.

5. Convert to scientific notation: \[ 81970.410 = ? \]
   
   a) I might not be able to do this one correctly.
   
   b) I don't need any help with this.
6. Multiply: \((5.0 \times 10^4) (3.0 \times 10^2) = ?\)
   
a) I am not sure whether or not I could do this one.
b) I understand completely how to multiply expressions containing exponents.

7. Solve for \(K\): \(E = \frac{hK}{\lambda}; K = ?\)
   
a) Sometimes I have problems with rearranging equations.
b) I very seldom have any trouble rearranging expressions like this.

8. If \(E\) is plotted on the \(y\)-axis and \(v\) is plotted on the \(x\)-axis, a straight line is obtained, having a slope of \(340\) and a \(y\)-intercept of \(-670\). The equation for this line is
   
a) I don't know for sure.
b) I would have no trouble writing this equation.

9. Simplify: \((300K/3) (4100K - 4000K) \sqrt{[100K (100K)]} = ?\)
   
a) I am not very sure I could simplify this expression correctly.
b) This would be very easy for me to do.

10. Multiply: \(\left(\frac{900 \text{ torr}}{720 \text{ torr}}\right) \left(\frac{3600 \text{K}}{300 \text{K}}\right) (400 \text{ ml}) = ?\)
    
a) Sometimes I have trouble multiplying fractional expressions when units are involved.
b) I am sure I could get this one right.
11. Divide: \[ \frac{\frac{1}{9} \text{gram}}{9 \text{gram/mole}} = ? \]

a) I could use some help with dividing fractions containing units.
b) I would have no trouble dividing this expression.

12. Divide: \( \frac{1.3467 \text{ grams}}{0.670 \text{ ml}} = ? \)

a) I am not absolutely sure my answer to this would be correct.
b) Long division of decimals is no problem for me, even when units are involved.

13. Convert to decimal form: \( 8.712 \times 10^{-3} = ? \)

a) I don't know how to do this.
b) I am sure I could change this expression to a decimal number.

14. Divide: \( \frac{6.0 \times 10^7 \text{ moles}}{3.0 \times 10^3 \text{ liters}} = ? \)

a) I could use help with dividing exponential expressions containing units.
b) I can do this with no trouble.

15. A liquid has a density of 3.00 grams/ml. What volume would be needed to give 1450 grams of the liquid?

a) I am not sure whether or not my answer to this would be right.
b) I could solve this one easily.
16. Plot the following data, draw the line, and calculate the slope of the line.

<table>
<thead>
<tr>
<th>Mass (grams)</th>
<th>Volume (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.00</td>
<td>2.00</td>
</tr>
<tr>
<td>14.00</td>
<td>4.00</td>
</tr>
<tr>
<td>21.0</td>
<td>6.00</td>
</tr>
</tbody>
</table>

a) I don't know how to do this.
b) I understand how to plot a graph and find the slope of the line very well.

17. Simplify: \((70/7.0 \text{ grams}) (5.0 \text{ grams}) (6.0 \text{ grams}) \quad (17.0 \text{ grams} - 12.0 \text{ grams}) = ?\)

a) I would not be very sure about my answer to this one.
b) I very seldom have any trouble with simplifying expressions like this.

18. Multiply: \((48.000 \text{ grams}) \left( \frac{1.0000 \text{ mole}}{32.000 \text{ grams}} \right) \left( \frac{22.414 \text{ liters}}{1.0000 \text{ moles}} \right) = ?\)

a) Multiplying fractions containing both decimals and units might cause me some trouble.
b) I am certain I could do a problem like this.

19. Convert to percentage: \((8/15) = ?\)

a) I might not be able to get this one correct.
b) I am sure I know how to convert a fraction to percent.
20. Divide: \( \frac{70052.802 \text{ ml}}{14.0100 \text{ ml}} = ? \)

a) Long division of numbers containing decimals and units is sometimes a problem for me.

b) I would have no difficulty in getting this one correct.

21. Find: \( \log_{10} \left( 10^{-3} \right) = ? \)

a) I don’t know how to convert a logarithm to a decimal or exponential expression.

b) I can handle this with no trouble.

22. Multiply: \( \frac{2.7 \times 10^3 \text{ ml}}{2.7 \times 10^4 \text{ ml}} \times \frac{2.4 \times 10^2 \text{ ml}}{1.2 \text{ liters}} = ? \)

a) I might have trouble with multiplying fractions containing both decimals and units.

b) I am sure I would get this one correct.

23. Given: \( P = \frac{K_1}{V} \) and \( V = K_2T \) Find: \( \frac{K_1}{K_2} = ? \)

a) Rearranging an expression like this sometimes causes me trouble.

b) I would have no problem finding the correct answer to this.

24. Refer to this phase diagram for a pure substance. If we start with the solid at 2.0 atmospheres pressure and 20°C, and gradually increase the temperature, holding pressure constant, what will happen?

a) I am not sure.

b) I am certain I would know what would happen.
The Ohio State University
Department of Chemistry
Autumn Quarter, 1972

Chemistry 101 Test

Form 08
1. Simplify: \( 2 + 3(5 \times 10) = ? \)
   a) 180
   b) 150
   c) 80
   d) 92
   c) none of the above

2. Add: \( \frac{5}{9} + \frac{8}{27} + \frac{7}{18} = ? \)
   a) \( \frac{20}{27} \)
   b) \( \frac{17}{63} \)
   c) \( \frac{67}{63} \)
   d) \( \frac{67}{65} \)
   e) none of the above

3. Divide: \( \frac{(1/3) \text{ cal}}{(1/6) \text{ cal/} \circ C} = ? \)
   a) \( (1/18) \circ C \)
   b) \( (1/9) \circ C \)
   c) \( 2 \circ C \)
   d) \( 18 \circ C \)
   e) \( (1/2) \circ C \)

4. Multiply: \( (0.020000)(777.770) = ? \)
   a) 1.5555\% 
   b) 0.1555\% 
   c) 0.001555\% 
   d) 15.555\% 
   e) none of the above

5. Convert to scientific notation: \( 81970.410 = ? \)
   a) \( 8.1970410 \times 10^{-4} \)
   b) \( 8.1970410 \times 10^{4} \)
   c) \( 8.1970410 \times 10^{5} \)
   d) \( 8.1970410 \times 10^{3} \)
   e) none of the above
6. Multiply: \((5.0 \times 10^4) (3.0 \times 10^5) = ?\)
   a) \(1.5 \times 10^9\)
   b) \(1.5 \times 10^{10}\)
   c) \(1.5 \times 10^{20}\)
   d) \(1.5 \times 10^5\)
   e) \(1.5 \times 10^{20}\)

7. Solve for \(K:\) \(E = \frac{hK}{\lambda}; K = ?\)
   a) \(Eh/\lambda\)
   b) \(Eh\lambda\)
   c) \(Eh\)
   d) \(Eh/\lambda\)
   e) none of these

8. If \(E\) is plotted on the y-axis and \(v\) is plotted on the x-axis, a straight line is obtained, having a slope of 340 and a y-intercept of -670. The equation for this line is
   a) \(E = 340v + 670\)
   b) \(E = 670v - 340\)
   c) \(E = 340v - 670\)
   d) \(E = 670v + 340\)
   e) none of these

9. Simplify: \((30^\circ K/3) (410^\circ K - 400^\circ K)/[(10^\circ K) (10^\circ K)] = ?\)
   a) 1.0
   b) 1/3
   c) 3.0
   d) 10.0

10. Multiply: \(\left(\frac{900 \text{ torr}}{720 \text{ torr}}\right) \left(\frac{360^\circ K}{300^\circ K}\right) (400 \text{ ml}) = ?\)
    a) 200 ml
    b) 400 ml
    c) 600 ml
    d) 480 ml
11. Divide: \( \frac{\frac{1}{2} \text{gram}}{9 \text{ gram/mole}} \) = ?

   a) \( \frac{1}{81} \text{ mole} \)
   b) \( \frac{1}{61} \text{ gram/mole} \)
   c) \( \frac{1}{51} \text{ gram}^2/\text{mole} \)
   d) \( \frac{1}{61} \text{ mole} \)

12. Divide: \( \frac{1.3467 \text{ grams}}{0.670 \text{ ml}} \) = ?

   a) 20.1 grams/ml
   b) 2.01 grams/ml
   c) 0.201 grams/ml
   d) 0.00201 grams/ml

13. Convert to decimal form: \( 8.712 \times 10^{-3} \) = ?

   a) 0.8712
   b) -8712
   c) 0.008712
   d) 0.0008712
   e) 87120.0

14. Divide: \( \frac{6.0 \times 10^2 \text{ moles}}{3.0 \times 10^3 \text{ liters}} \) = ?

   a) \( 2.0 \times 10^2 \text{ moles/liter} \)
   b) \( 2.0 \times 10^3 \text{ moles/liter} \)
   c) \( 2.0 \times 10^4 \text{ moles/liter} \)
   d) \( 2.0 \times 10^5 \text{ moles/liter} \)
   e) \( 2.0 \times 10^{-4} \text{ moles/liter} \)

15. A liquid has a density of 3.00 grams/ml. What volume would be needed to give 450 grams of the liquid?

   a) 150 ml
   b) 1350 ml
   c) 450 ml
   d) none of the above
16. Plot the following data, draw the line, and calculate the slope of the line.

