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The construction and comparison of an objective test in high school chemistry with other educational measures and an attempt to predict success on the college entrance examination board achievement test in chemistry from this constructed test

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Boston University

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Boston University
BOSTON UNIVERSITY
SCHOOL OF EDUCATION

Thesis

THE CONSTRUCTION AND COMPARISON OF AN OBJECTIVE TEST IN
HIGH SCHOOL CHEMISTRY WITH OTHER EDUCATIONAL MEASURES
AND AN ATTEMPT TO PREDICT SUCCESS ON THE COLLEGE
ENTRANCE EXAMINATION BOARD ACHIEVEMENT TEST IN CHEMISTRY
FROM THIS CONSTRUCTED TEST

Submitted by

Stuart Raymond Rist
(B.A., Ottawa University, 1955)

In Partial Fulfillment of Requirements for
the Degree of Master of Education
1958

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CHAPTER I
PURPOSE OF THE STUDY

1. Statement of the Problem

The purpose of this study is two-fold: (1) to construct and compare with other methods of educational evaluation a test to be used with a college preparatory course in chemistry that includes one laboratory period per week; and (2) to attempt to predict success on the College Entrance Examination Board achievement test in chemistry from the results obtained from this constructed test.

2. Justification of the Study

The major function of the College Entrance Examination Board, as stated by Paul Brandwein, "is to make available to its consumers progressively more valid and reliable instruments for the selection, guidance and placement of candidates for college entrance." Aligned with this is the fact that 54 per cent of fifty New England colleges surveyed by Girardin require both the College Entrance Examination Board achievement test and aptitude test scores for admission.


Inasmuch as the group for which the test is constructed is one in which college entrance and college preparation are of foremost importance, the need can be seen for a device which would predict success in surmounting one of these hurdles to higher education. Finally, the *Encyclopedia of Educational Research* states that further investigation of prognostic value of ability patterns and differential prognosis is one of the areas of need in educational research.

3. Scope of the Study

The test was administered to sixty-three chemistry students in the college preparatory course at a large suburban high school in the Boston area. This course included four lectures (50 minutes in duration) and one laboratory period (150 minutes in duration) per week. The material for the test was based upon twelve experiments which the students performed or witnessed as demonstrations during the period from November 1957 to March 1958. Question sheets based upon the experiments were given to each student before he attempted the experiment. The student was to answer these questions and return the question sheet and answers, together with his completed experiment write-up, on the first class period following the completion of the experiment. The results of

the student responses on these questions were tabulated and used, in part, to determine which questions were selected to be administered as a test in March 1958. The scores on the test were used to obtain a product-moment coefficient with class grade, scores on Otis Quick-Scoring Test of Mental Ability, Beta Test, Form CM, and the College Entrance Examination Board achievement test in chemistry. Finally, the predictive value of the test was determined by correlation with the scores on the College Entrance Examination Board achievement test in chemistry.
CHAPTER II
INVESTIGATION OF PRESENT DAY METHODS
OF OBJECTIVE TEST CONSTRUCTION

1. Determining Course Objectives

In a survey of 150 secondary school teachers in Colorado David Torbet discovered that the majority of teachers interviewed did not use or understand the mechanics of good testing. There appeared to be little transfer of principles and practices taught in measurement courses to actual classroom situations. F. E. Condon states that there should be an abolition of the practice of using examinations solely as inducements to study and for the establishment and distribution of grades. Hendrick also expresses dissatisfaction with this use of examinations. Teaching, Condon asserts, must be done with the examination in mind rather than basing the examination upon what the teacher thinks has been covered and/or what he thinks he has taught. The examination to which Condon


refers is one in which the course objectives are stated, made known to the student, and then the test constructed from these objectives. If, as Condon affirms, "an examination is an expression of a philosophy of education," many teachers would recognize the need for a re-examination of either the test or the philosophy of education. It is to the former that the writer's attention has been directed.

The research has been concerned with testing as it relates to the general field of science with a specific inquiry into high school chemistry which incorporates a laboratory period.

Historically, the point of reference for any test was the text book from which the subject was taught. This, according to Gerberich, is too narrow a base in terms of the functional, factual, and intangible outcomes of learning for which we are hoping in today's educational system. The modern base for testing, continues Gerberich, is dependent upon those "pupil behaviors indicating or representing the attainment of instructional objectives established or determined for the school or particular instructional area of the course."

8/F. E. Condon, loc. cit.


10/Ibid., p. 17.
Supporting Gerberich in emphasizing the need for establishing or outlining a series of goals from which a test will be constructed are: Hendricks, Bloom and Heyns, Angell, Munch, Condon, Van Paursem, Frutchey, Dunning, as well as the Committee on Examination and Testing of the Division of Chemical Education of the American Chemical Society and the Cooperative Testing Service. At this point the writer deemed it safe to say that the modern trend in achievement test construction and test construction in general is to start with the premise that the aims and objectives of instruction are of foremost importance and the test should be devised and constructed so as to measure the pupils' attainment of these objectives. The aims and objectives upon which science tests should be constructed, in the opinion of authorities in the field of testing and of science, are listed below. These aims and objectives are divided into three broad general classes:

1. Information level
   a. Skill and knowledge
   b. Identification of a scientific problem
   c. Basic concept of each science
   d. Laboratory technique
   e. Reading comprehension and vocabulary of science
   f. Acquisition of functional science information

2. Understanding
   a. Apply principles in new situations
   b. Select validating process in an experiment
   c. Interpret data and draw conclusions
   d. Evaluate critical claims of others
   e. Reason quantitatively and symbolically
   f. Perceive relationship of science to life--
      effect upon society (i.e., cultural, social,
      economic, and home or practical).

3. Measurement of desired general pattern of behavior
   resulting from outcomes of instruction
   a. Appreciations
   b. Attitudes
   c. Interests
   d. Adjustments

The list of objectives shown above is a consolidation of
the opinions of the previously mentioned authorities fitted
into the outline of Curtis. It is the writer's conclusion
that the list presented covers the major aims and objectives
of science teaching.

2. Steps in Actual Test Construction

First, of utmost importance, is the stating of objectives
for outlining the course of instruction. Troyer and Pace,
of the American Council on Education, say that stated objec-
tives will be ignored by students unless evaluation practice
honors these objectives with sincere attempts at measurement.
Herein is seen the importance of the test to the total


13/M. R. Troyer and C. R. Pace, Evaluation in Teacher
Education, American Council on Education, Washington, D. C.,
1944.
institutional pattern. It is imperative that the instruction and the test of instruction both be guided and governed by the objectives of the course with no area of aims or objectives overlooked or slighted. It is the function of the test to determine to what degree the students have attained the aims and objectives of the course. The writer realises that tests will of necessity continue to be, to some degree, a motivating force for some students to study and also will provide for the teacher a degree of measurement of accomplishment for each student, but it is re-emphasized that these functions of the test are of secondary importance.

There are many types of questions that may be used in testing. Therefore, the second step is the choice of either subjective or objective questioning. There are several advantages to be found in both types of testing. The objective test allows for coverage of a maximum amount of material in a minimum amount of time, provides with reliability a distinctive approach to measurement of a student's capacity, and reduces grading time to a minimum. The subjective test allows for greater measurement of individual differences and creative thinking on the part of the student. Many experiments have shown that subjective and essay type examinations are not very

reliable inasmuch as two different instructors, even in the same department, may assign very different grades to the same paper. Because of this characteristic, the writer chose to concentrate on the objective type test as a more accurate measuring device.

There are many types of objective questions, some of which are: multiple-choice, matching, true-false, and fill-in-the-blank. Paul Dressel states that "the use of objective multiple-choice test items involving a choice of one out of four or five proffered alternatives has become so extensive that many test writers now use no other form." For this reason, and also because so many examples of this type of question are available for the in-service teacher to study, it was decided to deal in this paper with the construction of the objective multiple-choice type of question.

