A PROPOSED PLACEMENT PROGRAM FOR FRESHMAN CHEMISTRY STUDENTS
AT KANSAS STATE COLLEGE

by

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INTRODUCTION

The educational objective which underlies all scientific guidance is that the educator should keep each student working at his highest natural level for successful achievement in a field for which he has reasonable aptitude. Each year hundreds of students are enrolled in one of the three beginning courses of chemistry at Kansas State College. These students, who are at numerous levels of achievement and aptitude in the field of chemistry, find themselves in a very heterogeneous group when classes meet. This situation accentuates feelings of both superiority and inferiority. The instructor must assume all students to be at the zero level of achievement and of equal aptitude; conversely, the course should progress at a rate suitable to those students of greater achievement and more aptitude. Under the prevailing circumstances, each student cannot receive the right course material at the correct speed for his natural level of achievement and aptitude.

Interest in segregation and a feeling of need for some type of a placement program preceded any activity by approximately 10 years. The earlier programs were initiated in the early 1920's. Interest increased for the next several years until there were a number of institutions which were actively engaged in such a program.

Mattern's survey in 1928 of 50 institutions was one of the first extensive surveys. At the same time Cornog and Stoddard, of the University of Iowa, were initiating their testing

program which included placement tests for chemistry. Activity remained constant until the beginning of World War II when decreased enrollments hindered the administration of the placement program. Since the war, there is evidence of renewed interest and activity.

One may expect this type of work to become an increasingly important phase of the whole chemistry program, if not of the entire educational program.

The purpose of this thesis is to organize a proposed placement program which will guide each student who enrolls in Freshman Chemistry at Kansas State College into a class where he may progress at a rate commensurate to his achievement and aptitude.

To assure the construction of an educationally sound and practical placement program, the author set up the following procedures: (1) To secure advice from and work in cooperation with the administration of the Department of Chemistry at Kansas State College. (2) To determine the usability of available information from the testing program which is administered by the Counseling Bureau at Kansas State College. (3) To examine the literature which describes similar programs which have been carried on at other institutions. (4) To accumulate, by questionnaire, adequate information from various institutions where a testing program for the purpose of student placement in beginning chemistry is already in effect, in order that it may be used as a partial basis for organizing a satisfactory placement program at Kansas State College. (5) To develop or compose a combination achievement and aptitude test in chemistry

which may be used to determine the status of each student at the time of his enrollment so that he may be placed in a section which conforms to his level of achievement and mental potentiality.

RESEARCH RESULTS

Summary and Interpretation of the Data
from the Research Survey

A qualitative research survey seemed more pertinent as a partial basis for the proposed placement plan than a quantitative survey. Accordingly, 30 institutions were selected more or less at random from an alphabetical list of all institutions in the United States having a chemistry department approved by the American Chemical Society.

A postal card questionnaire was sent to each of these 30 institutions to ascertain whether or not they participated in some type of a placement plan for their freshman chemistry students. Twenty-seven answers were received from the 30 inquiries. Of these 27 answers, 18 institutions reported that they were actively engaged in some type of a placement program. This is a fair indication that a sufficient percentage of institutions participate in this type of program to merit the use of a summary of their plans as a partial basis for a proposed placement plan at Kansas State College.

A second detailed questionnaire, a sample of which is in-

cluded in the Appendix, was then sent to the 18 institutions which indicated that they were following some type of placement plan. An interpretation of the data received from these institutions appears in the following pages.

From the answers to the questionnaire, it was found that no one segregation device or any certain combination of devices was being used consistently. Almost all institutions (14 of 18) depended upon at least two devices for a basis of segregation, an indication that they believe this method to be more accurate for predictive purposes than the use of only one device. Apparently, preliminary segregation by curriculum is considered to be a sound educational policy. This preliminary segregation is then followed by other means of segregation within the various chemistry curricula. Segregation by curriculum refers to the separation of students into interest fields such as Home Economics, Engineering, Agriculture, and Chemistry. Almost one-half of the institutions surveyed agreed that they could more validly predict a student's success by surveying his high school achievement, but very few relied on that method alone.

The achievement tests used were most consistently divided into three sections: namely, mathematics, chemistry achievement or aptitude, and reading comprehension. Statistics furnished by several institutions indicated high validity and reliability on this type of achievement test. Several replies indicated satisfaction with this type of segregation device, while two institutions found other devices to be more desirable for their pur-

pose. The University of Illinois, which formerly segregated students in freshman chemistry by the use of a placement test, now uses the grades made in high school as a basis for segregation, having found that the results were just as good and that this method was much less work. The University of Wisconsin formerly segregated its chemistry students by use of a placement test but discontinued this practice when some students deliberately failed the test so that they would be placed in a lower level group. Segregation at that institution is now based on high school credit presented for enrollment.

In a few cases, the intelligence test was used to increase the prognostic value of some other primary device. Apparently, a high intelligence test score did not assure a comparable achievement and so did not have high predictive value.

The California Institute of Technology has been using an entrance examination for a basis of segregation. This examination is composed of sections on physics, chemistry, mathematics, and English. Princeton University has been using an entrance examination as a basis for segregation. This examination is mainly an achievement test in chemistry.

Those institutions that use some form of an achievement test for segregation are approximately equally divided as to whether or not the test should be given to just those students who presented credit in high school chemistry. Washington University gives the same test to both groups because frequently students with no high school credit in chemistry rank in the

upper division of scores.

Whatever plan of segregation has been used, a vast majority (13 of 17) of the institutions required freshman chemistry students to be placed in different sections. A few institutions placed the initiative with the student; after receiving his score on the placement test, each student selected his own level. A number of institutions stated that they made their system flexible enough that students, upon the advice of the instructor, could be transferred from one section to another which better fit his standards of achievement and ability.

Institutions making use of a placement plan resorted to two levels more often than three. The use of three levels involved more problems of assignment of students to classes and assignment of teaching schedules to instructors; however, it gave more homogeneity than would the use of two levels. Washington University of St. Louis desired more than three levels, but the problems previously mentioned prohibited the use of this plan.

The greater number (13 of 18) of institutions applied the segregation device before enrollment, usually during freshman orientation week. This method makes possible the completion of the placement of students before the first class meets.

Quite uniformly, segregation was effected in lecture and laboratory as well as in recitation; however in several cases, all the students were placed together in the lecture, particularly when the same text book was used in all of the sections. Of the 11 institutions where segregation was provided in lecture, 7 used different text books in the various levels.

One-half of the institutions used the same text book in all sections, while the other half used a different book; however, to fit more nearly the needs of the group, some institutions that did use the same text book made some omissions or additions for certain levels or curricula. The number of institutions reporting the use of different text books is high because they did not distinguish between segregation by curricula and within the curricula. Naturally different text books of chemistry may be used in different curricula. Only in a small percentage of cases were different manuals used in the various sections of laboratory. In those cases, different text books were also used.