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<tr>
<td>21.0</td>
<td>6.00</td>
</tr>
</tbody>
</table>

(Slope calculations:
- a) Slope = 7.0 grams/ml
- b) Slope = 0.0 grams/ml
- c) Slope = 3.5 grams/ml
- d) Slope = 2.0 grams/ml

17. Simplify: \( \frac{(70/7.0 \text{ grams}) (5.0 \text{ grams}) (6.0 \text{ grams})}{(17.0 \text{ grams} - 12.0 \text{ grams})} \) = ?
   
   - a) 60
   - b) 60 grams
   - c) 60 grams
   - d) 60 grams

18. Multiply: \( (48,000 \text{ grams}) \left( \frac{1,0000 \text{ mole}}{32,000 \text{ grams}} \right) \left( \frac{22.414 \text{ liters}}{1,0000 \text{ moles}} \right) \) = ?
   
   - a) 33.621 liters
   - b) 33.621 grams
   - c) 33.621 moles
   - d) 33.621 grams/mole
   - e) 33.621 liters/mole

19. Convert to percentage: \( (8/15) = ? \)
   
   - a) 80%
   - b) 70%
   - c) 60%
   - d) 56%
   - e) none of these

20. Divide: \( (70052.802 \text{ ml}) / (14.0100 \text{ ml}) = ? \)
   
   - a) 5000.2
   - b) 5020.0
   - c) 5200.0
   - d) 5002.0
21. Find: \( \log_{10} \left[10^{-5}\right] = ? \)
   a) -500
   b) 0.00005
   c) -5
   d) 5
   e) 10^{-5}

22. Multiply: \( \frac{5.4 \times 10^5 \text{ grams}}{2.7 \times 10^4 \text{ ml}} \times \frac{2.4 \times 10^3 \text{ ml}}{1.2 \text{ liters}} = ? \)
   a) 4.0 \times 10^3 \text{ grams/liter}
   b) 4.0 \times 10^4 \text{ grams/liter}
   c) 4.0 \times 10^5 \text{ grams/liter}
   d) 4.0 \times 10^6 \text{ grams/liter}
   e) 4.0 \times 10^9 \text{ grams/liter}

23. Given: \( P = K_1/\gamma \) and \( V = K_2T \) Find: \( K_1/K_2 = ? \)
   a) \( T/P \)
   b) \( P/T \)
   c) \( P\gamma/T \)
   d) \( PV/T \)
   e) none of the above

24. Refer to this phase diagram for a pure substance. If we start with the solid at 2.0 atmospheres pressure and 20°C, and gradually increase the temperature, holding pressure constant, what will happen?
   a) the substance will first vaporize and then liquefy
   b) the substance will first liquefy and then vaporize
   c) the substance will vaporize and not liquefy
   d) the pressure will increase until the triple point is reached, where solid, liquid and vapor will remain at equilibrium

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{phase_diagram.png}
\caption{Phase diagram for a pure substance.}
\end{figure}
25. Combine: \(-9 - (-27) = ?\)
   a) -36
   b) +18
   c) -18
   d) +36
APPENDIX C

1. ADMINISTRATION INSTRUCTIONS FOR CHEMRIC PRETESTS
   a) Self-Evaluative, Incentive Form
   b) Self-Evaluative, No Incentive Form
   c) Objective, Incentive Form
   d) Objective, No Incentive Form

2. INSTRUCTIONS TO STUDENT FOR CHEMRIC PRETESTS
   a) Self-Evaluative, Incentive Form
   b) Self-Evaluative, No Incentive Form
   c) Objective, Incentive Form
   d) Objective, No Incentive Form
CHIMIC PRETEST

ADMINISTRATION INSTRUCTIONS - FORM SH-INC.
(For recitation or lab instructors)

1. Pass out instruction sheets and answer sheets to the students as they arrive for recitation or a few minutes before they take the test in lab.

2. You should have some pencils and a plastic sharpener. Be sure the students use pencil only.

3. Write the section number for your section on the blackboard and announce it to the students several times as they fill out the answer sheet.

4. Pass out the booklets. Tell the students that they may write all over them in figuring our the problems, but you have to collect them at the end.

5. Read the following to the students: "Try each problem on the test. This should help you to decide whether or not you need help with that particular type of problem. Tomorrow you will get a set of explanations of how to do the problems you didn't understand on this pretest. Also, you will get some problems to solve between tomorrow and next week. You will get up to 10 points for working them out. Work them as soon as possible. If you need more help than is given in the explanations, see your recitation instructor. You should turn in your worked-out problems in either lab or recitation class, whatever you have, on Thursday, October 5."

6. Give them thirty to thirty-five minutes to work on the pretest. It is not a timed test, so if they need a little more time, give it to them.

7. When they finish, pick up the instruction sheets, answer sheets, and test booklets. Make sure the answer sheets are complete. We need last name and the section number only. The information must be blackened in in the columns for the computer to read it, so please check them over.

8. Separate the answer sheets, test booklets and information sheets into three piles, and put them back in the file folder.

9. In recitation or lab next week Thursday, pick up the worked-out problems. Recitation instructors will grade them as follows:
   0 - 5 points for a rather poor effort
   5 - 10 points for a better effort
   Make the average come out to 7.

Dr. Peterson's Sections - Use 10 points of your recitation subjective grade, and record this on the quiz card. Some of Dr. Peterson's sections will not get 10 points for these problems, but they will get 10 more points for their recitation subjective grade, so everyone will get the same total possible points overall.

Dr. Frey, Dr. Ouellette, and Mr. Batchelor's sections - Use 10 points of the laboratory subjective grade and record this on the lab card. Some of Mr. Batchelor's sections will not get 10 points for these problems, but they will get 10 more points from their laboratory instructor, so everyone will get the same total possible points overall. All of Dr. Frey's and Dr. Ouellette's students get the points.
CURIRICULUM PRETEST

ADMINISTRATION INSTRUCTIONS - FORM SB-NO INC
(For recitation or lab instructors)

1. Pass out instruction sheets and answer sheets to the students as they arrive for recitation or a few minutes before they take the test in lab.

2. You should have some pencils and a plastic sharpener. Be sure the students use pencil only.

3. Write the section number for your section on the blackboard and announce it to the students several times as they fill out the answer sheet.

4. Pass out the booklets. Tell the students that they may write all over them in figuring out the problems, but you have to collect them at the end.

5. Read the following to the students:
   "Try each problem on the test. This should help you to decide whether or not you need help with that particular type of problem. Tomorrow you will get a set of explanations of how to do the problems you said you didn't understand on this pretest. Also, you will get some additional problems to solve."

6. Give them thirty to thirty-five minutes to work on the pretest. It is not a timed test, so if they need a little more time, give it to them.

7. When they finish, pick up the instruction sheets, answer sheets, and test booklets. Make sure the answer sheets are complete. We need last name and the section number only. The information must be blackened in in the columns for the computer to read it, so please check them over.

8. Separate the answer sheets, test booklets and information sheets into three piles, and put them back in the file folder.

9. For your information:

   These students will not get 10 points for doing the problems which will come with the explanations tomorrow.

   None of Dr. Wojcicki's students will get the 10 points.

   Some of Dr. Peterson's and Mr. Batchelor's.

Other sections will get the points, but those, such as this one, which do not, will get 10 additional points from either their laboratory or recitation instructor later in the course.
CHEMRIC PRETEST

ADMINISTRATION INSTRUCTIONS - FORM OB-INC.
(For recitation or lab instructors)

1. Pass out instruction sheets and answer sheets to the students as they arrive for recitation or a few minutes before they take the test in lab.

2. You should have some pencils and a plastic sharpener. Be sure the students use pencil only.

3. Write the section number for your section on the blackboard and announce it to the students several times as they fill out the answer sheet.

4. Pass out the booklets. Tell the students that they may write all over them in figuring out the problems, but you have to collect them at the end.

5. Read the following to the students:

"Tomorrow you will get a set of explanations of how to do the problems you didn't understand on this pretest. Also, you will get some problems to solve between tomorrow and next week. You will get up to 10 points for working them out. Work them as soon as possible. If you need more help than is given in the explanations, see your recitation instructor. You should turn in your worked-out problems in either lab or recitation class, whatever you have, on Thursday, October 5."

6. Give them thirty to thirty-five minutes to work on the pretest. It is not a timed test, so if they need a little more time, give it to them.

7. When they finish, pick up the instruction sheets, answer sheets, and test booklets. Make sure the answer sheets are complete. We need last name and the section number only. The information must be blackened in the columns for the computer to read it, so please check them over.

8. Separate the answer sheets, test booklets and information sheets into three piles, and put them back in the file folder.

9. In recitation or lab next week Thursday, pick up the worked-out problems. Recitation instructors will grade them as follows:

- 0 - 5 points for a rather poor effort
- 5 - 10 points for a better effort

Make the average come out to 7.

Dr. Peterson's Sections - Use 10 points of your recitation subjective grade, and record this on the quiz card. Some of Dr. Peterson's sections will not get 10 points for these problems, but they will get 10 more points for their recitation subjective grade, so everyone will get the same total possible points overall.

Dr. Frey, Dr. Ouellette, and Mr. Batchelor's sections - Use 10 points of the lab instructor subjective grade and record this on the lab card. Some of Mr. Batchelor's sections will not get 10 points for these problems, but they will get 10 more points from their laboratory instructor, so everyone will get the same total possible points overall. All of Dr. Frey's and Dr. Ouellette's students get the points.
CHEMICAL PRETEST

ADMINISTRATION INSTRUCTIONS - FORM CH-NO INC

(For recitation or lab instructors)

1. Pass out instruction sheets and answer sheets to the students as they arrive for recitation or a few minutes before they take the test in lab.