Finally, the measuring device should embody some of the characteristics of good testing. The major characteristics of a good examination are summarized by Gerberich and classified as follows: Validity; Reliability; Objectivity; and Adequacy. These terms he defines as follows:

Validity: the degree to which a test measures what its user intends it to measure.

Reliability: the degree to which a test measures whatever it actually measures. A test measures accurately and consistently if it is reliable.

Objectivity: the degree to which a test measures without the intrusion of personal opinions and subjective judgments on the part of the person doing the scoring.

Adequacy: the degree to which a test is of sufficient length to sample widely the behavior it is designed to measure.

Outlined below is a possible pattern for the construction of an objective test.

Step 1. Determine the principle to be tested.

Step 2. Determine the phrasing of the problem situation so that the student is required to draw a conclusion, make a prediction, choose a course of action, explain a phenomenon, criticize an explanation or prediction made by someone else.

Step 3. Set up a problem situation involving the principle with directions for the student to draw conclusions and defend the answers or conclusions he gives.

Step 4. Edit the student responses and select for re-use those which best represent the students' thinking.

Step 5. Add those items deemed necessary to cover the prominent points involved in the subject. From the items collected in Steps 4 and 5, assemble the alternate responses necessary for multiple-choice items.

Step 6. Submit the test to judges for criticism. Revise the test after criticism.

Step 7. Administer the test. Follow this with a discussion of the test by the class.

Step 8. Conduct an item analysis.

Step 9. In light of Steps 7 and 8, revise the test.

Four general rules have been established by many test writers and summed up by Travers in the following manner.

(1) The problem that the student is to solve is set up in such a manner that if he, the student, solves the problem correctly it will be evidence that he has attained an important goal.

(2) Questions which are intended to measure insight must present new situations to the student which are based on old principles.

(3) The language of the test questions must be in context with the subject matter.

(4) Each test item should be independent of every other test item so that no clues to any question may be found within the other test questions.

As well as the general rules, Travers has assembled rules for stating the problem, developing suggested solutions and controlling the difficulty of test questions. Each of these areas is covered briefly by the writer.

In stating a problem the lead item or root must present a single central problem, only material relevant to the


19/Ibid., p. 125.
problem must be presented, and the problem must be accurately stated. The problem should contain no unusual words, or encompass involved sentence structure unless it is the desire of the tester to measure the students' abilities in these particular areas. The problem is usually stated in positive form; and, if an item requires the student to express a judgment or opinion, it is usually the opinion or judgment of an authority.

For development of the solution to multiple-choice questions, the following pattern is suggested. The right answer should be unquestionably right. Wrong answers should direct the examinee away from the right answer if he does not know the correct answer. Finally, all proffered answers should be as brief as possible.

The difficulty of the questions can be altered by the teacher by changing the problem or modifying the answer. It is suggested that modifying the answer is the more practical operation since a wider range of possibilities is available. All problems should be ones which the student can solve if he has attained the goals of the course. It should be remembered that all alternatives which fail to operate as distractors tend to reduce the difficulty of the problem. Travers suggests that a good rule to follow is "Decoys should distract."
3. Correct English and Usage of Language in Test Construction

The language involved in the writing of a test is of utmost importance. Adams and Torgerson have enumerated some of the more common errors made by teachers in test construction. The following are a few of the pitfalls in the area of English that should be avoided: poor wording of questions which involve bookish terms; extra long phrases or statements; vocabulary which is advanced beyond the level of the student and out of context with the subject. The use of "specific determiners" which afford clues to students who do not have an adequate knowledge of the subject but are able to answer the question in the absence of knowledge because of clues in phrasing or because of specific determiners.

Items containing the following are more often false than true: totally, entirely, exactly, completely, solely, fully, exclusively, very perfectly, absolutely, all, always, no, none, not, nothing, only, alone, never. Items containing the following are more often true than false: was one of, may, usually, generally, most commonly, as a rule, as a whole, even if, almost all, mainly, almost entirely, some, sometimes, often, frequently, several, many, probably, approximately, larger, ever.

Avoid giving clues through grammatical construction or other means ("a", "an," singular or plural subject or verb). Tricky


21/Ibid., p. 247.
sentence structure, long involved wording, and unnecessary modifiers represent common errors in English.

Another area of English which is often handled poorly by teachers constructing a test is the giving of directions. The elimination of ambiguity in unique multiple-choice questions lies in the completeness and clarity of the directions accompanying the exercise. The questions lose their ability to measure knowledge if they are "fogged" with non-clarity. The student must know exactly what he is to do.

4. Summary

Objectives for the course were outlined. It was stated that an attempt at evaluation of these objectives is the only justification of a testing program. Ashford asserts that the objective tests which we are striving to construct can and will, if properly constructed, measure accurately, quickly, and with reliability a great number of ideas, all of which are important and common to the vast majority of courses. In addition to this type of measurement, Ashford asserts that the teacher must do some evaluation of the attainment of more abstract and intangible aspects of the listed aims and objectives.


Dressel, in his *Questions and Problems of Science*, presents a very complete and inclusive outline for testing objectively a majority of the aims and objectives such as those listed on page six. He suggests grouping test material and questions in the following manner and under the following headings:

I. Knowledge—specifics; ways and means of dealing with specifics; universal and abstract

II. Comprehension—translation; interpretation and extrapolation

III. Application

IV. Analysis—of the elements; relationships; organizational principles

V. Synthesis—production of unique communication; plan or proposed set of objectives; derivation of a set of abstract relations

VI. Evaluation—judgment in terms of internal evidence; judgment in terms of external criteria

A test may be used for many purposes. Listed below are some of the uses proposed by the committee of the Testing Program of the Division of Chemical Education of the American Chemical Society.


1. Measure achievement at course termination
2. Compare achievement of sections
3. Compare results of different teachers in the same course
4. Find out what was successfully taught and what was not successfully taught
5. Discover gaps in teaching
6. Maintain and improve standards
7. Call attention to objectives of teaching
8. Evaluate work of transfer students
9. Aid in guiding student to curriculum and career
10. Augment teacher's estimate of student grade achievement

In the test constructed by the writer an attempt was made to evaluate the attainment of the course objectives as outlined in Chapter III. This was in accordance with the authorities mentioned on page six. The questions on the test were, for the most part, included in the categories outlined by Dressel and Curtis. Reference was made to Adams and Torgerson and also to Travers to avoid incorrect English and the use of "specific determiners" in the test questions.
CHAPTER III

GOALS OF THE SPECIFIC COURSE, NATURE OF THE GROUP
AND PROCEDURES USED IN THE STUDY

1. Goals of the College Preparatory Chemistry Course
Including Laboratory at a Suburban Boston High School

The following are, in the opinion of the writer, some of
the objectives established for the college preparatory course
which has been taught with outstanding results for twenty
years by the same teacher, hereafter referred to as senior
instructor.

1. Knowledge relating to the following areas of the
field of chemistry: oxygen; oxides, electrolysis; hydrogen;
active metals; reduction; distillation; hard and soft water;
flames; solutions; titration; hydrogen chloride gas; oxidation
and reduction.

2. Relationship of chemistry to everyday life and its
practical application

3. Function of chemistry in industry

4. Relationship of chemistry to other sciences

5. Relationship of the basic principles of chemistry to
the students' everyday knowledge in an attempt to stimulate
learning by thinking and application rather than by just
memorizing.
6. Development of laboratory technique and ability to manipulate equipment

7. Interpretation, evaluation, and acquisition of knowledge of chemistry from performed experiments and observation of demonstrated experiments

8. Development by the student of the ability to stand on his feet, think, and express concisely his thinking and observations.