A large majority of the institutions (13 of 16) carried their plans of segregation over into the second semester. These institutions favored basing the second semester sectioning upon first semester performance.

One-half of the institutions required the same total amount of time per semester in all levels, while the other half did not. Apparently no relationship existed between the time required and whether or not the same text book was used. Generally speaking, for those institutions which required variable amounts of time, the chemistry majors and the lower level groups were required to spend more time in the course.

Sixty-five per cent of the institutions gave equal credit for all levels. In almost every case where the credit hours varied, time requirements also varied. In 4 cases, where high level groups and chemistry majors put in more time, more credit

was given. This was not the practice with the lower level groups.

The basis for some of the interpretations listed above does not appear in the table. Rather it appears in the remarks submitted on the second questionnaire. In several instances an institution reported only an achievement test as a basis for its segregation. In such instances when the test consisted of separate sections, they were tallied as separate devices.

An over-all interpretation of the research survey seems to indicate extensive variability in the 18 placement plans studied. The modal pattern would make use of several segregation devices, applied to all students prior to their enrollment in freshman chemistry. On that basis, the students would then be divided into either two or three levels. This segregation is particularly important in recitation and laboratory, and is carried over into the second semester on the basis of first semester performance. In any one curriculum the same text book is being used with some omissions. To attain an equal number of credit hours, more class time is required of those students in the lower levels than of those in the higher groups.

An Analysis of the Prognostic Value
of Available Information

During Freshman Orientation Week, a series of Examinations is given by the Counseling Bureau of Kansas State College. This series includes among others a mathematics and an ACE examina-

tion. To determine the degree of correlation between scores on these tests and the final grades made in freshman chemistry, the author selected at random the final chemistry percentage scores for 99 students, and tabulated these along with the respective percentile scores in the mathematics and in the ACE examinations.

The mean chemistry final grade was 69.4 with a standard deviation of 17.5 and a standard error of the mean of 1.77. In interpreting this data, one could safely predict that for 95 per cent of the samples that might be chosen, the mean of the universe has been included within 1.96 standard deviations from the mean of the sample considered.

The mean mathematics percentile score was 49.8 with a standard deviation of 29.1 and a standard error of the mean of 2.94.

The mean ACE percentile score was 47.9 with a standard deviation of 29 and a standard error of the mean of 2.93.

Correlation coefficients were determined between the final chemistry grades and the ACE scores. There was a correlation of 0.54 between the mathematics scores and the final chemistry grades, which gives an r/S.E. of approximately 6 so that one can conclusively say that a positive correlation exists.

In terms of the standard error of estimate, chances are 2 to 1 that by using a known mathematics score as a basis, one can predict within 15 points a final chemistry percentage grade. As an index to forecasting efficiency, the extent of errors of prediction from a knowledge of the correlation between these two variables could be reduced by at least 16 per cent.

A correlation of 0.50 was obtained between the final chemistry grades and the ACE scores. Apparently the ACE scores could be used, but less effectively than the mathematics scores since the forecasting efficiency would be slightly lower.

In another method of comparison of the mathematics scores and the final chemistry grades, it was found that of the 99 students previously mentioned, 27 rated in the upper quartile of the mathematics examination; of these 27 students, 22 made a percentage rating of at least 75 or above in their final chemistry grade; of these 27 students, 4 made a percentage rating between 50 and 74, while only 1 fell below 49 per cent.

Twenty-five of the 99 students rated in the lower quartile of the mathematics examination. Of these 25, 3 had a percentage average above 75; 9 averaged between 50 and 74 per cent; 11 averaged between 25 and 49 per cent; and 2 averaged less than 25 per cent.

A similar treatment of the combined mathematics and ACE examination scores in relation to the final chemistry grade did not show any significantly greater efficiency in determining probable chemistry grades in regard to categorical ratings.

On the basis of a selection ratio in predicting who will do satisfactory work in chemistry, based on a rough estimate of previous standards, the following hypothetical case might be set up: Suppose that on the average, 80 per cent of the students enrolled in Freshman Chemistry did satisfactory work. Through the use of a prediction ratio table formulated by H. C. Taylor

and J. T. Russell[1], one can show that a correlation coefficient of 0.54 indicates that 95 per cent of the students who ranked in the upper quartile in the mathematics examination would do satisfactory work. This percentage reveals a close correlation with that found in this study, for of the 27 students who ranked in the upper quartile on the mathematics examination, 25 did satisfactory work, a percentage of nearly 93 as compared to the previous percentage of 95.

In conclusion of this phase of the study, considering the prognostic value of the available devices, it is quite certain that the addition of a standardized achievement and aptitude examination in chemistry, as a placement device, would increase even more our ability to properly place students according to their aptitude and achievement.

THE PROPOSED PLACEMENT PROGRAM

The Segregation Device

Earlier studies by Bird, Scofield, MacPhail and Foster, Smith, and Ruesser confirm the results of the research done at Kansas State College on the correlation between the final chemistry grades of 99 students and the scores they received in the

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[1] H.C. Taylor and J.T. Russell, "The Relationship of Validity Coefficients to the Practical Effectiveness of Tests in Selection: Discussion and Tables," Journal of Applied Psychology, American Psychological Association, XXIII (1939), 565-78.

mathematics and the ACE tests. The results were also in agreement with the general consensus based on a summary of the research survey from the 18 institutions. These two phases of research indicate the possible use of the mathematics and the ACE test scores as a basis for placement of the freshman chemistry students, but they also indicate that their predictive value can be increased by the use of certain additional factors.

A brief review of the correlation between various devices, or combinations of devices, and final chemistry grades will substantiate the preceding statements. In the local research work, a correlation of 0.54 was obtained between the mathematics test scores and the final chemistry grades. In the research survey, Washington University of St. Louis reports "surprisingly good" correlation between the placement test scores and final chemistry grades. The placement test was composed of sections on mathematics, chemistry achievement, and reading ability. The basis for the use of this particular type of a test is the result of four years of experimentation. The University of California has used the placement plan for many years and in doing so has accumulated information and statistics on various correlations. The placement test which this institution has found to predict best the student's success is a combination of sections on meanings of terms, chemical facts, ability to read, and problems in chemical arithmetic. Information supplied by that institution gave a correlation between the final chemistry grades of 50 students and their scores on the placement test of about 0.62. Under this placement plan, it is significant that the percentage

of failures is low. One group of 90 students had only 1.1 per
cent failures; another group of 112 students had only 4.5 per
cent failures. The percentage of failures at Kansas State
College for first semester freshman in chemistry varies from 15
to 20 per cent. The University of California rejects a small
percentage of students whose scores are excessively low on the
placement test. The information supplied shows the failing stu-
dents to have the most difficulty with the section on problems.
Dr. J.H. Hildebrand, of the Chemistry Department at the Univer-
sity of California, expressed his pleasure with the homogeneity
produced by this method of sectioning.