2. You should have some pencils and a plastic sharpener. Be sure the students use pencil only.

3. Write the section number for your section on the blackboard and announce it to the students several times as they fill out the answer sheet.

4. Pass out the booklets. Tell the students that they may write all over them in figuring out the problems, but you have to collect them at the end.

5. Read the following to the students:

"Tomorrow you will get a set of explanations of how to do the problems you didn't understand on this pretest. If you wish, you may see your recitation instructor for more help."

6. Give them thirty to thirty-five minutes to work on the pretest. It is not a timed test, so if they need a little more time, give it to them.

7. When they finish, pick up the instruction sheets, answer sheets, and test booklets. Make sure the answer sheets are complete. We need last name and the section number only. The information must be blackened in in the columns for the computer to read it, so please check them over.

8. Separate the answer sheets, test booklets and information sheets into three piles, and put them back in the file folder.

9. For your information:

These students will not get 10 points for doing the problems which will come with the explanations tomorrow.

None of Dr. Wojcicki's students will get the 10 points.

Some of Dr. Peterson's and Mr. Batchelor's.

Other sections will get the points, but those, such as this one, which do not, will get 10 additional points from either their laboratory or recitation instructor later in the course.
This test is designed to help you to tell us about what kind of help you need in order to handle the mathematical parts of the Chemistry 101 course. Try to work out each exercise, and, using the responses provided, indicate whether or not you could use any help with that kind of problem. Very soon you will be given a sheet which will show you how to do the kinds of problems you said you didn't understand. Also, you will be asked to work out some exercises for which you will be given up to ten points. This test, itself, will not be used for grading purposes, but it is important to be honest and careful.

INSTRUCTIONS FOR FILLING OUT ANSWER SHEET

1. Use pencil only - NOT INK!

2. Starting at the far left of the place for your last name, fill in your name in the boxes, and blacken the appropriate letters under each letter in your name.

3. Fill in your first name, again starting at the far left in the space for your first name, and blacken the appropriate letters under each letter.

4. MI means "middle initial"

5. Section Number - Your recitation or lab instructor will tell you this number. Please fill it in and, again blacken in the appropriate numbers in each column.

6. You will be given thirty-five minutes to do this test, which should be plenty of time.

(TURN IN THIS SHEET WITH YOUR TEST BOOKLET AND ANSWER SHEET)
This test is designed to help you to tell us about what kind of help you need in order to handle the mathematical parts of the Chemistry 101 course. Try to work out each exercise, and, using the responses provided, indicate whether or not you could use any help with that kind of problem. Very soon you will be given a sheet which will show you how to do the kinds of problems you said you didn’t understand. Also, you will be given several exercises which will help you to see if you understand the explanations. This test will not be used for grading purposes, but it is important to be honest and careful.

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LECRER
RECRATION OR LAB ROOM NO.
RECRATION OR LAB INSTRUCTOR.
CALL NUMBER

This test is designed to help us provide you with help you may need with the mathematical parts of the Chemistry 101 course. Very soon you will be given a sheet which will show you how to do the kinds of problems you had trouble with on this test. You will also be asked to work out some exercises for which you will be given up to ten points. This test, itself, will not be used for grading purposes, but it is important to try your best.

INSTRUCTIONS FOR FILLING OUT ANSWER SHEET

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6. You will be given thirty-five minutes to do this test, which should be plenty of time.

(TURN IN THIS SHEET WITH YOUR TEST BOOKLET AND ANSWER SHEET)
LEC TU R ER
RECITATION O R  LAB ROOM NO. _________________
RECITATION O R  L A B  IN STRU CTO R ________________________
CALL NUMBER ________________________

CHEMRIC
Diagnostic Pro test
Instruction Sheet (Form OB, NO INC.)

This test is designed to help us provide you with help you may need with
the mathematical parts of the Chemistry 101 course. Very soon you will be
given a sheet which will show you how to do the kinds of problems you had
trouble with on this test. You will also be given several exercises which
will help you to see if you understand the explanations. This test will not
be used for grading purposes, but it is important for you to try your best.

INSTRUCTIONS FOR FILLING OUT ANSWER SHEET

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2. Starting at the far left of the place for your last name, fill in your name
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Please fill it in and, again blacken in the appropriate numbers in each
column.

6. You will be given thirty-five minutes to do this test, which should be
plenty of time.

(TURN IN THIS SHEET WITH YOUR TEST BOOKLET AND ANSWER SHEET)
APPENDIX D

FIRST MIDQUARTER EXAMINATIONS

1. Lecture Section A - Mr. Batchellor
2. Lecture Section B - Dr. Ouëllette
3. Lecture Section C - Dr. Wojcicki
4. Lecture Section D - Dr. Frey
R.W. Hatchellor
Chemistry 101
Autumn Quarter 1972
FIRST MIDQUARTER EXAMINATION
Monday, October 30, 1972
6:30 PM

Name__________________________Lab Instructor___________
(last) (first) Recitation Instructor___________

Instructions for filling out information on examination answer sheets.

1. Students must use pencil only -- NOT INK!
2. Fill in last name, starting at far left, and block in the appropriate letters under each letter in the name.
3. Fill in first name, again starting at the far left in the space allocated to first name, and block in the appropriate letters.
4. MI means "middle initial".
5. SECTION NUMBER -- Refer to the list below to find your number according to your lab section. Again, it is necessary to blacken in the spaces below the numbers.

<table>
<thead>
<tr>
<th>LAB INSTRUCTOR</th>
<th>NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rothlein</td>
<td>00101</td>
</tr>
<tr>
<td>Morey</td>
<td>00102</td>
</tr>
<tr>
<td>Wood</td>
<td>00103</td>
</tr>
<tr>
<td>Brown</td>
<td>00104</td>
</tr>
<tr>
<td>Mackenzie</td>
<td>00105</td>
</tr>
<tr>
<td>Lackner</td>
<td>00106</td>
</tr>
<tr>
<td>Cipollo</td>
<td>00107</td>
</tr>
<tr>
<td>Mason</td>
<td>00108</td>
</tr>
<tr>
<td>Gallucci</td>
<td>00109</td>
</tr>
<tr>
<td>Rouse</td>
<td>00110</td>
</tr>
<tr>
<td>Friedl</td>
<td>00111</td>
</tr>
<tr>
<td>Poliz</td>
<td>00112</td>
</tr>
</tbody>
</table>

6. Check to see that there are 7 pages of questions (all legible).
8. You may tear off the periodic table and use the back for calculations.
9. At the end of the exam time, turn in the answer sheet. Keep the exam booklet and bring it to your next recitation.
R.W. Batchelor
MQ 1

Each of the 30 questions is worth 7 points. Read each question carefully and choose the one best answer for each and mark that answer in pencil on your answer sheet. Do not spend too much time on any one question. Good luck.

1. Which of the following is not an intrinsic property?
   a. mass  b) weight  c. volume  d. shape  e. none of the preceding are intrinsic properties

2. How many millimeters in 1.00 kilometers?
   a. \(10^5\)mm  b. \(10^6\)mm  c. \(10^3\)mm  d. \(10^4\)mm  e. none of these

3. A typical furnace may provide 10,000 BTU's of energy. What is this in ergs?
   (1.00 BTU = 250 calories; 1 cal = \(4.180 \times 10^7\) ergs)
   a. \(1.05 \times 10^8\) ergs  b. \(5.95 \times 10^{-1}\) ergs  c. \(1.60 \times 10^{12}\) ergs  
   d. \(4.2 \times 10^{14}\) ergs  e. none of these

4. Which of the following changes would be exothermic?
   a. converting water to steam  b. burning coal  
   c. melting ice  d. more than one of these  
   e. none of these

5. Consider a bullet which is shot from a gun directed straight upward. As the bullet rises its
   a. kinetic energy increases - potential energy increases  
   b. kinetic energy increases - potential energy decreases  
   c. kinetic energy decreases - potential energy decreases  
   d. kinetic energy decreases - potential energy increases  
   e. kinetic energy changes - potential energy remains constant

6. A 40.0 gram sample of calcium carbonate (CaCO₃) consists of 4.8 grams C and 19.2 g O. What is the percent of Ca in the CaCO₃?
   a. 40%  b. 19.2%  c. 16.0%  d. insufficient information to calculate  
   e. none of these
7. How many different compounds of N and O are there among these samples?