The material covered in the course was determined by the senior instructor. It was the task of the writer to present information, directions, and instruction necessary before the students started the experiment, supervise the students during the experiment, prepare a question sheet to be answered by each student as a homework exercise, and to correct the completed experiments of the students. The students were required to bring to class a preparation sheet outlining the experiment to be performed. They were not permitted to have laboratory manuals or other such aids at their desks during the experiment. This procedure was followed so that it would eliminate, as much as possible, a student coming to the laboratory without having studied or prepared for the experiment.

The time spent by the student in this course was outlined on page two of this paper and was as follows: four lectures (50 minutes in duration) and one laboratory period (150 minutes in duration) per week. If on any given laboratory
day the experiment was completed in less than the 150 minutes, the remainder of the time was used by the senior instructor for lecture or review of the experiment.

2. Nature of the Group Enrolled in the College Preparatory Course

A total of sixty-eight students were enrolled in the course at the time the test was given and these students were used in the testing. Of these students, forty-five were boys and twenty-three were girls. There were forty-four juniors and twenty-four seniors. The mean I.Q. test score (Otis Quick-Scoring) of sixty-two of these students was 120.42 and the standard deviation of this group was 7.69. All the students in the course were classed as college preparatory based upon the following criteria: I.Q. test score, course grade, and teacher recommendation.

3. Nature of the Test Constructed

Table 1 describes the type, number, and point values of the questions in the constructed test. In scoring the test no correction was made for guessing. The multiple-choice questions had five possible responses, and according to Green, Jorgensen, and Gerberich, it is not necessary to correct

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for chance when this number of responses is presented. Ten were alternate response questions, five of which specify the showing of mathematics to obtain correct answers. Because of this it was not deemed practical to correct for chance on the five remaining questions of the alternate response type.

Table 1. Type, Number, and Point Value of Questions in the Constructed Test

<table>
<thead>
<tr>
<th>Type of Question</th>
<th>Number Used</th>
<th>Point Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Multiple-choice— one correct answer ...............</td>
<td>43</td>
<td>43</td>
</tr>
<tr>
<td>2. Alternate response .......</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>3. Multiple-choice— one correct answer with mathematics required..</td>
<td>6</td>
<td>21</td>
</tr>
<tr>
<td>4. Alternate response, mathematics required..</td>
<td>5</td>
<td>15</td>
</tr>
</tbody>
</table>

Table 2 describes the subject matter coverage by showing the number of references to each specific subject. It should be noted that the number of references does not necessarily correspond to the number of questions on the test since a question could easily deal with two or more specific subject areas.
Table 2. Number of Questions in the Constructed Test Dealing with the Various Areas of Subject Matter

<table>
<thead>
<tr>
<th>Subject</th>
<th>Reference</th>
<th>Subject</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>11</td>
<td>Distillation</td>
<td>5</td>
</tr>
<tr>
<td>Oxides</td>
<td>10</td>
<td>Hard water</td>
<td>4</td>
</tr>
<tr>
<td>Electrolysis</td>
<td>5</td>
<td>Flames</td>
<td>3</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>8</td>
<td>Solutions</td>
<td>3</td>
</tr>
<tr>
<td>Active metals</td>
<td>4</td>
<td>Titration</td>
<td>5</td>
</tr>
<tr>
<td>Reduction</td>
<td>6</td>
<td>HCl gas</td>
<td>5</td>
</tr>
</tbody>
</table>

4. Procedures Used in the Construction of the Test

The questions used in the test were constructed, as far as possible, to measure the attainment of the goals of the course. They were first presented to the students as a homework exercise to be answered and returned with the laboratory experiment. The experiment and exercise were due on the first class meeting following the laboratory experiment. The students were given a mimeographed sheet with the questions which was returned with the experiment and an exact check was kept on the number of sheets distributed and returned. The exercises were corrected and returned to the students. The exercises were discussed, correct answers noted, and a record was kept by the writer of student comments as to the clarity of the questions and how they, the students, thought the questions might have been more clearly stated or improved. It was in light of these comments that the questions were revised.
if necessary, before being incorporated into a test. The
writer endeavored to use all the rules and methods outlined
in Chapter II in writing the test questions, giving particular
attention to the directions by Travers27 and referring to the
type of questions, format, and examples given by Dressel and
Nelson.28 As the exercises were corrected, a tally was kept
as to the number of students who answered specific questions
incorrectly. This tally was used in part to select questions
for the test. Also the tally of incorrect answers was used
to set up a pattern of question difficulty in groups of five,
increasing in difficulty from question one to five. After the
test was assembled in final form it was given to an authority
in the field of testing for comment, correction, and evalua-
tion before being mimeographed. The test was then reviewed
by a novice in the field of chemistry to see if any of the
questions could be answered by noting "specific determiners"
and also to determine whether the student directions and
questions themselves were stated clearly as far as English was
concerned.

5. Administration of the Test

It was necessary to administer the test at a time when

27/Robert M. W. Travers, loc. cit.
28/Paul L. Dressel and Clarence H. Nelson, loc. cit.
29/Dr. John G. Read, School of Education, Boston University
the senior instructor was absent from the classroom to avoid the loss of any classroom instruction time. The test was administered to three of the four classes in one day and to the fourth class the first period of the following day. In the school where the study was performed all of the sections did not meet on any one day when it was possible to give the test. The students were not informed of the test prior to taking it. It was decided that the test would be of thirty minutes duration. There were fifty-nine questions of the multiple-choice type and the standard time allotted for this type of question is two questions per minute.\footnote{Ibid.}

Since eleven of the fifty-nine questions involved mathematics, it was anticipated that very few students would finish the test. This was desired because an attempt was later made to predict success on the College Entrance Examination Board achievement test in chemistry which was a similarly constructed test.

The following are the directions which were read at the time the test was administered. These directions were read verbatim to all four groups taking the test.

(Directions: Teacher-read:)

One of the objectives of this course is to help you as students to learn how to take achievement tests effectively
and to obtain higher scores. This test should help you to understand testing and help you to obtain higher scores on tests.

You will not be allowed to use a slide rule during this test. You will have only the question sheet, answer sheet, two pencils and an eraser on your desk.

The test will be thirty minutes in duration. You are not expected to answer all the questions on the test. In general it is best to answer all the questions about which you have any knowledge at all because a shrewd guess is more often right than wrong. On the other hand it is best to skip questions about which you have absolutely no knowledge, since you can use your time more profitably on other parts of the test. If you complete the test before time is called it is wise to go back and reconsider any questions about which you were not certain at first.

Many times tests of this type (achievement) are assembled in groups of five questions of increasing difficulty or some similar pattern of increasing difficulty. Keep this in mind as you do this test for it is assembled in groups of five in increasing difficulty.

You will not be penalized for wrong answers on this test. Your score will be the total of right answers times the point value of the given question.

Read every question carefully. Do not jump to conclusions.
Do not depend upon your memory to answer questions but treat each question as a new problem. Some of the questions have been revised from their original form so you must not depend upon memory. These revisions have been made to increase the clarity of the question and in many cases were made in light of your comments. Many of the questions involving mathematics have had the numbers changed but are testing the same basic knowledge as in the original problem. There are no trick questions in the test.

The answer sheet will now be distributed. Place your name, block letter, and the date in the space provided.

Now read the directions on the answer sheet.

Directions: This is a test of your knowledge of chemistry. There will be two types of questions on this test, examples of which are given below.

Type I: Choose the one correct answer from those listed. If you mark more than one answer the question will be marked wrong. Example No. 1—NaCl is the formula for:

(a) water
(b) chlorine
(c) hydrogen
(d) sodium
(e) salt

Answer: The correct answer is (e) and this letter should be marked as shown below with a circle (O) containing an (X).

a b c d E
**Type II:** Indicate which of the following compounds has the larger atomic weight. Circle (O) and (X) the letter of the compound with the larger atomic weight.