A detailed study of failures in beginning chemistry courses
was made at Michigan State College. This study indicated that
insufficient facility in simple arithmetic and reading ability
was one of the principal causes for failure. It is believed
that, by the use of a chemistry pre-test including these two
phases, 25 to 30 per cent of the present failures could have
been eliminated. The students eliminated by this test are re-
quired to take remedial work in arithmetic and reading. A
block graph, constructed by K.L. Bird of Stanford University,
indicated a high degree of correlation between chemistry apti-
tude scores and the final grades in the course.[1] MacPhail and

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[1] K.L. Bird, "The Use of an Aptitude Test as a Basis for
Sectioning Freshman College Chemistry Students," Journal of
Chemical Education, VII (May, 1930), 1121.

Foster of Brown University found a correlation of 0.56 between the Iowa Chemistry Training Test scores and final chemistry scores. They also found a multiple correlation coefficient of 0.638 between final grades in chemistry and the scores received on the Iowa Chemistry Training Test and on the mathematics section of the Sones-Harry High School Achievement Test.[1] These men also found a correlation of 0.57 between final chemistry grades and the scores from the Iowa Chemistry Training Test combined with the standing of the student in his high school graduating class.[2]

Several studies indicate that the use of the student's intelligence test score as a segregation device is not as valid as other available devices. It has been found that at Kansas State College, a correlation of 0.50 exists between final chemistry grades and intelligence test scores. It was also found that there was no significant increase in predictive value from its use in combination with the mathematics test scores. Ruesser found that both the Chemistry Training Test scores and the Chemistry Aptitude test scores correlated more highly with final chemistry grades than did the intelligence test scores.[3] He

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[1] A.H. MacPhail and L.S. Foster, "Placement in Beginning Chemistry Courses at Brown University," Bibliography Journal Chemical Education, XVI (June, 1939), 271.

[2] A.H. MacPhail and L.S. Foster, "New Data for Placement Procedures," Journal of Chemical Education, XVIII (May, 1941), 235.

[3] W.C. Ruesser, "Predicting Success in First Year College Chemistry," Sch. and Soc., XL (August 11, 1934), 199.

also pointed out that the combination of these devices did not increase the correlation. Michigan State College found that chemistry pre-test scores correlated more closely with final chemistry grades than psychological test data.

On the basis of these studies, it is proposed that the segregation device consist of a test which will be composed of sections on mathematics common to chemistry, on chemistry aptitude interspersed with a small portion of chemistry achievement, and on reading comprehension in the field of chemistry. Additional information such as credit and grades in high school chemistry, physics, and algebra should be made available on the test sheet by the student. This information could well be used by the placement officer as an aid in more accurate placement.

Segregation by curriculum is already in effect at Kansas State College. This plan which groups students by their interest fields may be considered as an extra aid in assuring each student a proper course in freshman chemistry.

It is suggested that, when the placement program is initiated, only one curricular type of chemistry be involved until further experience is gained. This would also give time for standardization of the testing device and the improvement of the program as a whole.

A sample of the Iowa Chemistry Aptitude test is included in the Appendix. This test may be purchased at a cost of $4.00 a hundred. Oklahoma A & M uses the Iowa Chemistry Achievement test for segregation of chemistry majors and chemical engineers. Nebraska University formerly used the Iowa Chemistry Aptitude

test as its segregation device.

A sample of another usable test, formulated by the author, for segregation purposes is included as a portion of this thesis. It is patterned after samples of tests which were received from Colorado University, Washington University, Michigan State, and the University of California. This test, if used, would need to be standardized after its inception. Further study would then be necessary to determine its validity, reliability, and prognostic value as a placement device.

Scope of Application

Statistics from the research survey show that 4 institutions gave the same test to all of the students, regardless of whether or not they had taken high school chemistry. Three institutions apparently gave the test only to those students with no high school chemistry credit, or to those students who were enrolling in one curricular type of chemistry. Following are 4 alternative plans for various scopes of application of placement tests. Most of these plans have both advantages and disadvantages, some of which will be mentioned.

The first alternative plan emphasizing chemistry achievement, includes a placement test to be given to those students who present credit in high school chemistry at enrollment. Another test emphasizing chemistry aptitude could be given to those students who do not present credit in high school chemistry. The use of both tests would involve the problem of equat-

ing one test against the other. If this could be done satis-
factorily, valid and reliable results should be obtained; for
the achievement test usually has the highest predictive value.
There is, however, some question as to whether or not these
tests can be satisfactorily equated.

Under a second plan an achievement test is administered
only to those students who present credit in high school chem-
istry. This plan segregates those students into various levels
but, automatically places all students who have not had high
school chemistry in the lower level. This plan does not take
into consideration all of the potentially good students who do
not present credit in high school chemistry at enrollment.
Washington University has found that frequently students who
have not had chemistry in high school rank in the upper range
of the placement test scores, even though the test had been
given to all of the students. The University of Nebraska finds
that approximately 10 per cent of the students not having had
high school chemistry rank in the highest level group.

A third plan segregates on the basis of scores received on
a chemistry aptitude test only those students who do not present
credit in high school chemistry. This plan automatically places
all those students who present credit in high school chemistry
in the upper level group. The University of Nebraska finds a
sizeable percentage of students having had high school chemistry
ranking in the lower quartile of a placement test. The fact
that various high schools have different grading standards and a
variable quality of teachers makes this method unreliable. From

experience, the writer knows frequently a student who has had high school chemistry fails the college freshman course because of the reasons stated previously or because of the development of a false sense of security which leads to careless study habits.

A fourth plan, that which is proposed, rates most desirable from these various standpoints. This plan would give the outstanding freshman chemistry students who have had no high school chemistry an opportunity to be placed in the upper level group, so that they may make more effective use of their capabilities. This plan gives some consideration to the advantage of having had high school chemistry; yet, it separates those students who have had a poor course in high school chemistry. With this plan the same test is administered to all freshman chemistry students regardless of whether or not they present credit in high school chemistry. The test that best fits these suggestions is the one which is composed of a section on mathematics common to chemistry, a section on chemistry aptitude interspersed with a small portion of chemistry achievement, and a section on reading comprehension of chemical literature.

Is Placement Required or Optional

After the placement test has been administered and scored, should the student be required to enroll in the section which most nearly fits his achievement and capacity, or should he be given the prerogative of choosing his section? The students at

all levels must realize the significance of being placed in a
proper section of chemistry. Many students, if the initiative
is placed with them, will follow what they think to be the line
of least resistance; that is, they would enroll in a level
below their capacity just to have less competition. This pro-
cedure would partially defeat the purpose of this program.

The research survey indicated that a large majority (13 of
17) of institutions required all freshman chemistry students to
be guided into certain classes by the use of a placement plan.
With the results of this survey as a basis, it is proposed that
placement in a specific section of chemistry be required. To
discourage a recurrence of the "deliberate failing" of the
placement test that occurred at Wisconsin University, the plan
should be made flexible. This flexibility would allow the
shifting of the student from one level to another, upon presen-
tation of sufficient evidence by the instructor.