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Mass N</th>
<th>Mass O</th>
<th>Total Mass of Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.4 grams</td>
<td>3.2 grams</td>
<td>4.6 grams</td>
</tr>
<tr>
<td>2</td>
<td>0.7 grams</td>
<td>0.8 grams</td>
<td>1.5 grams</td>
</tr>
<tr>
<td>3</td>
<td>2.8 grams</td>
<td>4.8 grams</td>
<td>7.6 grams</td>
</tr>
<tr>
<td>4</td>
<td>2.8 grams</td>
<td>6.4 grams</td>
<td>9.2 grams</td>
</tr>
<tr>
<td>5</td>
<td>1.4 grams</td>
<td>1.6 grams</td>
<td>3.0 grams</td>
</tr>
</tbody>
</table>

a. 1  b. 2  c. 3  d. 4  e. 5

8. Which of the following laws is illustrated in the data in question 7?

a. law of conservation of matter
b. law of definite composition
c. law of multiple proportions
d. all of these
e. none of these

9. What is the relative molecular mass of Ca(NO₃)₂?

a. 168 amu  b. 92 amu  c. 150 amu  d. 184 amu  e. none of these

10. What would be the relative atomic mass of oxygen if carbon was assigned a mass of 12.0 amu?

a. 16.0 amu  b. 40.0 amu  c. 64.0 amu  d. 48.0 amu  e. none of these

11. How many grams are represented by 2.00 moles of HCl?

a. 2.00 grams  b. 36.5 grams  c. 18.0 grams  d. 36.0 grams  e. none of these

12. How many Ca(OH)₂ units in 37.0 grams of Ca(OH)₂?

a. 3.01 x 10^{23} units  b. 6.02 x 10^{23} units  c. 12.04 x 10^{23} units
d. 1.63 x 10^{23} units  e. none of these

13. When steam is passed over hot iron, Fe₃O₄ is produced along with H₂ gas. Balance the equation for this reaction:

\[ \text{Fe} + \underline{\text{H}_2\text{O}} \rightarrow \underline{\text{Fe}_3\text{O}_4} + \underline{\text{H}_2}\]

What is the sum of all four of the coefficients in the balanced equation? (Be sure to include coefficients of 1 if present and use the smallest combination of whole number coefficients resulting in a balanced equation).

a. 6  b. 18  c. 10  d. 12  e. none of these
Boric acid, $\text{H}_3\text{BO}_3$, a weak acid and mild antiseptic sometimes used in medicine is commonly obtained by treating a hot solution of sodium tetraborate, $\text{Na}_2\text{B}_4\text{O}_7$, with sulfuric acid:

$$\text{Na}_2\text{B}_4\text{O}_7 + 5\text{H}_2\text{O} + \text{H}_2\text{SO}_4 \rightarrow \text{Na}_2\text{SO}_4 + \frac{4}{2}\text{H}_3\text{BO}_3$$

Use this equation to answer questions 14-16.

14. How many moles of $\text{Na}_2\text{B}_4\text{O}_7$ are required to produce 1.6 moles of $\text{H}_3\text{BO}_3$?
   a. 6.4 moles  
   b. 0.4 moles  
   c. 2.8 moles  
   d. 5.6 moles  
   e. none of these

15. How many grams of $\text{H}_3\text{BO}_3$ could be produced from 98.0 grams of $\text{H}_2\text{SO}_4$ and excess $\text{Na}_2\text{H}_4\text{O}_7$ and $\text{H}_2\text{O}$?
   a. 98.0 grams  
   b. 392 grams  
   c. 500 grams  
   d. 21.7 grams  
   e. none of these

16. How many grams of $\text{H}_3\text{BO}_3$ could be produced from a mixture of 198 grams of $\text{H}_2\text{SO}_4$, 198 grams of $\text{H}_2\text{O}$ and 60.8 grams of $\text{Na}_2\text{H}_4\text{O}_7$?
   a. 43.4 grams  
   b. 682 grams  
   c. 544 grams  
   d. 600 grams  
   e. none of these

17. The charge on the nucleus of an atom could be deduced from
   a. cathode ray tube experiments  
   b. oil drop experiment  
   c. mass spectrometer  
   d. metal foil type experiments

18. James Chadwick in his experiments that characterized the neutron in 1932 produced neutrons by using a mixture of beryllium and an alpha particle emitter (such as $^{212}\text{Pb}$). The reaction may be written:

$$^9\text{Be} + ^4\text{He} \rightarrow ? + ^1\text{H}_0$$

What other substance (?), besides the neutron ($^1\text{H}_0$) was produced?
   a. $^1\text{He}$  
   b. $^{20}\text{Ne}$  
   c. $^1\text{H}_0$  
   d. $^3\text{He}$  
   e. none of these

19. How many neutrons are found in $^{39}\text{K}$?
   a. 36  
   b. 93  
   c. 57  
   d. 129  
   e. none of these
20. A naturally occurring sample of an element has the following distribution of isotopes as indicated by mass spectrometry:

<table>
<thead>
<tr>
<th>Mass</th>
<th>Per Cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>116</td>
<td>14.24%</td>
</tr>
<tr>
<td>117</td>
<td>7.57%</td>
</tr>
<tr>
<td>118</td>
<td>24.01%</td>
</tr>
<tr>
<td>119</td>
<td>8.58%</td>
</tr>
<tr>
<td>120</td>
<td>32.97%</td>
</tr>
<tr>
<td>121</td>
<td>5.96%</td>
</tr>
</tbody>
</table>

What is the element?

a. Cd  b. In  c. Sn  d. Sb  e. Te

21. Consider the following energy level diagram for an atom:

Energy (ergs)

-0.900 x 10^{-12} \[5\]
-1.40 x 10^{-12} \[4\]
-2.40 x 10^{-12} \[3\]
-5.50 x 10^{-12} \[2\]
-21.8 x 10^{-12} \[1\]

What wavelength of light would be emitted by an electron dropping from level 5 to level 1? (\(h = 6.62 x 10^{-34}\) erg \cdot sec; \(C = 3.00 x 10^{10}\) cm/sec.)

a. 13.2 x 10^{-15} cm
b. 6.95 x 10^{-25} cm.

c. 3.31 x 10^{-29} cm.
d. 1.48 x 10^{-30} cm.
e. none of these
22. Which of these postulates of the Bohr Theory is not valid?
   a. electron in the hydrogen atom can have only certain energies
   b. associated with each allowed level is an orbit of definite radius.
   c. emission spectra is due to an electron dropping from a higher allowed
      level to a lower allowed level.
   d. all of these are valid.
   e. none of these are valid.

23. The fact that single lines in emission spectra are often 'split' into a
    number of fine lines if the spectra is taken in a magnetic field (Zeeman
    Effect) gives evidence for the existence of
   a. shells  b. subshells  c. orbitals  d. e/m ratio of electron
   e. e/m ratio of positive particles

24. How many electrons are needed to completely fill all the energy levels in
    the third shell?
   a. 8  b. 10  c. 18  d. 36  e. none of these

25. Which of the following is the proper electron configuration for 18P?
   a. 1s²2s²2p⁶3s²3p³
   b. 1s²2s²2p⁶3d⁵
   c. 1s²2s²2p⁶3s²3d³
   d. 1s²2s²2p⁶3s²3p⁵
   e. none of these

26. Consider the following electron configuration:
    1s²2s²2p⁶3s²3p⁶
    Which one(s) of these species would have that configuration?
   a. 10⁸⁺  b. 16Ar  c. 18K⁺  d. all of these  e. none of these

27. How many valence electrons are associated with 64Po?
   a. 4  b. 5  c. 6  d. 7  e. none of these

28. The reason the atomic radius increases among the representative elements
    within a period (horizontal row) as one goes from left to right can best be
    attributed to
   a. decreasing number of shells
   b. increasing nuclear charge
   c. shielding effect
   d. the radius doesn't increase from left to right, but from right to left
29. The ionization potentials for an atom increases from first, to second, to third, etc. There are usually large jumps in ionization potentials at certain points. For C we would expect to see a large jump in ionization energy for removal of the ________ electron.

a. 2  b. 3  c. 4  d. 5  e. 6

30. Which of the following elements would have the highest electronegativity?

a. Al  b. K  c. Ba  d. As  e. P
A PERIODIC CHART OF THE ELEMENTS
(BASED ON $^{12}$C)
Dr. Ouellette  
Chemistry 101  
Autumn Quarter 1972  
FIRST MIDQUARTER EXAMINATION  
Monday, Oct. 30, 1972  
6:30 - 7:30 PM

Name ___________________________ Lab Instructor ____________________________

INFORMATION FOR ANSWER SHEET

1. Use pencil only - not ink.

2. Your Last Name - Fill in last name, starting at left, and then blacken in the letters in the columns.

3. First Name - Fill in first name, starting at left, and then blacken in the letters in the columns.

4. MI - 'Middle Initial'

5. Section Number - Refer to the list below to find your section number. Again, blacken in the numbers in the columns.

6. Do not fill in: Student number, Sex, Date, Test Form

7. In the bottom, right corner, where it asks for INSTRUCTOR, please fill in your lab instructor's name.

<table>
<thead>
<tr>
<th>LABORATORY - INSTRUCTOR</th>
<th>SECTION NUMBER</th>
<th>LABORATORY - INSTRUCTOR</th>
<th>SECTION NUMBER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alligh - O'Shanick</td>
<td>00023</td>
<td>F - Fosnaugh</td>
<td>00029</td>
</tr>
<tr>
<td>Alm - De Luca</td>
<td>00024</td>
<td>G - Wright</td>
<td>00030</td>
</tr>
<tr>
<td>Blih - Chang-Frederick</td>
<td>00025</td>
<td>H - Manos</td>
<td>00031</td>
</tr>
<tr>
<td>Blow - Shallenberger</td>
<td>00026</td>
<td>J - Mutchler</td>
<td>00032</td>
</tr>
<tr>
<td>L - Crawford</td>
<td>00027</td>
<td>M - Kidwell</td>
<td>00033</td>
</tr>
<tr>
<td>K - Jung</td>
<td>00028</td>
<td>N - Weaver</td>
<td>00034</td>
</tr>
</tbody>
</table>

There are 40 questions on this examination. The scoring formula is number right times 5.

Place all answers on the multiple choice test sheet. Multiple (more than one answer for same question) answers will be graded as incorrect. Erase carefully if you change your answer.