**Example No. 2**

(a) NO
(b) AlCl$_3$

**Answer:** The correct answer is AlCl$_3$; therefore the letter (b) is circled with an (O) and marked with an (X).

The questions involving mathematical calculations are of higher point value than those which do not involve mathematical calculations. Questions 7-9, 26-30, 31, and 51, and 52 are valued at three points each; question 10 is valued at six points. The remainder of the questions are valued at one point each. There is a total of eighty-four points on the test.

To receive credit for the correct answer to a question involving mathematics your work must appear in the properly numbered space of page 2 of your answer sheet and you must mark the correct answer on page 1 of the answer sheet. In the problems involving mathematics if your work is not in the space provided you will receive no credit for the problem regardless of whether you have the correct letter indicated on the answer sheet. The number of each question involving mathematics has been circled in red on your question sheet to remind you that you must show your work in the properly numbered space on page 2 of your answer sheet.
The back side of either page of your answer sheet may be used for scratch paper if you need such space for any of the other questions.

Your final score on this test will be your percentile rank based on all students taking this test. Therefore, if any information is given to students who have not taken the test it will be to your disadvantage.

The question sheet will now be distributed face down. Do not turn these sheets over until you are told to do so. You are to make no marks on the question sheets. Do you have any questions? Turn the question sheet over and begin the test. Stop.

Place your pencils on the desk and pass your answer sheet to the front of the room.

Pass your question sheets to the front of the room.

(End of Directions)

The test was administered in a well lighted, well ventilated room and there were no distracting incidents during the test. The students were properly spaced during the test and the test itself was mimeographed with clarity. Each student had an individual question sheet and an individual answer sheet. The test was scored by hand using a punched key. It was also scored again using a matching key.
6. Problems Involved in the Study

1. The first problem was that the class was not totally under the supervision of the writer; and, even though a great deal of cooperation was received from the senior instructor, it was not as though the class were completely under the tester's jurisdiction.

2. A specific problem existed as far as selecting the questions for the test. Ideally the questions should have been given as a test, the items of the original test analyzed, and then a revised test constructed. As it was, the students had the questions overnight and could talk with other students about the questions. It was felt by the writer that in some cases the results on certain papers did not represent the work of the individuals submitting them. However, one advantage did result from this procedure, it being that many students expended time and effort to determine the correct answers to the questions and thus were motivated so that learning did take place. The writer also felt that many of the students did develop the ability to think critically and analyze test questions.

3. The final form of the test could not be given at a time which coincided with the College Entrance Examination Board achievement test in chemistry. Ideally the two tests should have been administered within a few days of each other. This could not be done since the test, which took one complete
day of classes, a laboratory period, and a period of a second
day, had to be administered about eight weeks before the
College Entrance Examination Board test.

4. Ideally the test should have been administered to
the four classes as a group. Because of the class schedule
in the high school this was impossible.

5. All of the students (68) who took the test were not
required to take the College Entrance Examination Board test.
The seniors and juniors enrolled in the course took the
College Entrance Examination Board test at different times.
Thus the largest number that could be used in a predictive
correlation was twenty-seven.

6. The number used in the correlation with the Cooperative
Chemistry Test was reduced to forty-four since the seniors
and juniors took the examinations at different times and under
different conditions.
CHAPTER IV
PRESENTATION OF DATA AND ANALYSIS OF TEST

1. Introduction

**Measures of Central Tendency:** The mean and the standard deviation are the measures of central tendency which are presented. These are provided for intelligence quotient test scores, class grades, scores on the College Entrance Examination Board achievement test in chemistry, scores on the Cooperative Chemistry Test-Form X, and scores on the constructed test. The above-mentioned measures of central tendency are presented for the total group and also for the twenty-seven students used in the prognosis.

**Mean and Standard Deviation of Groups or Blocks.** Since the test was given to four different blocks in consecutive class periods, the mean and standard deviation of intelligence quotient test scores and constructed test scores were computed for the total group and also for each block which took the test. These computations were figured to detect any possible collaboration between the blocks inasmuch as each of the four blocks took the test at a different time.

**Item Analysis.** An item analysis was made on the test to determine the discrimination and difficulty indexes of the individual items.
Reliability. The reliability of the test was computed by the Kuder-Richardson method and the chance-half method using the Spearman-Brown prophecy formula.

Validity. The statistical validity was figured by correlating the results on the constructed test with class grade, intelligence quotient test score, Cooperative Chemistry Test score, and the College Entrance Examination Board achievement test score.

2. Measures of Central Tendency

The mean, or arithmetic mean, is defined as "a point on the scale such that the sum of the deviations of the values larger exactly equals the sum of the deviations of the values smaller than it is." With this definition in mind, and using the formulas of Gerberich, the mean and the standard deviation were computed. The following is the formula used in computing the mean.

\[ M = A.M. + c.i. \times \frac{\Sigma f d}{N} \]

in which:

- A.M. = Assumed Mean
- c.i. = Class Interval
- f = Frequency
- d = Deviation
- N = Number of Students

18/Ibid., p. 334.
19/Harry A. Greene, Albert N. Jorgensen, J. Raymond Gerberich, op. cit., p. 318.
30/Ibid., pp. 320-334.
The formula used to obtain the standard deviation is given below. Data used to compute the mean were also used in computing the standard deviation as shown in Table 3.

\[ \text{S.D.} = \sqrt{\frac{\sum fd^2}{N} - \left(\frac{\sum fd}{N}\right)^2} \]

in which:

- \( \sum fd^2 \) = sum of frequencies multiplied by the square of deviations from the assumed mean
- \( \sum fd \) = sum of frequencies multiplied by deviations from the assumed mean
- \( N \) = number of students

It should be noted that whenever means or standard deviations were computed the above formula was employed. See Tables 4 and 5.

Table 3. Tabulated Data of I.Q. Test Scores of 58 Students

<table>
<thead>
<tr>
<th>c.i.</th>
<th>( f )</th>
<th>( d )</th>
<th>( fd )</th>
<th>( fd^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>104-106</td>
<td>1</td>
<td>7</td>
<td>7</td>
<td>49</td>
</tr>
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<td>107-109</td>
<td>0</td>
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</tr>
<tr>
<td>110-112</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>113-115</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>116-118</td>
<td>4</td>
<td>3</td>
<td>12</td>
<td>36</td>
</tr>
<tr>
<td>119-121</td>
<td>6</td>
<td>2</td>
<td>12</td>
<td>24</td>
</tr>
<tr>
<td>122-124</td>
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<td>12</td>
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</tr>
<tr>
<td>125-127</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>128-129</td>
<td>5</td>
<td>-1</td>
<td>-5</td>
<td>5</td>
</tr>
<tr>
<td>130-131</td>
<td>11</td>
<td>-2</td>
<td>-22</td>
<td>43</td>
</tr>
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<td>132-133</td>
<td>5</td>
<td>-3</td>
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<td>-5</td>
<td>25</td>
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<td>138-139</td>
<td>0</td>
<td>-6</td>
<td>-6</td>
<td>36</td>
</tr>
<tr>
<td>140-141</td>
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<td>-7</td>
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</tr>
<tr>
<td>96-98</td>
<td>1</td>
<td>-8</td>
<td>-8</td>
<td>64</td>
</tr>
</tbody>
</table>

\[ \text{Total: } 58 \times -10 = 368 \]
Table 4. Measures of Central Tendency of Class Grade and Scores on I.Q. Test, College Entrance Examination Board Achievement Test in Chemistry, Constructed Test, Constructed Test Revised, and Cooperative Chemistry Test-Form X.