Number of Levels

The question of the number of levels is usually solved by
the size of the enrollment in freshman chemistry and the number
of available teaching personnel. Although complete homogeneity
cannot be attained, the degree of homogeneity increases with an
increase in the number of levels. It is quite generally be-
lieved that the greater the degree of homogeneity, the easier
and more effective is the teaching. The opportunities to keep
each student at his highest level of accomplishment are in-

creased since the rate of progress may be governed to a greater extent than it may be in groups representing various levels of achievement and ability.

It is proposed to use three levels in the placement program advocated in this study since three levels will fit more nearly than will two levels a normal distribution of the students. These divisions can be made, assuming normality, on the following basis: ±0.85 sigma from the mean on the placement test will include the middle 60 per cent of the students, who will make up the middle level. Approximately 20 per cent of the students will score more than 0.85 sigma above the mean of the placement test, which will place them in the upper level group. Approximately 20 per cent of the students will score more than 0.85 sigma below the mean of the placement test, which will place them in the lower level group. For example, in 18 sections of 20 students each, there would be 11 or 12 sections at the middle level, three at the high level, and 3 or 4 at the low level. That approximately 20 per cent of Kansas State College freshman chemistry students receive failing grades partially justifies placing those who rank in the lower 20 percentile at the lower level. The enrollment in each of these low level classes should be held to 20 students to produce the best possible results.

Partial facility for the shifting from one level to another of those students whose accomplishments are greater or less than their indicated ability may be obtained by scheduling the high and the low level classes at hours when some of the middle level classes are scheduled.

The author proposes the use of three levels in Chemistry II as well as in Chemistry I, these levels to be determined on the basis of grades in Chemistry I. A normal distribution would place in the high level group those students making an A in Chemistry I. It would place those students making B or C in Chemistry I in the middle level group. It would place those students making D in Chemistry I in the low level group.

Should the Device be Applied
Before or After Enrollment

It is proposed that the placement test be given during Freshman Orientation Week. That 13 of the 18 institutions applied the segregation device before enrollment presents convincing evidence that this is the best time. To have the student in the proper class at its first meeting would be the ideal situation. The program could get underway immediately. Less confusion would be experienced if the student is identified with a definite class at the time of his enrollment.

The Counseling Bureau at Kansas State College will administer and score, by machine, the placement test. The dividing points, on the basis of the previously stated method, would then be determined. The student's score on the placement test, in addition to the proper course to which he should be assigned, should appear in the student's Dean's card. This information may be presented, by the student, to his enrollment officer at the time of his enrollment. This procedure is used for guidance

into proper classes by the English Department at Kansas State College.

Second-semester segregation, upon the basis of first semester grades in Chemistry I, should occur at the first meeting of the classes after enrollment. In so far as possible, classes may be scheduled by triplicates to facilitate the shifting of the students from one level to another.

Should Segregation Apply to Lecture and Laboratory as Well as to Recitation

L.W. Mattern's survey indicated more variation and modification in laboratory than in lecture and recitation.[1]

The crux of the entire placement program depends upon segregation in the recitation sections. On the basis of this statement, it is proposed to provide segregation in the recitation sections.

The research survey portion of this study revealed that all but one of the institutions which segregated in recitation also segregated in laboratory. One-half of the institutions surveyed segregated in lecture. This is an indication that at least one-half of the institutions believe that segregation in lecture is not necessary, particularly when the same text book

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[1] L.W. Mattern, "The Correlation of High School Chemistry with First Year College Chemistry," Journal of Chemical Education, V (December, 1928), 1627-1633.

is used at all levels. Considerable difficulty would be experienced in scheduling a sufficient number of lecture sections for the three levels. Since the lecture as used at Kansas State College, is an illustrated prevue of the week's assignments, the usefulness of lecture segregation is decreased. The lecture period also serves as the quiz section for the students. Since it is recommended to administer the same examinations to all levels, sectioning in lecture serves no real purpose. Therefore, segregation of the students in lecture is not advocated.

If the enrollment is sufficiently high to permit flexibility in scheduling laboratory sections, segregation in laboratory is strongly proposed. Segregation in laboratory is apparently just as vital to this program as segregation in recitation. A good reason for this proposal is that one can observe more individuality in laboratory work than in recitation work. Furthermore, laboratory work is a mere repetition of procedure to the student who has had high school chemistry. In such cases segregation would provide a more appropriate environment for the practice of scientific procedure.

With the present enrollment at Kansas State College, there are approximately 15 laboratory sections in Chemistry I. Of this number, not more than three sections for each of the high level and low level students need be scheduled. This division provides for a nearly normal distribution of students.

If insufficient enrollment interferes with the flexibility

in scheduling laboratory sections, segregation is not proposed. In that event a substitute system for segregation is proposed. A number of experiments, mainly quantitative and qualitative should be made available for those students who do not feel the need of duplicating previous experimental work. Oral quizzing on these additional experiments could then supplement the regular laboratory examinations. Under this system an extra laboratory period per week and an instructor should be made available for the "slow" students. This practice is in keeping with the philosophy that there should be few failures among students taking chemistry as a terminal course.

There is no real need for segregation in Qualitative Analysis which is given in conjunction with Chemistry II in some curricula. Homogeneity is automatically increased because experience has shown that the lower level students are usually not in curricula which require Qualitative Analysis. In addition, the course is so designed that the students may progress at their own speed.

Should the Same Text and Laboratory Manual be Used in All Sections

Since the number of institutions using different text books for each of the levels was the same as the number which used identical textbooks in all sections, the advantages apparently equal the disadvantages. The decision on this question needs to be integrated with other portions of the program. If it is de-

cided not to segregate in lecture; if the same examinations are given to all levels; and if more time can be made available to the lower level group; then, the use of the same text book for all levels is proposed.

Consistency of philosophy of the entire placement program favors the incorporation of current reference material into the higher level course. Class discussion would naturally tend toward theoretical chemistry. Few omissions of text-book material would be necessary in any of the levels, especially if extra discussion periods are made available for the lower level groups. If different text books should be used, the student would need to delay the purchase of a text book until after his placement in the proper section. The use of different textbooks would also involve a separate testing program.

The decision to use different laboratory manuals depends largely on whether or not segregation is provided in laboratory. Theoretically, a complete separation of the levels, with different laboratory manuals, would make more nearly possible the application of the theory underlying this program; that is, to place each student in a class where he can most profitably and economically function. However, this method would be quite impractical from an administrative view point. To avoid difficulty, the use of a different laboratory manual in only the high level sections is proposed. This manual should be more quantitative, more qualitative, and should include more problems than the manual which is used by the other two levels.