The time limit is ONE HOUR.
1. An Angstrom unit is defined as \(10^{-10}\) cm. A micron is defined as \(10^{-6}\) m. What is the equivalent length in Angstroms of an object 1 millimicron long?
   a) 1     b) 10     c) 100     d) 0.1     e) 0.01

2. Liquid hydrogen boils at 20°K. What is the boiling point on the Fahrenheit scale?
   a) -901     b) -253     c) -422     d) -933     e) -454

3. Which of the following masses is the smallest?
   a) 50 pounds
   b) \(1.8 \times 10^8\) milligrams
   c) 1,500 grams
   d) 2 kilograms
   e) 600 ounces

4. It has been found experimentally that two elements X and Y combine to form several compounds. The data on the combining proportions of the elements are given below.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>g of X</th>
<th>g of Y</th>
<th>g of compound</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3.04</td>
<td>4.00</td>
<td>7.04</td>
</tr>
<tr>
<td>B</td>
<td>18.24</td>
<td>12.00</td>
<td>30.24</td>
</tr>
<tr>
<td>C</td>
<td>12.16</td>
<td>8.00</td>
<td>20.16</td>
</tr>
</tbody>
</table>

Using the key list given below, select the proper answer for questions 4 through 6.

4. Experiments A and B illustrate the
   a) law of conservation of mass
   b) definite proportions
   c) multiple proportions
   d) combining volumes

5. Experiments B and C illustrate the
   a) law of \(\ldots\)

6. Experiment B alone illustrates the
   a) law of \(\ldots\)

7. If a liquid whose density is \(3.4\) g/ml were used in the construction of a barometer, one atmosphere would support a column \(\ldots\) cm high. (The density of Hg is \(13.6\) g/ml)
   a) \(3.4\) \(\frac{76}{13.6}\)
   b) \(13.6\) \(\frac{76}{m}\)
   c) \(13.6\) \(\frac{76}{3.4}\)
   d) \(\frac{76}{13.6(3.4)}\)
   e) \(76(3.4)(13.6)\)
8. A one liter sample of a gas is heated from \(-73^\circ C\) to \(127^\circ C\) at constant pressure. What is the final volume of the gas in liters?
   a) 1  b) 2  c) \(\frac{1}{2}\)  d) \(\frac{1}{4}\)  e) 1/4

9. The pressure on a one liter sample of a gas is increased from 38 cm Hg to 2 atmospheres at constant temperature. What will be the volume of the gas in liters at 2 atmospheres?
   a) 1  b) 2  c) \(\frac{1}{2}\)  d) \(\frac{1}{4}\)  e) 1/4

10. A ten liter sample of a gas at \(-23^\circ C\) and 38 cm of Hg is heated to \(227^\circ C\) and the pressure is increased to one atmosphere. What is the volume of the gas in liters under the latter conditions?
    a) \(\frac{227 \times (38)}{76}\) 10  b) \(\frac{500 \times (28)}{500 \times (76)}\) 10  c) \(\frac{250 \times (38)}{76}\) 10  d) \(\frac{500 \times (76)}{250 \times (38)}\) 10
    e) none of the above is correct

11. A 200 ml sample of O2 at 2 atm and \(0^\circ C\) is transferred into a rigid one liter vessel containing H2 at 3 atm and \(0^\circ C\). What will be the total pressure (in atm) of the resulting mixture?
    a) 2.6  b) 0.4  c) 3.4  d) 5  e) none of the preceding is correct

12. Two liters of a diatomic molecule \(X_2\) combine with one liter of the diatomic molecule \(Y_2\) to yield one liter of a gas of the molecular formula \(\_ \_ \_ \_ \_ \_ \_ \_ \_ \_ \_ \) under identical conditions of pressure and temperature.
    a) \(XY\)  b) \(XY_2\)  c) \(X_2Y\)  d) \(X_4Y_2\)  e) \(X_2Y_4\)

13. Six liters of \(H_2\) combine with one liter of an element X to yield four liters of \(XH_3\) under the same conditions of pressure and temperature. What is the correct molecular symbol for the element X?
    a) \(X\)  b) \(X_2\)  c) \(X_3\)  d) \(X_4\)  e) none of the preceding is correct

14. The density of a diatomic gas at STP is 19 times that of the elemental form of hydrogen at STP. What is the molecular weight of the diatomic gas in amu?
    a) 19  b) 38  c) 19/2  d) 76  e) none of the preceding is correct

15. The density of a gas at STP is \(1.44 g/l\). What is the molecular weight of the gas in grams?
    a) \(\frac{1.44}{22.4}\)  b) \(\frac{22.4}{1.44}\)  c) \(22.4(1.44)\)  d) \(\frac{1.44}{22.4(22.4)}\)  e) none of the above is correct.
16. The density of CO at 2 atmospheres and 0°C is _____ g/L. The atomic weights of carbon and oxygen are 12 and 16 amu respectively.
   a) 2.5 b) 5.0 c) 1.25 d) 0.62 e) the answer cannot be calculated from the available information

17 - 21 Consider a 2.24 L sample of O₂ at 2 atm and 0°C and a 1.12 L sample of SO₂ at 1 atm and 546 K in answering the next five questions. Use the Key List below in answering questions 17 through 21. Answers may be used more than once. The molecular weights of O₂ and SO₂ are 32 and 64 amu respectively.

Key List

17. Which sample contains the largest number of molecules?
   a) O₂ b) SO₂ c) both are equal d) cannot be compared or calculated
18. Which sample contains the largest quantity of matter?
19. Which sample contains molecules with the highest average kinetic energy?
20. Which sample contains molecules with the highest average velocity?
21. Which sample would have the highest average kinetic energy at STP?

22. Thirty two grams of O₂ gas contain _______. (The atomic weight of O is 16 amu)
   a) 2(6.02 x 10²³) molecules of oxygen b) ½(6.02 x 10²³) molecules of oxygen
c) 6.02 x 10²³ molecules of oxygen d) 6.02 x 10²³ atoms of oxygen e) none of the above is correct

23. One molecule of oxygen has a mass of _____ g.
   a) 32 b) 16/6.02 x 10²³ c) 6.02 x 10²³/16 d) 32/6.02 x 10²³ e) 6.02 x 10²³/32

24. A sample of a substance containing 3.01 x 10²² molecules has a mass of 0.9 g. The molecular weight of the substance is ______ amu.
   a) 90 b) 45 c) 36 d) 18 e) 9

25. The rate of diffusion of helium is ⅓ times that of a gas X under the same conditions of pressure and temperature. What is the molecular mass of X in amu? The atomic mass of helium is 4 amu.
   a) 8 b) 16 c) 32 d) 64 e) 128
26. Pressure increases as the volume decreases in Boyle's law experiment because ____________________.
   a) the temperature increases.
   b) the energy of the particles increases.
   c) the average impact per collision increases.
   d) the number of collisions per unit area per unit time increases.
   e) none of the above is correct.

27. The number of particles possessing the average velocity in one mole of a gas at 100°C is ________ the number of particles possessing the average velocity for the same one mole at 500°C.
   a) less than  b) more than  c) the same as

28. Intermolecular attractive forces for a particular gas at 300°C are ______ the intermolecular attractive forces for the same gas at 150°C.
   a) greater than  b) less than  c) the same as

29. At 270 mm Hg water boils at 70°C. The vapor pressure of water at 80°C at 760 mm Hg is
   a) less than 270 mm Hg
   b) greater than 270 mm Hg
   c) 270 mm Hg
   d) insufficient information is given to answer the question

30. The molar heat of vaporization of most liquids are ______ to their boiling points in degrees Kelvin.
   a) directly proportional  b) inversely proportional  c) related in no way

31. The heat of vaporization of carbon bisulfide is 6.00 cal/mole. The normal boiling point in degrees Celsius is approximately ________.
   a) 32  b) 305  c) 75  d) 125  e) -15

32. The heat of vaporization of a liquid is 87 cal/g at its normal boiling point of 111°C. What is the molecular weight of the substance?
   a) $\frac{87 \times 111}{21}$  b) $\frac{21 \times 111}{87}$  c) $\frac{21(111)}{87}$  d) $\frac{304(21)}{87}$  e) $\frac{111(87)}{21}$

33. The heat capacity of a solid metal element is 0.72 cal/°C deg. What is the atomic mass of the element?
   a) 9.2  b) 6.9  c) 18.9  d) 44.6  e) 117.5
34. The number of calories required to change 1 gram of ice at 0°C to steam at 100°C is ______.
   a) 540  b) 620  c) 720  d) 960  e) none of the above is correct

35 - 38 Consider the heating curves for one gram each of substance A and B illustrated below. Use these curves to answer questions 35 through 38.

35. Which substance has the highest heat capacity in the liquid state?
   a) A  b) B  c) both are equal

36. Which substance has the largest heat of vaporization?
   a) A  b) B  c) both are equal

37. Which substance melts at the higher temperature?
   a) A  b) B  c) both are equal

38. The entropy change for melting for A is ______ the entropy change for vaporization.
   a) greater than  b) less than  c) equal to

39. An increase in pressure _____ the melting point of water.
   a) decreases  b) increases

40. The volume of 1g of a liquid X is less than the volume of 1g of the solid X. The melting point will _____ with increasing pressure.
   a) decrease  b) increase
Name___________________________________ Lab Instructor
(last) (first) Recitation Instructor

Instructions for answer sheet

1. Use pencil only — not ink.

2. Your Last Name - Fill in last name, starting at left, and then blacken in the letters in the columns.

3. First Name - Fill in first name, starting at left, and then blacken in the letters in the columns.

4. MI - 'Middle Initial' 

5. Section Number - Refer to the list below to find your section number. Again, blacken in the numbers in the columns.

6. Do not fill in: Student ANSWER, Sex, (Date), Test Form

7. In the bottom, right corner, where it asks for INSTRUCTOR, please fill in your lab instructor’s name.

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GENERAL DIRECTIONS

This examination consists of 33 multiple choice questions, the answers to which are to be placed on the answer sheet. There is only one best answer to each question. Correct answers will be worth six points each. A point will be deducted for every incorrect answer. 198 points constitute a perfect score.