<table>
<thead>
<tr>
<th>Measuring Device</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Range</th>
<th>Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Class Grade given in points</td>
<td>833.43</td>
<td>5.00</td>
<td>466-1125</td>
<td>60</td>
</tr>
<tr>
<td>2. I.Q. Test</td>
<td>120.49</td>
<td>2.51</td>
<td>96-143</td>
<td>58</td>
</tr>
<tr>
<td>3. College Entrance Examination Board Achievement Test in Chemistry</td>
<td>696.81</td>
<td>2.59</td>
<td>517-792</td>
<td>27</td>
</tr>
<tr>
<td>4. Constructed Test</td>
<td>43.80</td>
<td>2.44</td>
<td>25-70</td>
<td>60</td>
</tr>
<tr>
<td>5. Constructed Test Revised</td>
<td>33.40</td>
<td>2.44</td>
<td>15-54</td>
<td>44</td>
</tr>
<tr>
<td>6. Cooperative Chemistry Test-Form X</td>
<td>61.75</td>
<td>3.40</td>
<td>43-76</td>
<td>44</td>
</tr>
</tbody>
</table>

Table 5. Measures of Central Tendency of Class Grade and Scores on I.Q. Test, College Entrance Examination Board Achievement Test in Chemistry, Constructed Test, Constructed Test Revised, and Cooperative Chemistry Test-Form X, for 27 Students Used in the Prognosis.

<table>
<thead>
<tr>
<th>Measuring Device</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Class Grade given in points</td>
<td>886.87</td>
<td>2.00</td>
<td>703-1125</td>
</tr>
<tr>
<td>2. I.Q. Test</td>
<td>120.67</td>
<td>2.54</td>
<td>110-143</td>
</tr>
<tr>
<td>3. College Entrance Examination Board Achievement Test in Chemistry</td>
<td>696.81</td>
<td>2.59</td>
<td>517-792</td>
</tr>
<tr>
<td>4. Constructed Test</td>
<td>46.89</td>
<td>2.14</td>
<td>29-70</td>
</tr>
<tr>
<td>5. Constructed Test Revised</td>
<td>37.11</td>
<td>3.16</td>
<td>24-54</td>
</tr>
<tr>
<td>6. Cooperative Chemistry Test-Form X</td>
<td>66.83</td>
<td>3.71</td>
<td>48-76</td>
</tr>
</tbody>
</table>
Table 6 was prepared to establish the fact that scores were not affected by the test being administered to each block at a different time. The measures of central tendency are presented first for the total group taking the test and then for each block in the order in which the test was taken.


<table>
<thead>
<tr>
<th>Group</th>
<th>Mean I.Q. Test Score</th>
<th>Standard Deviation I.Q.</th>
<th>Mean Test Score</th>
<th>Standard Deviation Test Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Total Group</td>
<td>120.49</td>
<td>2.51</td>
<td>43.58</td>
<td>3.52</td>
</tr>
<tr>
<td>2. Block F....</td>
<td>123.45</td>
<td>2.56</td>
<td>51.25</td>
<td>3.39</td>
</tr>
<tr>
<td>3. Block E....</td>
<td>115.92</td>
<td>2.88</td>
<td>37.79</td>
<td>3.01</td>
</tr>
<tr>
<td>4. Block C....</td>
<td>120.61</td>
<td>2.92</td>
<td>41.03</td>
<td>2.47</td>
</tr>
<tr>
<td>5. Block E....</td>
<td>117.61</td>
<td>1.49</td>
<td>39.06</td>
<td>3.19</td>
</tr>
</tbody>
</table>

3. Item Analysis

It was necessary to conduct an item analysis to determine which items should be included in the final form of the test. The item analysis was concerned with the difficulty and discriminatory indexes of the individual test items. The method used in determining the difficulty and discriminatory indexes was that outlined by Davis in his paper, Item-Analysis Data.  

35 Frederick E. Davis, Item-Analysis Data, Graduate School of Education, Harvard University, Cambridge, Massachusetts, 1946.
The actual indexes were taken from his Item-Analysis Chart.

Following the method developed by Flanagan, 27 per cent was used to represent the extreme groups of superior and inferior pupils taking the test. A chart was constructed using the responses of the students in these two groups to obtain statistics which could be referred to Davis' chart.

Investigation indicated that usually items at the 20 per cent level of extremes in discrimination are not used in revised forms of tests. In view of this, the writer included no items below the 20 per cent level of discrimination and only one above the 80 per cent level of discrimination. The revised form of the test was comprised of forty-one items.

An attempt was made to assemble the questions in groups of five of increasing difficulty. Observation of the difficulty index in Table 7 will reveal that this was accomplished to some degree. The indexes of high numerical value represent easy problems while those of low numerical value represent the more difficult problems.


Table 7. Individual Item Analysis of the Unrevised Test from 62 Cases.

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Per Cent of successes</th>
<th>Indexes</th>
<th>Revised Item Number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High 27% of cases</td>
<td>Low 27% of cases</td>
<td>Discrimination</td>
</tr>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>1</td>
<td>89</td>
<td>76</td>
<td>12*</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>71</td>
<td>39</td>
</tr>
<tr>
<td>3</td>
<td>100</td>
<td>89</td>
<td>28</td>
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<tr>
<td>4</td>
<td>100</td>
<td>89</td>
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<td>5</td>
<td>59</td>
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<td>6</td>
<td>94</td>
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<tr>
<td>7</td>
<td>94</td>
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<td>8</td>
<td>100</td>
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<tr>
<td>9</td>
<td>89</td>
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<td>89</td>
<td>11*</td>
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(continued on next page)
Table 7. (concluded)

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Per Cent of successes</th>
<th>Indexes</th>
<th>Revised Item Number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High 27% of cases</td>
<td>Low 27% of cases</td>
<td>Discrimination</td>
</tr>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>31</td>
<td>94</td>
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<td>46</td>
</tr>
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<td>32</td>
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<tr>
<td>55</td>
<td>76</td>
<td>6</td>
<td>-17*</td>
</tr>
<tr>
<td>56</td>
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<td>18</td>
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<td>57</td>
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<td></td>
</tr>
<tr>
<td>58</td>
<td>35</td>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>

* Did not meet the requirements of discrimination.

** Indexes not figured due to two possible answers.
The mean difficulty index of the forty-one items on the test was 52.41. According to Gerberich, there is "general agreement, however, that the test as a whole should have about a 50 per cent difficulty for the average pupil."

The revised form of the test met the requirements of the discrimination index which was set up.

4. Reliability

"Reliability," as defined by Gerberich, is "an examination criterion indicating the degree to which a test measures what it does measure; consistency of measurement." There are basically three correlation and two non-correlation methods for determining the reliability of a test. Since it was possible to give the test only once in the situation where the study was made, there remained only two methods for determining the reliability. The "chance half" method which depends upon correlation is in essence a measure of internal consistency that incorporates the Spearman-Brown formula to give the reliability for the total test.

A Pearson product-moment correlation was used to determine the correlation between the odd and even items on the test. The following scatter diagram is typical of those used in all of the product-moment correlations computed.

38/Harry A. Green, Albert N. Jorgensen, and J. Raymond Gerberich, op. cit., p. 90.