If the number of laboratory sections is too small to war-

rant segregation because of decreased flexibility in the scheduling, then it is proposed that all students use the same laboratory manual. This plan necessitates the availability of an adequate number of optional exercises, mainly qualitative and quantitative in nature, for the higher, level students. Those experiments which duplicate high school experiments should probably be omitted in favor of unexplored fields, as repetition may invite the student to "dry-lab." The use of this plan places emphasis on the instructor's ability to supervise adequately the work of the better students. The criteria for measuring student success in these optional exercises should be the degree of independent thought and action together with accuracy of results.

Should the Plan Apply to One or Two Semesters

This question is pertinent for the two-semester course which is required in some curricula. Thirteen institutions in the survey indicated that they projected the placement program into the second semester. Basically, the policy would be inconsistent if such were not the case; hence, second-semester segregation is proposed. The students failing the first semester of chemistry will automatically be eliminated from Chemistry II, thus raising the average achievement and ability of the group. There still will be considerable heterogeneity among the students so they will need the same consideration as those

in Chemistry I.

It is proposed that placement in Chemistry II be made on the basis of first-semester grades. Washington University of St. Louis uses this method.

With a random selection of 50 students from 1948-'49, a correlation of 0.674 was found between their first and second semester chemistry grades. Considering correlation coefficients previously mentioned, together with the fact that Chemistry II students are a more homogeneous group, this method seems to offer the most usable basis for segregation in Chemistry II.

Should the Same Total Time be Required in All Levels

The research survey indicated an equal division on whether or not the same total time should be required in all sections. Therefore, the question seems to be a matter of local option.

From practices reported by various institutions, it is proposed that the two upper level groups be required to spend the same total amount of time per credit hour, as now required at Kansas State College. For the lower level group, it is highly recommended that, in addition to the regular required time, extra discussion periods be made available during the week for purposes of review and further explanation. Attendance at these discussion periods would be optional for the students. The author had found, by experience, that most students who are not

doing well in chemistry appreciate the opportunity of attending these extra sessions if their schedules permit. These discussion periods should be a definite portion of an instructor's teaching assignment and should be scheduled and announced after placement has been effected.

A similar procedure seems desirable for the lower level students in laboratory. Several extra laboratory periods per week might well be scheduled for review and "catch-up" work. The number of extra periods for both recitation and laboratory may be adjusted to fit the need.

Should the Same Amount of Credit be Given in All Sections

In keeping with the rest of the proposed program, it is proposed that the same amount of credit be given in all sections. This proposal is consistent with the thinking of the majority of the institutions surveyed. To give a different number of credit hours at the three different levels may destroy the balance within the curricula of the various schools.

Those institutions which give different amounts of credit in different levels use different text books or require different amounts of time per week. Under this plan the lower level group spends additional time per credit hour to compensate for the lack of background or ability. This is a policy which is already accepted by many students as a means to reach their desired goals or to maintain certain standards.

It is understood that the present amount of credit will be

retained for each curricular type of chemistry.

Credit by Examination

Credit by examination is proposed as a supplementary device to this placement program. Such a procedure assures even greater satisfaction and more definite results from participation in the program. Some few students who have a high level of intelligence and who have completed an excellent course in high school chemistry can undoubtedly pass a general examination over freshman college chemistry. Should they choose this plan and pass the test successfully, Chemistry majors would be given credit for that course along with the privilege of enrolling in an advanced course. Others would use the credit to meet chemistry requirements of their curricula. Several institutions, such as the universities of Buffalo, Ohio State, California, Illinois, Syracuse, Mills College, Antioch College, and Muskingum College, now give chemistry credit by examination, according to a study made by W.F. Ehret in 1948. According to his report, credit by examination meets with the approval of the Chairman of the Committee on Professional Training of the American Chemical Society; hence it may be expected that this plan will not interfere with the accredited standing of a college or university. This plan furnishes incentive to better high school teaching; it increases

efficiency of college teaching by removing "fast" students.[1]

R.J. Perry's research done in the United States Coast Guard Academy at New London, Connecticut, indicated the uselessness of repetition of chemical facts and description which had been received in high school chemistry. This study indicated that the better students in high school chemistry, after skipping elementary college chemistry, do just as well in advanced courses of chemistry as those who take their first year college chemistry.[2]

It is interesting, however, to know that another study by M. Meyer found that 87 per cent of 160 students indicated they found it worthwhile to take a year of college chemistry after having had high school chemistry.[3] The other 13 per cent evidently did not believe it to be worthwhile.

SUMMARY

The philosophy underlying the entire proposed placement program is to make available to each student who enrolls in

[1] W.F. Ehret, "Correlation of High School and College Chemistry Courses," Journal of Chemical Education, XXV (December, 1948), 669-701.

[2] R.J. Perry, "A Re-evaluation of Methods of Teaching First-year College Chemistry," Journal of Chemical Education, XX (October, 1945), 497-500.

[3] M. Meyer, "A Case Study of College General Chemistry," Journal of Chemical Education, XX (July, 1945), 325-336.

freshman chemistry at Kansas State College a course in which
he can progress at a speed commensurate to his level of a-
chievement and aptitude.

All freshman chemistry students should be segregated into
three levels of achievement and aptitude by means of a place-
ment test, given during freshman orientation week. Flexibility
of the program should allow shifting of students from one level
to another wherever necessary. Segregation should apply in
recitation and laboratory only. Since the scheduling of lab-
oratory sections is subject to limitations, not applicable to
recitation sections, it may be necessary to follow an alterna-
tive plan of making available optional exercises for the higher
level students and more time for the lower level students. The
same text book should be used in all three levels, and the same
amount of credit should be given all students although extra
discussion periods should be made available for the lower level
students.

A supplementary detail allows the giving of credit for
Chemistry I on the basis of an examination given at the begin-
ning of the semester to those few students who have had high
school chemistry and who may request such an examination.

Some of the benefits derived from this placement plan are
these: (1) A higher level of achievement for each student. (2)
Less repetition for the higher level students with credit in high
school chemistry. (3) A better relationship among the students
within the class. (4) Increased opportunity for the lower level

students to succeed in the course. (5) More effective college teaching. (6) An incentive for better high school teaching, and also for learning on the part of the pupil. (7) A basis for selection and guidance of those students majoring in Industrial Chemistry or Chemical Engineering.

Suggested fields of further study and investigation include: (1) Standardization of the placement test constructed by the author of this thesis. (2) Determination of the predictive value of the placement test. (3) Determination of the effect of the program on the percentage of failures in freshman chemistry. (4) A factor analysis of success in freshman chemistry.

ACKNOWLEDGMENT

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APPENDIX

The first questionnaire was sent to all of the following institutions and the second questionnaire was sent to the institutions which are starred.

Prof. Linus Pauling *
Calif. Inst. of Technology
Pasadena 4, Calif.

Dean Philip A. Leighton
Stanford University
Stanford University, Calif.

Prof. Paul M. Dean *
University of Colo.
Boulder, Colo.

Prof. Roger Adams *
University of Illinois
Urbana, Illinois

Prof. R.K. Summerbell
Northwestern University
Evanston, Ill.