Check that you have all 6 pages of the exam.

Time limit: 60 minutes
Dr. Wojciech

MQ 1

1. Liquid hydrogen boils at 20°K. What is the boiling point on the Fahrenheit scale?
   a) -901° b) -253° c) -422° d) -933° e) -454°

2. Which of the following masses is the smallest?
   a) 50 pounds b) 1.8 x 10⁶ milligrams c) 1,500 grams d) 2 kilograms e) 800 ounces

3. If a liquid whose density is 3.4 g/ml were used in the construction of a barometer, one atmosphere would support a column ___ cm high. The density of mercury is 13.6 g/ml.
   a) \( \frac{3.4}{13.6} \) (76) b) \( \frac{13.6}{3.4} \) (76) c) \( \frac{13.6}{13.6} \) (76) d) \( \frac{76}{13.6} \) (3.4) e) 76(3.4)(13.6)

4. A one-liter sample of a gas is heated from -73°C to 127°C at constant pressure. What is the final volume of the gas in liters?
   a) 1 b) 2 c) \( \frac{1}{2} \) d) 4 e) \( \frac{1}{4} \)

5. The pressure on a one-liter sample of a gas is increased from 38 cm of mercury to 2 atmospheres at constant temperature. What will be the volume of the gas in liters at 2 atmospheres?
   a) 1 b) 2 c) \( \frac{1}{2} \) d) 4 e) \( \frac{1}{4} \)

6. A ten-liter sample of a gas at -23°C and 38 cm of mercury is heated to 227°C and the pressure is increased to one atmosphere. What is the volume of the gas in liters under the latter conditions?
   a) \( \frac{227}{34} \) \( \frac{38}{76} \) \( \frac{10}{10} \) b) \( \frac{500}{250} \) \( \frac{38}{76} \) \( \frac{10}{10} \) c) \( \frac{250}{500} \) \( \frac{38}{76} \) \( \frac{10}{10} \) d) \( \frac{500}{250} \) \( \frac{38}{76} \) \( \frac{10}{10} \)

   e) none of the above is correct

7. A 200-ml sample of oxygen at 2 atm and 0°C is transferred to a rigid one-liter vessel containing hydrogen at 3 atm and 0°C. What will be the total pressure (in atm) of the resulting mixture?
   a) 2.6 b) 0.4 c) 3.4 d) 5 e) none of the preceding is correct
8-12 Consider a 2.24-liter sample of oxygen at 2 atm and 0°C and a 1.12-liter sample of sulfur dioxide at 1 atm and 54°C in answering the next five questions. Use Key List I in answering questions 8 through 12. Answers may be used more than once. The weights of individual particles (molecules) of oxygen and sulfur dioxide are 32 and 64 amu, respectively.

8. Which sample contains the larger number of particles?

9. Which sample contains the larger quantity of matter?

10. Which sample contains particles with the higher average kinetic energy?

11. Which sample contains particles with the higher average velocity?

12. Which sample would have the higher average kinetic energy at STP?

13. A sample of hydrogen is present in a closed two-liter container at 373°C and one atmosphere. The temperature of the container is then lowered to -240°C, the volume staying constant.

13. What pressure is predicted using Gay-Lussac's Law?

\[
\begin{align*}
    a) & \ \frac{373}{273} \ atm \\
    b) & \ \frac{240}{373} \ atm \\
    c) & \ \frac{33}{64} \ atm \\
    d) & \ \frac{64}{33} \ atm \\
    e) & \ \text{none of the preceding is correct}
\end{align*}
\]

14. However, the actual observed pressure will be

\[
\begin{align*}
    a) & \ \text{less than that calculated in No. 13.} \\
    b) & \ \text{higher than that calculated in No. 13.}
\end{align*}
\]

15. Gay-Lussac's Law is particularly invalid at

\[
\begin{align*}
    a) & \ \text{low temperature and low pressure} \\
    b) & \ \text{low temperature and high pressure} \\
    c) & \ \text{high temperature and low pressure} \\
    d) & \ \text{high temperature and high pressure}
\end{align*}
\]

16. The density of gas Q is 0.3 g/liter, and the density of gas R is 0.9 g/liter, both at STP.

16. What is the density of a 50:50 mixture by volume of Q and R at STP?

\[
\begin{align*}
    a) & \ 1.2 \ g/liter \\
    b) & \ 0.6 \ g/liter \\
    c) & \ \text{cannot be calculated} \\
    d) & \ \text{none of the above}
\end{align*}
\]

17. What is the density of a 50:50 mixture by mass of Q and R at STP?

\[
\begin{align*}
    a) & \ 1.5 \ g/liter \\
    b) & \ 0.6 \ g/liter \\
    c) & \ 0.45 \ g/liter \\
    d) & \ \text{none of the preceding}
\end{align*}
\]
18. When a liquid freezes it
   a) absorbs heat   b) evolves heat   c) becomes less viscous
   d) does so over a wide temperature range

19. A drop of liquid tends to assume special shape because of
   a) viscosity   b) Brownian movement   c) surface tension   d) diffusion
   e) none of the preceding

20. The phenomenon known as supercooling cannot occur if
   a) a crystal of the solid is added to a liquid at its freezing point.
   b) a mixture of liquids is used.
   c) the cooling is carried out very rapidly.
   d) the liquid being cooled is very pure.

21. When a certain gas is cooled, part of it condenses at -50°C and part at -90°C.
    One may conclude that
   a) the gas is a chemical compound.
   b) the gas is a heterogeneous mixture.
   c) the gas is a two-component homogeneous mixture
   d) none of the above is correct

22. Water boils at 100°C when the atmospheric pressure is 760 mm of mercury. When
    the atmospheric pressure is 800 mm of mercury, the boiling point of water will be
   a) also 100°C   b) less than 100°C   c) greater than 100°C

23. The temperature at which the vapor pressure of a liquid just equals the vapor
    pressure of its solid form is called
   a) critical point   b) boiling point   c) freezing point   d) surface tension
24. Which curve illustrates the distribution at a higher temperature for a given liquid?
   a) A    b) B

25. What is the energy of the largest number of particles at the temperature represented by graph A?
   a) F    b) G    c) C

26. How many grams of water at 40°C are necessary to condense 20 g of ice at 0°C without changing its temperature?
   a) 20    b) 40    c) 800    d) none of the above is correct

27. How many calories are required to change 5 g of ice at 0°C to steam at 100°C?
   a) 500    b) 3100    c) 3600    d) 2300

28. The mass of 6.02 x 10^{23} particles of chlorine is 71 g. What is the density of chlorine at STP?
   a) \frac{71(6.02 \times 10^{23})}{273(22.4)} g/l    b) \frac{71}{273(22.4)} g/l    c) \frac{71}{22.4(6.02 \times 10^{23})} g/l
   d) \frac{71}{22.4} g/l    e) none of the preceding is correct
29. The mass of $6.02 \times 10^{23}$ particles of neon is 20 g. What is the mass of each particle of neon?
   a) \( \frac{20}{6.02 \times 10^{23}} \) amu  
   b) 20 amu  
   c) \( 20 \times 6.02 \times 10^{23} \) amu  
   d) \( \frac{20 \times 6.02 \times 10^{23}}{22.4} \) grams  
   e) none of the preceding is correct

30. A certain gas at 273 K and 0.5 atm occupies 2.24 liters. How many moles of this gas are present?
   a) 0.1  
   b) 0.2  
   c) 0.05  
   d) 0.025  
   e) none of the preceding is correct

31. Equal volumes of gases at the same temperature and pressure contain equal masses of particles. Assuming that the gases are ideal, is this a correct statement?
   a) yes  
   b) no

32. Pressure increases as the volume of a gas decreases at a constant temperature because
   a) the energy of the particles increases.  
   b) the velocity of the particles increases.  
   c) the average impact per collision increases.  
   d) the number of collisions per unit area per unit time increases.

33. The vapor pressure of liquid A at 25°C is equal to that of liquid B at 50°C. If the molecular masses of A and B are identical
   a) intermolecular attractive forces are stronger in liquid A than B.  
   b) intermolecular attractive forces are stronger in liquid B than A.  
   c) the heat capacities of the two liquids are the same.  
   d) none of the above is correct
Dr. Frey
MTW 2:00
Chemistry 101
Autumn Quarter 197?
FIRST MIDQUARTER EXAMINATION

Monday
October 30, 197?
6:30 p.m.

Name ____________________________  Lab Instructor ____________________________
(last) ____________________________ (first) ____________________________
Signature ____________________________  Recitation Instructor ____________________________

Instructions for answer sheet

1. Use pencil only -- not ink.
2. Your Last Name -- Fill in last name, starting at left, and then blacken in
the letters in the columns.
3. First Name -- Fill in the first name, starting at left, and then blacken in
the letters in the columns.
4. MI -- "Middle Initial"
5. Section Number -- Refer to the list below to find your section number. Again,
brown in the numbers in the columns.
6. Do not fill in: Student number, Sex, Date, Test Form
7. In the bottom, right corner, where it asks for INSTRUCTOR, please fill in
your lab instructor's name.