39/Ibid., p. 661.
**Figure 1. Scatter diagram of scores on alternate halves of test.**

<table>
<thead>
<tr>
<th>Y VARIABLE: EVEN TEST SCORES</th>
<th>X VARIABLE: ODD TEST SCORES</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-7</td>
<td>26-28</td>
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<tr>
<td>26-28</td>
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</tr>
<tr>
<td>5-7</td>
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</tr>
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<td>d_12</td>
<td>60</td>
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</tbody>
</table>

---

*Note: The table represents scores on alternate halves of a test, with X and Y variables correlating test scores.*
The following formula was used to compute the correlation coefficient:

\[ r = \frac{\langle xy \rangle - c_x c_y}{\sigma_x \sigma_y} \]

In which:

- \( r \) = Coefficient of correlation
- \( N \) = Number of items in the correlation
- \( c_x \) = Correction factor for the \( x \) variable
- \( c_y \) = Correction factor for the \( y \) variable
- \( \langle xy \rangle \) = Summation of product-moments
- \( \sigma_x \) = Standard deviation of \( x \) variable
- \( \sigma_y \) = Standard deviation of \( y \) variable

The Spearman-Brown prophecy formula is given below:

\[ r_1 = \frac{2r_B}{1 + r_B} \]

in which:

- \( r_1 \) = Reliability of the whole test
- \( r_B \) = Reliability of the chance halves of the test taken from the Pearson product-moment

The reliability of the test determined by the chance-half method of correlation and the Spearman-Brown prophecy formula for whole test reliability was .814.

The "footrule" method developed by Kuder and Richardson determines reliability from the variance of total scores on a test and the sum of item variance.

Table 8 presents data used in computing the reliability coefficient for the revised test as determined by using the following formula:
\[ r = \frac{N}{N-1} \frac{(\sigma^2 - \epsilon pq)}{(\sigma^2 - \epsilon)} \]

In which:

- \( N \) = Number of items in the test
- \( \sigma^2 \) = Standard deviation of the test scores squared
- \( \epsilon \) = Proportion of students responding correctly
- \( q \) = Proportion of students responding incorrectly

Table 8. Percentages of Right and Wrong Responses on the Revised Test

<table>
<thead>
<tr>
<th>Revised Item Number</th>
<th>Percentage of Responses</th>
<th></th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Right</td>
<td>Wrong</td>
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<tr>
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<td>.226</td>
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(concluded on next page)
Table 8. (concluded)

<table>
<thead>
<tr>
<th>Revised Item Number</th>
<th>Percentage of Responses</th>
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</thead>
<tbody>
<tr>
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<td>Right</td>
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<tr>
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<tr>
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<tr>
<td>41</td>
<td>.436</td>
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</tbody>
</table>

The reliability of the test using the "footrule" method of Kuder and Richardson was .949.

In addition to the measures of reliability given above, the standard error of measurement was computed so that the hypothetical "true" score of the students could be determined.
The following formula was used:

\[ S.E._m = \sigma \sqrt{1 - r_1} \]

in which:

\( \sigma \) = Standard deviation of the test scores
\( r_1 \) = Reliability of the test (chance-half method)

The standard error of measurement which was obtained from this formula was 24.31

5. Validity

Validity, according to Gerberich, has two major aspects, these being curricular and statistical. Evidence of curricular validity is presented in Chapter III. Evidence of statistical validity is presented in Tables 9 and 10. The correlations were computed in the manner described on page 39.

Table 9. Correlations Between the Revised Constructed Test and Various Criteria.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Correlation</th>
<th>Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
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<td>(2)</td>
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<tr>
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</tr>
<tr>
<td>Class Grade</td>
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</tr>
<tr>
<td>Cooperative Chemistry</td>
<td>.673</td>
<td></td>
</tr>
<tr>
<td>Test-Form X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^{10}\text{Ibid.}, p. 387.\)

\(^{11}\text{Ibid.}, p. 68.\)
Table 10. Correlations Between the Revised Constructed Test and Various Criteria. The 27 Students who Took the College Entrance Examination Board Achievement Test in Chemistry Were Used in These Correlations.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
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<tr>
<td>I.Q. Test</td>
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<tr>
<td>Class Grade</td>
<td>.538</td>
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<tr>
<td>College Entrance Examination Board Achievement Test in Chemistry</td>
<td>.508</td>
</tr>
<tr>
<td>Cooperative Chemistry Test-Form X</td>
<td>.647</td>
</tr>
</tbody>
</table>

Only twenty-seven students of the original group used in the study took the College Entrance Examination Board achievement test in chemistry. The correlation of the results on this test with other criteria is presented in Table 11.

Table 11. Correlations Between the College Entrance Examination Board Achievement Test in Chemistry and Various Criteria for Twenty-seven Students

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>I.Q. Test</td>
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<td>Class Grade</td>
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CHAPTER V
SUMMARY AND CONCLUSIONS

1. Summary of Data

The purpose of this study was two-fold: to construct and compare with other methods of educational evaluation a test to be used with the college preparatory course in chemistry that includes one laboratory period per week; and to attempt to predict success on the College Entrance Examination Board achievement test in chemistry from the results obtained on this original test.

A test was constructed containing forty-one items which met the established requirements of discrimination and which met the format requirements of good test writing as outlined in Chapter II. The items included in the test had a mean difficulty of 52.41 with a range from 28 to 79.

The reliability of the test was determined by the chance-half method and Spearman-Brown prophecy formula and was .814. The reliability as computed by the "footrule" method of Kuder and Richardson was .949.

The standard error of measurement was 4.31 using a reliability of .814.

The test had statistical validity as evidenced by a .80 correlation with class grade, using a maximum number of students.
(60) in the correlation. The correlation between the constructed test and the Cooperative Chemistry Test-Form X was .67 using forty-four students; and, finally, the correlation between the constructed test and the College Entrance Examination Board achievement test in chemistry was .508 for twenty-seven students.

2. Conclusions

The reliability as computed by the "footrule" method of Kuder and Richardson was found to be .949. This value is somewhat high in that it depends upon the percentage of right and wrong answers. The test was timed and there were questions which were not answered by students. These had to be counted as incorrect in figuring the reliability by this method. The reliability of .814 as computed by the chance half method is a minimum for the test. As shown in Table 7 the items in the test were grouped in series of five in relation to difficulty. Because of this grouping it was possible to use the chance half method to obtain a reliability on a timed test.

The standard error of measurement was 4.31 and was computed using a reliability of .814. Therefore this is a maximum standard error.

The test had content validity as evidenced by Table 2. It had statistical validity as evidenced by a .80 correlation with the class grade, using sixty students in the correlation.
The correlation of .67, using forty-four students, between the constructed test and the Cooperative Chemistry Test-Form X was below that of the correlation with the class grade because the content of the constructed test and the Cooperative Test was not the same. If items dealing with the same subject matter as the constructed test as presented in Table 2 were taken from the Cooperative Test and the scores on these items correlated, it is assumed by the writer that the correlation between the tests would then be higher.

The correlation of .508 between the constructed test and the College Entrance Examination Board achievement test in chemistry for twenty-seven students was low because of the lack of similarity in content. The writer feels that a higher correlation would be noted if similar content items were correlated.

The twenty-seven students used in the prognosis correlation were a selected group that differed to quite a degree from the original group used in the study. Tables 9 and 10 show some of the differences between these groups. A correlation of only .72 existed between the Cooperative Chemistry Test and the College Entrance Examination Board achievement test in chemistry using twenty-seven students.

The limitations of the study were several in number.

1. The writer did not have complete jurisdiction over the group being tested. Therefore the ideal pattern for the
experiment could not be followed.

2. The test could not be given as an untimed test for item analysis and then as a timed test for computing correlations and statistical validity.

3. The group used in the final correlation was much too small to obtain a very significant correlation or result.

4. The test could not be administered at the most ideal time which would have been approximately the same time that the College Entrance Examination Board achievement test in chemistry and the Cooperative Chemistry Test-Form X were administered.

3. Suggestions for Further Study

1. Additional items should be added to the test to increase its reliability.

2. Additional students should be used in the prognostic correlation and thus the predictive validity would be increased.

3. Investigate the effect of proficiency in mathematics on a high score on the test. Correlate the score on the chemistry test with the results of several tests of mathematics ability.