Prof. Frank T. Gucker, Jr. *
Indiana University
Bloomington, Indiana

Prof. H.B. Hass *
Purdue University
Lafayette, Ind.

Prof. Ben King *
Iowa State College
Ames, Iowa

Prof. Ray Q. Brewster *
University of Kansas
Lawrence, Kans.

Prof. Lloyd McKinley
University of Wichita
Wichita, Kans.

Prof. C.P. McNally
Western Kentucky State College
Bowling Green, Ken.

Prof. Robert D. Fowler
Johns Hopkins University
Baltimore, Maryland

Prof. E.G. Rochow *
Harvard University
Cambridge 38, Mass.

Prof. Arthur C. Cope
Mass. Inst. of Technology
Cambridge 39, Mass.

Prof. Laurence L. Quill *
Michigan State College
East Lansing, Mich.

Prof. Allen E. Stearn
University of Missouri
Columbia, Mo.

Prof. Joseph W. Kennedy *
Washington University
St. Louis 5, Mo.

Prof. P.C. Gaines
Montana State College
Bozeman, Montana

Prof. C.S. Hamilton *
University of Nebraska
Lincoln, Neb.

Dean Hugh S. Taylor *
Princeton University
Princeton, New Jersey

Prof. P. Debye *
Cornell University
Ithaca, N.Y.

Prof. Edward Mack, Jr.
Ohio State University
Columbus, Ohio

Prof. Kenneth E. Crook
University of Okla.
Norman, Okla.

Prof. Otto M. Smith *
Okla. A & M College
Stillwater, Okla.

Prof. Leo Friedman *
Oregon State College
Corvallis, Oregon

Prof. James Miller Breckenridge
Vanderbilt University
Nashville 4, Tenn.

Dean Arthur M. Pardee *
University of South Dakota
Vermillion, S. Dak.

Prof. Victor S. Webster
South Dakota A & M College
Brookings, S. Dak.

Prof. Reuben L. Hill *
Utah State Agri. College
Logan, Utah

Prof. J.H. Mathews *
University of Wisconsin
Madison, Wis.

SAMPLE OF THE FIRST QUESTIONNAIRE

Manhattan, Kansas
October 9, 1949

Prof. Arthur C. Cope
Mass. Inst. Technology

Prof. Cope:

I am depending upon your cooperation in returning the attached card to me.

Respectfully,

Guy B. Homman, Dept. of Chem.
Kansas State College
Manhattan, Kansas

THIS SIDE OF CARD IS FOR ADDRESS

Guy B. Homman, Dept. of Chem.
Kansas State College
Manhattan, Kansas

SAMPLE OF THE FIRST QUESTIONNAIRE
(opposite side)

Do you segregate your Freshman Chemistry students into different classes upon any bases whatsoever, such as achievement, aptitude, etc.?

Check one:

YES   NO

If you do, would you answer pertinent questions describing your program in order that we may organize and initiate a similar program at Kansas State College?

Check one:

YES   NO

A questionnaire will follow if both of your answers are in the affirmative.

REPLY CARD
THIS SIDE OF CARD IS FOR ADDRESS

U.S. POSTAL CARD
ONE CENT
MARTHA WASHINGTON

Prof. Arthur C. Cope
Chemistry Dept.
Mass. Inst. of Technology
Cambridge 39, Mass.

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE
MANHATTAN
Nov. 4, 1949

DEPARTMENT OF CHEMISTRY

Prof. Linus Pauling
Calif. Inst. of Technology
Pasadena, Calif.

Dear Prof. Pauling:

You very kindly indicated that you would supply us with some information concerning your plan of segregation for your Freshman Chemistry Students.

The function of this questionnaire, as stated in previous correspondence, is to accumulate information from various institutions on their placement programs in Freshman Chemistry so that we may organize and initiate a similar program at Kansas State College.

I thank you kindly for your time and information.

Sincerely,

Guy B. Homman, Dept. of Chem.
Kansas State College
Manhattan, Kansas

GBH:d

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE
MANHATTAN

DEPARTMENT OF CHEMISTRY

Please check the response at the right which applies to your plan.

1. Which device or combination of devices do you use as a basis for segregation in Freshman Chemistry?

   Remarks:

   1 a. Achievement test

   1 b. Aptitude test

   1 c. College entrance examination

   1 d. High school grades

   1 e. Intelligence test

   Others:_____

2. If an achievement test is used, does it apply only to those students who have had High School Chemistry?

   2 a. Yes

   2 b. No

3. If a test is used, please include a copy with the questionnaire.

4. Whatever plan of segregation is used, is it required or optional?

   4 a. Required

   4 b. Optional

5. How many levels of achievement or aptitude do you use in your plan?

   5 a. Two

   5 b. Three

6. Do you apply the segregation device before or after enrollment?

   6 a. Before

   6 b. After

7. To which of the following does the segregation apply?

   7 a. Lecture

   7 b. Recitation

   7 c. Laboratory

8. Is the same text and laboratory manual used in all sections?

   If "yes," please elaborate if omissions or additions of material are made for various sections.

   8 a. Yes

   8 b. No

9. Does your plan apply to one or to two semesters?   9 a. One

                                                         9 b. Two

10. Is the same total time per semester required   10 a. Yes
    in all sections?
                                                         10 b. No
    If "no," please elaborate on the relative
    amounts of time.

11. Is the same amount of credit given in all   11 a. Yes
    sections?
                                                         11 b. No
    If "no," what are the relative amounts of
    credit given?

12. If any study of your plan has been made which
    indicates its success or value, we would like
    to have a copy, or, a reference to the study.

13. We would appreciate any further information
    you may care to add which you think may be
    pertinent.

    Remarks:

14. Would you care to have a copy of the tab-   14 a. Yes
    ulated data which will be compiled from the
    results of this questionnaire?   14 b. No

    Completion is expected by May 1, 1950.