LABORATORY-INSTRUCTOR  SECTION NUMBER  LABORATORY-INSTRUCTOR  SECTION NUMBER
F - Ramnarine  00011  F - Lee  00017
G - Brooks  00012  G - Wongnawa  00018
L - Zenisek  00013  P - Heasley  00019
H - Baldrich  00014  M - Munson  00020
J - Quan  00015  R - Edwards  00021
K - Lightmas  00016  N - Cardina  00022

GENERAL DIRECTIONS

This examination consists of 21 multiple choice items. The first 12 carry
a weight of 5 points each. The remaining are weighted at 10 points each. There
is only one correct response to each question. Mark only one response on the
answer sheet corresponding to your choice of the correct response. Items for which
you enter two marks on the answer sheet will be graded incorrect.

Heat of fusion of water is 80 cal/g
Heat of vaporization of water is 540 cal/g
Molar heat capacity for most metals is 6.2 cal/mole x deg
1. (5 pts.) A mathematical way of expressing Gay - Lussac's Law is:
   a. \( P = P_a \cdot P_b \)
   b. \( P \times T = k_n \)
   c. \( P_1V_1 = P_2V_2 \)
   d. \( P_2 = \frac{T_2P_1}{T_1} \)
   e. \( \frac{V_1}{T_1} = \frac{V_2}{T_2} \)

2. (5 pts.) The mass of an empty balloon is 5 grams. After being filled with helium the balloon floats away. It floats because:
   a. all hollow objects filled with helium float.
   b. the mass of the helium filled balloon is smaller than that of an equal volume of air.
   c. the helium filled balloon is lighter than the empty balloon.
   d. the density of air is less than the density of the helium filled balloon.
   e. a and c above

3. (5 pts.) Liquids differ from solids in that:
   a. there is attraction among atoms or molecules in solids but not in liquids.
   b. there is net translational motion of atoms or molecules in liquids but not in solids.
   c. there is vibrational motion of atoms or molecules in liquids but not in solids.
   d. they have vapor pressures but solids do not.
   e. a and d above

4. (5 pts.) At constant pressure the ratio \( V/T \) for an ideal gas is a constant. This is a statement of:
   a. Dalton's Law
   b. Gay - Lussac's Law
   c. Boyle's Law
   d. Graham's Law
   e. Charles Law

5. (5 pts.) Graham's Law of diffusion is \( r_1/r_2 = \sqrt{m_2/m_1} \). The density of \( O_2 \) gas is 1.429 g/L whereas that of \( N_2 \) is 1.251 g/L.
   a. \( O_2 \) gas diffuses more rapidly than \( N_2 \) gas under given conditions.
   b. the two gases diffuse at the same rate, as required by Avogadro's law.
   c. \( N_2 \) gas diffuses more rapidly than \( O_2 \) gas under given conditions.
   d. according to Dalton's Law the two gases diffuse at identical rates.
   e. none of the above
6. (5 pts.) The heat of fusion of a pure substance is:

a. the amount of heat released when a gram of the liquid solidifies at its melting point.
b. the amount of heat required to increase the temperature of a solid to just above its melting point.
c. the amount of heat required just to vaporize a pure liquid at its boiling point.
d. one way of estimating its molecular mass.
e. none of the above.

7. (5 pts.) According to Avogadro's hypothesis:

a. there are no attractive interactions among molecules or atoms of gases.
b. the ratio of densities for two gases is equal to the ratio of their rates of diffusion.
c. the ratio of densities for two gases should be equal to the ratio of particle masses.
d. a and b above

e. none of the above

8. (5 pts.) 125 mg corresponds to what mass in kg?

a. 0.125 kg
b. 1.25 x 10^{-5} kg
c. 1.25 x 10^{-4} kg
d. 1.25 kg
e. 1.25 x 10^{-6} kg

9. (5 pts.) Suppose you discover two pure substances which you find contain only neon and oxygen. You find that one of the substances contains 1.6 grams oxygen per gram neon and the other contains 2.4 grams oxygen per gram neon. The ratio 1.6/2.4 = 2/3. These data are most closely associated with:

a. Law of Definite Proportions
b. Law of Conservation of Mass
c. Law of Multiple Proportions
d. Law of Conservation of Energy
e. Graham's Law of Molecular Composition

10. (5 pts.) The partial pressure of one component in a gas mixture is equal to the total gas pressure minus the sum of the partial pressures of all the other component gases. This follows from:

b. Dalton's Law and Avogadro's Hypothesis.
11. (5 pts.) In a mercury barometer the mercury does not all flow out of the bottom of the tube. Instead a column of mercury remains inside the tube at an average height of 76 cm at sea level. This is because:

a. the vacuum above the mercury in the tube supports a column of mercury 76 cm long.
b. the pressure of air on the mercury outside the tube supports a 76 cm column of mercury.
c. the tube is not long enough for the mercury all to flow out as it would from a longer tube.
d. the tube is not short enough for the mercury to flow out as it would from a shorter tube.
e. the torricellian vacuum above the mercury in the tube is not perfect but contains enough mercury vapor to support a 76 cm column of mercury.

12. (5 pts.) Death Valley lies below sea level. We therefore expect that in Death Valley water should boil at temperatures slightly above 100°C but not at 100°C. This is because:

a. the vapor pressure of water at 100°C is lower in Death Valley than at sea level.
b. the vapor pressure required for boiling to occur in Death Valley is higher than that required at sea level.
c. one atmosphere of vapor pressure in Death Valley is only achieved at temperatures above 100°C.
d. none of the above

e. a, b and c above

13. (10 pts.) What will be the volume of 2.00 moles of an ideal gas at 0.70 atm pressure and 516 K?

a. 22.4 L
b. 44.8 L
c. 89.6 L
d. 11.2 L
e. 179 L

14. (10 pts.) The mass of a 200ml sample of an ideal gas at 217°C and 4.00 atm pressure is 0.976 gram. What is the relative mass of the gas particles (atoms or molecules) in atomic mass units (amu)?

a. 0.0244
b. 40
c. 24.4
d. 23.7
e. none of these

15. (10 pts.) What will be the increase in the volume of a 3.5 liter sample of an ideal gas at 500K if its temperature is increased to 700K while its pressure is held constant?

a. five-fold    c. 10.75 liter    e. 1.75 liter
b. 16.0 liter    d. 5.25 liter
16. (10 pts.) A sample of a pure metal whose mass is 2.5 grams is heated to 349.2°K and then dropped into 10.0ml of water whose temperature is initially 300.0°K. The total volume of the water plus the sample is found to be 11.7ml and the temperature of the water increases to 301.2°K. What is the specific heat (heat capacity per gram) of the metal?

a. 0.10  
b. 0.25  
c. 0.11  
d. 0.275  
e. 0.300

17. (10 pts.) What would be the approximate relative mass (amu) of the metal in question 16 if the correct specific heat were b., 0.25 cal/deg.g?

a. 1.54  
b. 2.5  
c. 25  
d. 15.4  
e. none of these

18. (10 pts.) How many calories of heat are required to transform 0.50 liter of liquid water at 32°F to water vapor at 373°K?

a. 3.2 x 10^5  
b. 3.6 x 10^5 cal  
c. 5 x 10^4  
d. 3.2 x 10^6  
e. 3.04 x 10^5

19. (10 pts.) What temperature in °K corresponds to 41°F?

a. 5  
b. 16.2  
c. 337  
d. 48.2  
e. 278

20. (10 pts.) On a day in July when the temperature is 80°F a tire is pressurized to 27 lb/in². What will be the pressure in the tire on a day in January when the temperature is 32°F? You may assume that air is an ideal gas and that you have an ideal tire (i.e. leakproof and constant volume).

a. 24.3 lb/in²  
b. 10.0 lb/in²  
c. 0.00 lb/in²  
d. 0.63 atm  
e. both b and d

21. (10 pts.) Argon is a gas whose behavior is ideal at moderate temperatures and pressures. What will be the final temperature of a sample of argon which is initially at 110cm Hg and 400°K if it is expanded from 2.00 liters to 5 liters and a final pressure of 1 atm?

a. 267°C  
b. 541°C  
c. 716°C  
d. 740°K  
e. none of these
APPENDIX E

QUESTIONNAIRE
Chemistry 101
Autumn Quarter, 1972

Chemric Questionnaire

To the student:

The results of this questionnaire should help us to understand and improve the CHEMRIC system. It is important that you be as frank and honest as you can in answering the questions. Thank you for your cooperation.

Instructions for answer sheet:

1. Use pencil only -- not ink.
2. Your Last Name -- Fill in last name, starting at left, and then blacken in the letters in the columns.
3. First Name -- Fill in the first name, starting at left, and then blacken in the letters in the columns.
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6. Do not fill in: Student number, Sex, Date, Test Form
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1. Approximately how many students were in the high school from which you graduated?
   a. more than 2000
   b. 1400-2000
   c. 900-1400
   d. 400-900
   e. fewer than 400

2. What would you consider your high school location to be?
   a. rural (perhaps consolidated)
   b. small town (Dellefontaine, Athens, etc.)
   c. suburban (Upper Arlington, Euclid, Whitehall)
   d. urban-medium sized city (Middletown, Zanesville)
   e. urban-big city (Cleveland, Columbus)

3. How much mathematics have you taken, starting with 9th grade?
   a. none
   b. one year of general math only
   c. one year of algebra only
   d. more than one year of algebra
   e. more than one year of algebra, plus additional math.