4. Administer the test under a non-timed situation. Conduct another item analysis in which the time element is not a factor. Then proceed to administer the test under a timed situation since the prognosis is concerned with a timed test.
5. Investigate factors which might have caused a low correlation between test scores and intelligence quotient scores.

Examine the intelligence test used to determine whether the intelligence test and the chemistry test measure enough of the same things to warrant a high positive correlation.

Attempt to determine whether the correlation between intelligence test scores and chemistry test scores is inclined to be less positive when the group being tested is selective as was this group.
APPENDIX

CONSTRUCTED TEST

Be sure you read the directions at the beginning of each group of questions.

Choose the one answer which will correctly complete the following statements.

1. The equation which represents satisfactorily the result of heating potassium chlorate is:
   (a) $\text{KClO}_3 \rightarrow \text{KCl} + \text{Cl}_2$
   (b) $\text{KClO}_4 \rightarrow \text{KCl} + \text{O}_2$
   (c) $2\text{KClO}_4 \rightarrow 2\text{KCl} + \text{Cl}_2 + \text{O}_2$
   (d) $2\text{KClO}_3 \rightarrow 2\text{KCl} + \text{Cl}_2 + \text{O}_2$
   (e) $\text{KClO}_2 \rightarrow \text{KCl} + \text{O}_2$

2. When a non-metallic oxide such as sulfur dioxide is dissolved in water:
   (a) no chemical change occurs
   (b) the resulting solution is acidic
   (c) the bond of the non-metal with oxygen is broken
   (d) the solution may be acidic or basic depending upon non-metallic oxide which is used
   (e) a larger number of OH ions is present in the solution

3. When metallic calcium acts on water the elemental gas given off is:
   (a) hydrogen
   (b) vaporized Cl
   (c) steam
   (d) oxygen
   (e) water gas

4. In the experiment concerned with the decomposition of potassium chlorate we can class the manganese dioxide as one of these:
   (a) reducing agent
   (b) drying agent
   (c) oxidizing agent
   (d) synthesizing agent
   (e) catalytic agent
5. If one unit volume of oxygen and two unit volumes of hydrogen combine at a high temperature and the water vapor formed is maintained at the same high temperature, the number of unit volumes of water vapor obtained:
   (a) is three
   (b) cannot be determined
   (c) is a fraction of one volume
   (d) is two volumes
   (e) is one volume

Questions 6-8 relate to the following data: In an experiment concerned with the synthesis of water a quantity of CuO was heated in a stream of hydrogen. The water produced by the reaction was collected by using a tube of CaCl₂ which readily absorbed the water. The following data were collected:
   (1) Loss in weight of the CuO is 4.8 grams
   (2) Gain in weight of the CaCl₂ is 5.4 grams

6. The residue in the copper oxide reaction was probably:
   (a) Cu(OH)₂
   (b) CuCl₂
   (c) Cu
   (d) CaO
   (e) H₂O

7. In the preceding experiment the weight of the hydrogen involved was:
   (a) .3 gram
   (b) 4.8 grams
   (c) 5.4 grams
   (d) 10.2 grams
   (e) .6 grams

8. In the experiment above the weight ratio of hydrogen to oxygen was:
   (a) 1 to 16
   (b) 5.4 to 4.8
   (c) 1.0 to 2.0
   (d) .6 to 5.4
   (e) .6 to 4.8

9. When magnesium burns to form magnesium oxide, 4 grams of oxygen always combine with 9 grams of magnesium. If an 18-gram sample of magnesium is burned in a closed container which contains 7 grams of oxygen,
   (a) oxidation will take place slowly
   (b) Mg₂O will be formed
   (c) MgO₂ will be formed
   (d) some Mg will be left over
   (e) the magnesium formed will contain a lower percentage of O₂
10. If three grams of potassium chlorate are decomposed to produce oxygen, determine how many 400 cc. gas bottles will be required to hold the gas formed if it is dry and at S.T.P. (Count any part bottle as another full bottle)
   (a) 1  
   (b) 2  
   (c) 3  
   (d) 4  
   (e) 5

11. In an experiment we attempt to collect a gas by downward displacement of water. The following results are observed after the generator has been operating for a 30-minute period—(1) the generator is acting vigorously; (2) only a small amount of gas had collected in the gas bottle; (3) the water in the pneumatic trough caused one's hands to hurt. Which of the following would you have to do to collect the gas in a larger quantity than is now possible?  
   (a) adjust the delivery tube and check for leaks  
   (b) add more chemicals to the generator  
   (c) set up a water exchange system in the pneumatic trough  
   (d) add some chemicals to the water in the pneumatic trough  
   (e) seek another method of collecting the gas

12. Which of the following is an alkali:
   (a) $\text{H}_2\text{SO}_4$  
   (b) $\text{CaOH}$  
   (c) $\text{HCl}$  
   (d) Zn  
   (e) FeO

13. The U. S. Government has given you the job of producing denatured alcohol. To best accomplish this task would you
   (a) add a highly volatile substance to the alcohol  
   (b) add a substance soluble in alcohol with a boiling point of about 80$^\circ$C.  
   (c) add a substance soluble in alcohol with a boiling point of 49$^\circ$C.  
   (d) add a substance soluble in alcohol with a boiling point of 151$^\circ$C.  
   (e) add a poisonous non-volatile substance to the alcohol
14. When a candle is burned completely in air, the carbon dioxide and water produced have a weight, compared with that of the candle, which is
(a) equal to the weight of the candle
(b) less than the weight of the candle
(c) sometimes less and sometimes greater—depending upon temperature
(d) greater than the weight of the candle
(e) indeterminate unless the composition of the candle is known

15. You are to test various samples of water to see if they are hard or soft water. Which of the following methods would you use?
(a) add soap to 20 cc. samples of water to be tested, then shake
(b) mix each sample with distilled water, soap, then test by shaking
(c) filter each sample, then add soap, and test by shaking
(d) add 5 cc of soap to each sample and test by shaking
(e) use 50 cc. of sample and 5 cc. of soap for each test and shake well.

Directions: Consider items (a) and (b) as one question. Indicate which would produce the most suds.

16. (a) rain water
(b) tap water

17. (a) tap water containing MgCl₂
(b) tap water containing sodium stearate

Directions: Consider items (a) and (b) as one question. Indicate the mixture which is more easily distilled.

18. (a) sulfuric acid and nitric acid
(b) sulfuric acid and water

19. (a) water and alcohol (not denatured)
(b) salt and water

20. (a) denatured alcohol and water
(b) ammonia and water
Directions: Choose the correct answer to the following questions.

21. Marble chips and hydrochloric acid yield:
   (a) CaCO₃, water and carbon dioxide
   (b) calcium chloride, water and carbon dioxide
   (c) Ca(HCO₃)₂ plus water
   (d) water + carbonic acid
   (e) CaC₂, water and carbon dioxide

22. A chemical explosion is always described as:
   (a) an endothermic change
   (b) union with oxygen
   (c) reactions between gases in which the volume of products
       is greater than the volume of reactants
   (d) a rapid exothermic change
   (e) a scattering of inflammable dust in air

23. Distilled water is used as the solvent in preparing reagents because:
   (a) it does not ionize as easily as tap water
   (b) impurities have been filtered out
   (c) it is free from impurities
   (d) distilled water is less volatile than tap water
   (e) it is less viscous than tap water

24. The greatest percentage of the industrial supply of oxygen is obtained by:
   (a) the electrolysis of water
   (b) the decomposition of potassium chlorate
   (c) the fractional distillation of air
   (d) the separation of oxygen from air by diffusion
   (e) the action of heat on an oxide of the common metals

25. If you had a mixture of water gas (carbon monoxide and hydrogen) which of the following methods would you use to separate them?
   (a) filtration
   (b) distillation
   (c) chemical action
   (d) reduction of the CO
   (e) compression

Directions: Consider items (a) and (b) as one question. Indicate that item which has the greater amount of solute by weight.