Summary of data from 18 institutions describing their plan of segregation for their freshman chemistry students into different sections.	Segregation Device Used								Factors Considered in the Placement Plan																		
	Mathematics Test	Achievement Test(Chem)	Aptitude Test	College Entrance Exam.	High School Credit & Grades	Intelligence Test	Reading Comprehension	Curriculum	Are achievement tests applicable only to high school chemistry students		Segregation		Number of levels used		Is the device administered before or after enrollment		Is the same text book used in all sections?		Does the segregation apply to one or two semesters?		Is the same total time required in all sections?		Is the same amount of credit given in all sections?		Segregation applies to:		
									Yes	No	Required	Optional	Two	Three	Before	After	Yes	No	One	Two	Yes	No	Yes	No	Lecture	Recitation	Laboratory
Oklahoma A & M		x						x	x		x				x		x		x	x	x		x		x	x	x
Iowa State					x			x			x		x		x		x		x	x	x		x		x	x	x
Uni. of S. Dakota					x	x					x				x		x		x	x	x		x		x	x	x
Uni. of Colorado	x	x			x		x			x	x	x	x		x		x		x		x	x		x	x	x
Purdue University	x		x		x	x					x	x	x		x		x	x		x				x	x	x
Washington Uni.	x	x	x			x	x		x	x			x		x	x		x	x	x			x	x
Princeton Uni.				x					x		x	x	x	x	x	x		x		x	x		x	x	x
Cornell University								x	x					x		x		x		x		x		
Uni. of Illinois					x				x		x	x	x		x	x		x		x		x		x	x
Utah State					x			x							x		x		x	x		
Harvard University		x							x	x	x		x		x	x		x			x	x	x	x	x
Calif. Inst. Tech.		x	x						x	x		x	x	x		x	x		x			x	x
Michigan State	x					x			x	x	x	x	x	x	x	x		x		x		x	x	x	x	x
Uni. of Wisconsin					x			x			x		x		x	x	x		x	x	x	x
Oregon State		x						x			x	x	x		x		x	x		x
Uni. of Nebraska	x	x							x	x	x		x	x	x		x	x		x	x	x
Indiana University					x			x			x		x		x		x		x	x	x		x	x	x
Uni. of Kansas								x			x	x	x		x		x		x		x	x	x	x

KANSAS STATE COLLEGE PLACEMENT TEST IN FRESHMAN CHEMISTRY

Directions

Do not open this folder until you are told to do so.

Complete the following blanks:

Name (print): _____ , _____ , _____
                    Last   First   Middle

Date: _____   Sex: M   F   Age: _____
                            (encircle one)   Yrs.   Mos.

Do you plan to specialize in either chemistry or chemical engin-
eering in college? _____
Indicate what profession you wish to follow after graduation.
_____

After each of the subjects named below, indicate those studied in
high school by marking the credit and the grade received.

General Mathematics _____   General Science _____

First Year Algebra _____   Physics   _____

Advanced Algebra   _____   Chemistry   _____

You will be allowed 60 minutes on this test. Do the easier
questions first, and return to the others if you have time.

All answers are to be placed on the special answer sheet.
Do not mark on the question sheet. Use the extra paper provided
for calculations.

Complete the blanks at the top of the answer sheet.

This test is of the multiple-choice type. Each item con-
sists of a question or incomplete statement which can be answered
or completed correctly by one of the choices given. For each item,
blacken with your pencil the space on the answer sheet having the
letter corresponding to the correct answer.

Example: The correct formula for water is:
(A) HO (B) HO_2 (C) H_2O (D) H_2O_2 (E) $(HO)_2$

A   B   C   D   E

The correct answer is H_2O; therefore the space marked C on
the answer sheet should be blackened.

Part	Raw Score	Percentile
Mathematics		
Information		
Reading		
Total		

Part I   ARITHMETIC TEST

1.   16.4 x 3.2 =

(A) 51.48   (B) 52.84   (C) 52.48   (D) 524.8   (E) 48.42

2.   13% of .06 =

(A) 0.0078   (B) 0.0780   (C) 0.7800   (D) 7.8000   (E) 0.0087

3.   .0734 ÷ 7.34 =

(A) 0.10   (B) 0.01   (C) 1.00   (D) 10.0   (E) 0.0001

4.   The nearest decimal value of 3/64 is:

(A) 0.045   (B) 21.33   (C) 0.470   (D) 0.050   (E) 0.047

5.   3/5 of 80 is the same as:

(A) 7/8 of 56   (B) 3/4 of 60   (C) 2/3 of 60   (D) 6/7 of 56
(E) none of these

6.   The square root of 7921 is:

(A) 83   (B) 98   (C) 89   (D) 3960.5   (E) 79.21

7.   If $4x^2 = 576$,   x =

(A) ± 12   (B) 48   (C) - 12   (D) 144   (E) + 12

8.   a/b = c;   b =

(A) a/c   (B) ac   (C) c-a   (D) c/a   (E) a-c

9.   30/y = 900/60,   y =

(A) 2   (B) 1/450   (C) 1/2   (D) 450   (E) none of these

10. B/L = X/K,   X=

(A) L/BK   (B) LK/B   (C) BK/L   (D) B/LK   (E) none of these

11. a/2b = c/d,   b =

(A) ad/2c   (B) 2b/ad   (C) 2ad/b   (D) 2abd   (E) 2bd/a

12. A correct weight of 20 grams was estimated at 24. The per-
centage of error =

(A) 2%   (B) 16 2/3%   (C) 20%   (D) 1.2%   (E) 8.34%

13. What kind of a proportion is represented by the statement "the higher the temperature the greater the volume?"

(A) Direct (B) indirect (C) squared (D) variable
(E) inverse

14. How many grams of 8% salt solution must be evaporated to get 75 grams of salt?

(A) 93.75 (B) 600 (C) .167 (D) 937.5 (E) none of these

15. If 6.5 grams of a certain substance occupies a volume of 4.25 cubic centimeters, what is its density in grams per cubic centimeter? (to nearest hundredth)

(A) 15.30 (B) 1.53 (C) 0.05 (D) 0.65 (E) 27.62

16. The statement "The greater the velocity the smaller the time required" exemplifies a (an)

(A) indirect proportion (B) inverse proportion (C) direct proportion (D) joint variation (E) none of these

17. 1 inch equals 2.54 centimeters. How many cubic centimeters are in 1 cubic inch? (to nearest thousandth)

(A) 1.638 (B) 163.870 (C) 7.620 (D) 5.080 (E) 16.387

18. The density of mercury is 13.6 grams per cubic centimeter, and that of alcohol, 0.789 grams per cubic centimeter. What volume of alcohol will have the same weight as 5 cc. of mercury? (to nearest tenth)

(A) 86.2 (B) 8.6 (C) 2.9 (D) 862.0 (E) 29.0

19. If 2.0 grams of A unite with 6.0 grams of B to give a compound of A and B, how many grams of A should be taken to give 2.0 grams of compound?

(A) 1.2 (B) 0.33 (C) 1.0 (D) 0.5 (E) 0.05

20. 3 tons of a certain type of coal contains 100 lbs. of sulfur. On the same basis how many tons would yield 233 1/3 lbs. of sulfur?

(A) 3 1/3 (B) 7 (C) 6 2/3 (D) 6 (E) 8

PART II

Directions: For each of the following items, five choices are given to complete the statements or answer the questions asked. Choose the one which completes the statement or answers most appropriately and blacken the space on the answer sheet corresponding to the answer you have chosen.