4. How much physical science (not biology) have you taken, starting with 9th grade?
   a. only physical science or general science
   b. chemistry only
   c. physics only
   d. both chemistry and physics
   e. chemistry, physics and more advanced physical science

5. How would you rate your mathematical preparation upon starting Chemistry 101?
   a. not adequate. I think I could have done much better if I had a better math background.
   b. not quite what it should be. It may have held me back somewhat.
   c. satisfactory. I didn't have any real trouble with the mathematical parts of the course.
   d. more than adequate. The mathematical parts of the course were quite easy.
   e. superior. The mathematical parts of the course were extremely easy for me.

6. through 10: These questions relate to the CHEMRIC system. Recall, the first day of class, you took the CHEMRIC pretest, and the next day you were given several pages of explanations and problems. Here is one of the CHEMRIC explanations:

   IT IS VERY IMPORTANT THAT YOU WORK ON MULTIPLICATION AND DIVISION OF DECIMALS, ESPECIALLY ON DECIMAL POINT PLACEMENT. IN MULTIPLYING DECIMALS, COUNT THE NUMBER OF PLACES TO THE RIGHT OF THE DECIMAL POINT IN EACH NUMBER TO BE MULTIPLIED AND FIND THE SUM. CALL THAT NUMBER 'X'. CARRY OUT THE MULTIPLICATION AS IF THERE WERE NO DECIMAL POINTS. TO PLACE THE DECIMAL POINT, 

   024
   *001
   024
   24 x 001, giving 00024. Then count over a total of five places (2 from .24 and 3 from .001) to give an answer of .00024
6. How would you describe the **length** of the average CHEMRIC explanation?
   a. much too short
   b. not quite long enough
   c. about the right length
   d. too long
   e. unnecessarily long

7. How would you describe the **reading level** of the CHEMRIC explanations?
   a. Insultingly easy
   b. very easy
   c. about right
   d. slightly too hard
   e. much too difficult

8. How would you rate the ability of the explanations to be understood?
   a. superior—very easy to understand
   b. above average—quite easy to understand
   c. average—understandable
   d. below average—they should be improved somewhat
   e. poor—they should be improved a great deal

9. When mathematical symbols were used in the CHEMRIC explanations, did you understand their meaning?
   a. always—I either already knew them or the explanations made the meaning of the symbols very clear.
   b. usually—I either understood the symbols or they were explained most of the time.
   c. sometimes—Part of the time I understood what the symbols meant, sometimes not.
   d. very seldom—More often than not I didn't understand what was meant when mathematical symbols were used.
   e. never—I didn't understand the mathematical symbols before the explanations or after either.

10. At the end of the CHEMRIC explanations there were several problems for you to work. How do you feel about giving credit for working the problems?
    a. I think I would do them for my own good, even if no credit were given.
    b. I think I probably wouldn't do the problems for less than 10 points.
    c. I think I probably wouldn't do the problems for less than 25 points.
    d. I think I probably wouldn't do the problems for less than 50 points.
    e. I would have to have more than 50 points to do the problems.
APPENDIX F

1. CHEMRIC PRETEST RESULTS (Items 1-25)

2. QUESTIONNAIRE RESULTS (Items 1-10)
## TABLE 32

### CHEMRIC PRETEST PERFORMANCE

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**Pretest Item Number 1**

**Mathematical Skill:** Simplifying expression with parentheses, no units

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**Mathematical Skill:** Adding fractions

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Pretest Item No 3
Mathematical Skill: Dividing fractions with units

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Mathematical Skill: Multiplying Simple expressions with exponents, no units

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Mathematical Skill: Rearranging simple algebraic expressions

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Mathematical Skill: Given the slope and intercept, writing equation for straight line

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Pretest Item Number 10
Mathematical Skill: Multiplying fractions with units

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Pretest Item Number 12
Mathematical Skill: Dividing decimals with units

| A                | Self/Inc        | 67                 | 0.57             |
| A                | Self/NoInc      | 66                 | 0.42             |
| A                | Obj/Inc         | 64                 | 0.73             |
| A                | Obj/NoInc       | 67                 | 0.65             |
| B                | Self/Inc        | 130                | 0.40             |
| B                | Obj/Inc         | 134                | 0.70             |
| C                | Self/NoInc      | 148                | 0.43             |
| C                | Obj/NoInc       | 118                | 0.72             |
| D                | Obj/Inc         | 300                | 0.74             |

Pretest Item Number 13
Mathematical Skill: Converting from scientific notation to decimal form

| A                | Self/Inc        | 67                 | 0.85             |
| A                | Self/NoInc      | 66                 | 0.76             |
| A                | Obj/Inc         | 64                 | 0.75             |
| A                | Obj/NoInc       | 67                 | 0.81             |
| B                | Self/Inc        | 130                | 0.76             |
| B                | Obj/Inc         | 134                | 0.78             |
| C                | Self/NoInc      | 148                | 0.82             |
| C                | Obj/NoInc       | 118                | 0.78             |
| D                | Obj/Inc         | 300                | 0.85             |
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| B | Self/Inc | 130 | 0.36 |
| B | Obj/Inc | 134 | 0.65 |
| C | Self/NoInc | 148 | 0.37 |
| C | Obj/NoInc | 118 | 0.58 |
| D | Obj/Inc | 300 | 0.63 |

| Pretest Item Number 16 | Mathematical Skill: Given X and Y data, finding slope of straight line |
| A | Self/Inc | 67 | 0.42 |
| A | Self/NoInc | 66 | 0.34 |
| A | Obj/Inc | 64 | 0.58 |
| A | Obj/NoInc | 67 | 0.52 |
| B | Self/Inc | 130 | 0.42 |
| B | Obj/Inc | 134 | 0.49 |
| C | Self/NoInc | 148 | 0.35 |
| C | Obj/NoInc | 118 | 0.55 |
| D | Obj/Inc | 300 | 0.60 |
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**Pretest Item Number 20**
Mathematical Skill: Long division of decimals with units

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**Pretest Item Number 21**
Mathematical Skill: Given a base 10 log, writing an equivalent decimal expression

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**Pretest Item Number 22**
Mathematical Skill: Multiplying fractions with decimals, exponents and units

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260
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<tr>
<td>C</td>
</tr>
<tr>
<td>C</td>
</tr>
<tr>
<td>E</td>
</tr>
<tr>
<td>NR</td>
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APPENDIX G

1. Test of Equality of Regression Coefficients for Both Cells of the Total Pilot Lecture Section for ANCOVA of the Effect of Feedback on Quantitative Achievement using Pretest Score as Covariate

2. Test of Equality of Regression Coefficients for Both Cells of the Lower Stratum of the Pilot Lecture Section for ANCOVA of the Effect of Feedback on Quantitative Achievement using Pretest Score as Covariate

3. Test of Equality of Regression Coefficients for Both Cells of the Upper Stratum of the Pilot Lecture Section for ANCOVA of the Effect of Feedback on Quantitative Achievement using Pretest Score as Covariate
### TABLE 34

**Test of Equality of Regression Coefficients for Both Cells of the Lower Stratum of the Pilot Lecture Section for ANCOVA of the Effect of Feedback on Quantitative Achievement Using Pretest Score as Covariate**

<table>
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<th>F Ratio</th>
<th>DF HYP</th>
<th>DF ERR</th>
<th>P Less Than</th>
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**Univariate F Tests**

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TABLE 35

TEST OF EQUALITY OF REGRESSION COEFFICIENTS FOR BOTH CELLS OF THE TOTAL PILOT LECTURE SECTION FOR ANCOVA OF THE EFFECT OF FEEDBACK ON QUANTITATIVE ACHIEVEMENT USING PRETEST SCORE AS COVARIATE

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<td>0.249</td>
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<td>176</td>
<td>0.780</td>
</tr>
</tbody>
</table>

Univariate F Tests

<table>
<thead>
<tr>
<th>Variable</th>
<th>F(1, 177)</th>
<th>Mean Square</th>
<th>P Less Than</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Midquarter Examination Quantitative Portion</td>
<td>0.190</td>
<td>0.625</td>
<td>0.657</td>
</tr>
<tr>
<td>Final Examination Quantitative Portion</td>
<td>0.163</td>
<td>1.962</td>
<td>0.687</td>
</tr>
</tbody>
</table>
TABLE 36

TEST OF EQUALITY OF REGRESSION COEFFICIENTS FOR BOTH CELLS OF THE UPPER STRATUM OF THE PILOT LECTURE SECTION FOR ANCOVA OF THE EFFECT OF FEEDBACK ON QUANTITATIVE ACHIEVEMENT USING PRETEST SCORE AS COVARIATE

<table>
<thead>
<tr>
<th>Test of Roots</th>
<th>F Ratio</th>
<th>DF HYP</th>
<th>DF ERR</th>
<th>P Less Than</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.387</td>
<td>2</td>
<td>86</td>
<td>0.681</td>
</tr>
</tbody>
</table>

Univariate F Tests

<table>
<thead>
<tr>
<th>Variable</th>
<th>F(1, 87)</th>
<th>Mean Square</th>
<th>P Less Than</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Midquarter Examination Quantitative Portion</td>
<td>0.165</td>
<td>0.406</td>
<td>0.685</td>
</tr>
<tr>
<td>Final Examination Quantitative Portion</td>
<td>0.777</td>
<td>10.330</td>
<td>0.962</td>
</tr>
</tbody>
</table>
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