26. (a) .9M HCl - 1000 cc.
    (b) .7N H₂SO₄ - 1000 cc.
27. (a) .2 Molar NaCl - 1000 cc.  
   (b) .2N AlCl₃ - 1000 cc.

28. (a) 5M Ca(OH)₂ - 1000 cc.  
   (b) 50 grams of 50% H₂SO₄

**Directions:** Consider items (a) and (b) as one question. Indicate the solution which has the higher boiling point.

29. (a) 1.2N HCl - 25 cc.  
   (b) 1.2N H₂SO₄ - 1000 cc.

30. (a) 1N HCl - 1000 cc.  
   (b) 1N Ca(OH)₂ - 1000 cc.

**Directions:** Choose the correct answer to the following questions.

31. Sand and water do not burn because:
   (a) they have a high kindling temperature  
   (b) of the physical state in which they are commonly found  
   (c) they are not readily separated into fine particles  
   (d) their valence requirements are already satisfied by oxygen  
   (e) their electrical charges repel oxygen

32. Which of the following statements is true when pure water is formed from hydrogen and oxygen?  
   (a) electrons are shared in the process  
   (b) it is a highly ionized compound  
   (c) protons are present in large numbers  
   (d) the process is a "pure" exothermic reaction  
   (e) the process takes place at a relatively high temperature

33. Which of the following substances is released at the anode during the electrolysis of water?  
   (a) O  
   (b) SO₄⁻  
   (c) H  
   (d) OH  
   (e) SO₃⁻

34. In electrolysis of water, the addition of an acid affects the reaction by influencing:
   (a) oxidation-reduction  
   (b) ionization  
   (c) polymerization  
   (d) the degree of isomerism  
   (e) the temperature at which water boils
35. One of the following is true of hydrogen
   (a) will support combustion
   (b) liquifies very easily
   (c) a good reducing agent
   (d) is tested with a glowing splint
   (e) burns with a luminous flame

36. The reaction which takes place in the experiment involving an active metal on water is:
   (a) a chemical change
   (b) endothermic
   (c) caused by catalytic agent in water
   (d) in essence the decomposition of water
   (e) is a physical change

37. The scientific principle observed when sodium moves about on the surface of water was first identified by:
   (a) Bernoulli
   (b) Newton
   (c) Venturi
   (d) Priestly
   (e) Cavendish

38. Which of the following methods or substances cannot be used to remove permanent hardness from water:
   (a) use of ion exchange minerals
   (b) boiling
   (c) distillation
   (d) Ca(OH)₂
   (e) zeolite

39. The amount of solution resulting from the preparation of a molar solution is
   (a) less in volume than a molar solution
   (b) less in volume than a normal solution
   (c) more in volume than a normal or molar solution
   (d) equal in volume to a molar solution
   (e) equal in volume to a normal solution

40. Concerning flames -
   (a) all fuels burn with the production of a flame
   (b) the hottest portion of the flame is the innermost part
   (c) a flame is a burning gas
   (d) the reducing portion of the flame is the extreme tip
   (e) flames containing incandescent carbon are most effective for heating
Directions: Questions 41-43 refer to the combustion of propane (C3H8), the complete combustion of which yields carbon dioxide and water as the only products.

41. How many carbon dioxide molecules are formed from each molecule of propane?
   (a) 5
   (b) 1
   (c) 4
   (d) 3
   (e) 2

42. How many water molecules are formed from each molecule of propane?
   (a) 6
   (b) 8
   (c) 5
   (d) 2
   (e) 4

43. How many atoms of oxygen are needed for the complete combustion of one molecule of propane?
   (a) 15
   (b) 3
   (c) 10
   (d) 2
   (e) 5

44. Solubility of NaNO₃ in water depends upon
   (a) the pressure of the air above the solution
   (b) the temperature of the water
   (c) the rate at which the salt is added
   (d) the rate at which the salt dissolves
   (e) the amount of salt added

45. When concentrated HCl is placed in distilled water
   (a) a chemical change takes place
   (b) acid is added to the water
   (c) an endothermic reaction takes place
   (d) an electric current is generated
   (e) water is added to the acid

46. A normal solution contains:
   (a) more solute than a molar solution
   (b) equal or less solute than a molar solution
   (c) more solute than a molal solution
   (d) more solvent than a molal solution
   (e) more solvent than a molar solution
47. In the synthesis of water from CuO and hydrogen we can say the resulting copper formed is in the form of:
(a) ions
(b) diatomic molecules
(c) triatomic molecules
(d) electrically charged particles
(e) none of these

48. The copper formed when water is produced by synthesis from CuO and hydrogen is the product of the following chemical process:
(a) single replacement
(b) decomposition
(c) synthesis
(d) double replacement
(e) double decomposition

49. When potassium chlorate is heated it decomposes to form potassium chloride and oxygen. Which of the following inferences may be drawn most accurately?
(a) The potassium chlorate has been decomposed, further heating will decompose the potassium chloride
(b) oxygen containing compounds usually lose oxygen on heating
(c) cooling a mixture of potassium chloride and oxygen will result in the formation of potassium chlorate
(d) Potassium chlorate has more kinetic energy than potassium chloride
(e) the resulting mixture of potassium chloride and oxygen has more potential energy than the potassium chlorate.

50. How much solvent is contained in 400 grams of a 10% solution of NaCl?
(a) 40 grams
(b) 290 grams
(c) 360 grams
(d) 400 grams
(e) 390 grams

51. One ml of a .2N NaOH solution contains how many grams of solute?
(a) .008
(b) .8 grams
(c) 4 grams
(d) .04 gram
(e) .02 gram
52. How many ml. of .1N solution of NaOH would be needed to titrate 10 ml. of .15N HCl acid solution?
(a) 1.5 ml.
(b) 6.67 ml.
(c) .667 ml.
(d) 66.7 ml.
(e) 15 ml.

53. Whenever titration reaches its end point we say that one of the following amounts or quantities has been added:
(a) equivalent amounts
(b) unequal amounts
(c) unequal ionic quantities
(d) equivalent quantities
(e) equal quantities

54. In the titration of a .1N solution of sulfuric acid by a .1N solution of NaOH we find the volume ratio of sulfuric acid to NaOH used to be one of the following when the end point of titration is reached:
(a) 1:2
(b) 1:1
(c) 2:1
(d) 3:1
(e) 1:3

55. All the air must be removed from a burette tube before titration because the volume of solution delivered will be:
(a) oxidized
(b) ionized
(c) increased
(d) decreased
(e) diluted

56. If we examine the water solution of hydrogen chloride gas that is formed in the gas bottle which contained a small amount of water at the beginning of the experiment we see that the liquid formed
(a) is discolored
(b) is heavier than water
(c) is colloidal in nature
(d) is not a true solution
(e) is non-volatile in nature
57. All the following substances are used in testing for a chloride except:
   (a) silver nitrate
   (b) aqua fortis
   (c) HNO₃
   (d) ammonia water
   (e) oil of vitriol

58. Sulfuric acid is used in the formation of hydrochloric acid because
   (a) it is a good oxidizing agent
   (b) of its high specific gravity
   (c) it ionizes to a high degree
   (d) it has such a high boiling point
   (e) it reacts with chlorides much more rapidly than HNO₃

59. What is the percent by weight of HCl gas that dissolves in water?
   (a) 50,000
   (b) 37
   (c) 500
   (d) 98.2
   (e) 35.5
BIBLIOGRAPHY