21. Chemistry is the study of:
(A) mathematical probabilities (B) matter and the changes which it undergoes (C) biological relationships (D) human relationships (E) rock strata and formations

22. The principal constituent of air is:
(A) oxygen (B) carbon dioxide (C) carbon monoxide (D) hydrogen (E) nitrogen

23. The most common characteristic property of gases is:
(A) combustibility (B) compressibility (C) color (D) odor (E) stability

24. The principal chemical element in steel is:
(A) carbon (B) copper (C) iron (D) silicon (E) oxygen

25. Hardness of water is caused by:
(A) aging (B) heating (C) storage at high altitudes (D) bacteria (E) dissolved impurities

26. Which of the following is used as an anesthetic?
(A) naphthalene (B) iodoform (C) ether (D) acetone (E) hydrogen cyanide

27. Which of the following terms means pertaining to or due to motion?
(A) lunar (B) potential (C) kinetic (D) static (E) constant

28. Which of the following substances is not a chemical element?
(A) silver (B) copper (C) brass (D) tin (E) lead

29. The boiling point of water on the centigrade scale is:
(A) 100° (B) 37° (C) 32° (D) 212° (E) 273°

30. The composition of a compound is indicated by its:
(A) boiling point (B) symbol (C) weight (D) density (E) formula

31. A product of animal respiration is:
(A) oxygen (B) nitrogen (C) carbon dioxide (D) carbolic acid (E) hydrogen

32. Ice has a higher melting point than:
(A) sodium chloride (B) ferric oxide (C) carbon dioxide (D) sand (E) limestone

In the following sets of substances, one best fits the description preceding it, or possesses the indicated property in the highest degree. Select the correct answer and blacken the space on the answer sheet corresponding to the answer you have chosen.

33. Important in making glass:
(A) sand (B) ferric oxide (C) sea weed (D) clay
(E) lava

34. Soluble in water:
(A) kerosene (B) sodium chloride (C) alcohol
(D) quartz (E) carbon

35. Industrial fuel:
(A) carbon dioxide (B) ammonia (C) coke (D) sulfur
dioxide (E) carbon tetrachloride

36. Used in making soap:
(A) sodium hydroxide (B) bones (C) calcium chloride
(D) hydrochloric acid (E) silver hydroxide

37. Light metal:
(A) selenium (B) aluminum (C) magnesium (D) chromium
(E) nickel

38. Important modern synthetic medicine:
(A) lastex (B) sulfanilamide (C) nylon (D) hormone
(E) plutonium

39. Useful in cutting glass:
(A) graphite (B) mica (C) monel metal (D) babbit
(E) diamond

40. Poisonous gas:
(A) ozone (B) freon (C) chlorine (D) hydrogen
(E) nitrogen

PART III

Directions: This is a test in reading comprehension. Read carefully the following passages and then select the number of the sentence or clause in which each of the topics listed under the passage occur. Then notice which letter occurs with the correct sentence or clause number and blacken the corresponding space on your answer sheet. For each question the correct sentence or clause number is included among the five choices. In answering these questions you may reread the paragraph as often as is necessary.

(1) Atoms are no longer regarded as hard, indivisible spheres, but are known, on the basis of numerous, independent evidences, to consist of smaller and simpler particles. (2) The mass of an atom is practically all concentrated in a very small, positively charged nucleus. (3) The nucleus of the hydrogen atom is a single proton having unit positive charge--1.59×10^{-19} coulombs--(4) and a mass of 1.655×10^{-24} grams or 1.0076 in terms of an atomic weight of 16.00 for the oxygen atom. (5) The nuclei of other atoms consist, according to present evidence, of protons and neutrons, the latter having almost the same mass--1.0090--but electrically neutral, as their name implies. (6) The nuclei have positive charges, therefore, which are integral multiples of the charge of the proton. (7) To balance the positive charge of the nucleus, the atoms of free elements have the proper number of electrons. (8) These are particles having a charge of the same magnitudes as the protons, but of negative sign, (9) so that an atom containing equal numbers of protons and electrons is electrically neutral. (10) The mass of an electron is only 1/1850 the mass of a proton (11) thus an atom can gain or lose electrons with no appreciable change in mass. (12) The composition and mass of the nucleus are relatively unimportant in determining the chemical behavior of an atom. (13) It is the charge alone which is important.

41. The numerical mass of the proton:
    (A) 10 (B) 4 (C) 5 (D) 3 (E) 2

42. The charge of the proton:
    (A) 5 (B) 6 (C) 5 (D) 11 (E) 3

43. The size of the nucleus:
    (A) 6 (B) 10 (C) 1 (D) 2 (E) 3

44. The division of mass within the atom:
    (A) 4 (B) 11 (C) 2 (D) 9 (E) 8

45. The mass of the electron:
    (A) 10 (B) 9 (C) 7 (D) 8 (E) 8

46. The relation between the charges of proton and nucleus:
    (A) 5 (B) 9 (C) 3 (D) 8 (E) 6

47. The condition of electric neutrality of atoms:
    (A) 3 (B) 5 (C) 9 (D) 8 (E) 11

48. The charge of the neutron:
    (A) 3 (B) 5 (C) 9 (D) 13 (E) 6

49. The number of protons in the nucleus of the hydrogen atom:
    (A) 6 (B) 12 (C) 5 (D) 3 (E) 4

50. The oxygen atom:
    (A) 12 (B) 5 (C) 9 (D) 6 (E) 4

51. The principal determinant of chemical behavior:
    (A) 1 (B) 6 (C) 11 (D) 13 (E) 12

CHEMICAL REACTIONS

Many chemical reactions like the tarnishing of metals such as copper proceed very slowly, taking months or even years, but others may proceed at an explosive rate. One factor affecting the speed of reactions is concentration of the substances, i.e., the quantity of material per unit volume. Some metals dissolve more slowly in dilute acids than in concentrated acids. Substances burn more rapidly in pure oxygen than in air which contains only 20% oxygen. Increasing the concentration increases the speed of reaction.

The kinetic-molecular theory is used to explain the effect of concentration upon speed. Gases consist of tiny molecular particles, in constant motion, and separated from each other by vast spaces relative to their size. In liquids the particles move freely but they have very little space between them. In solids the molecules merely vibrate about some fixed general position.

From this theory it becomes reasonable to think that for a reaction to take place, molecules of substances must come into contact. If by some change in conditions the number of collisions per unit time increases, the reaction rate increases. Thus, if the concentration is increased, more collisions occur, and the speed of reaction increases. In gases, increasing the pressure increases the concentration, but in liquids an increase in pressure has little effect because the volume of a liquid cannot be changed readily. This is also true of solids. In the case of solutions we may dissolve more of a substance in the same amount of solvent to increase the concentration.

Temperature also affects the speed of chemical reaction. On the average a 10° C. rise in temperature will double the speed of reaction. It is a well known fact that fuels such as coal and wood must be heated (ignited) before they will burn. Once ordinary fuels start to burn they generate sufficient heat for the reaction to continue. Some reactions absorb heat and will not continue unless heat from an outside source is supplied.

Items 52 to 60 are to be answered in reference to the paragraphs on chemical reactions. Select the one best answer.

52. The paragraphs above imply that

   A. heavy metals like lead rust more rapidly than a light metal such as magnesium.
   B. all metals will rust greatly.
   C. increased pressure will increase the rate of solution of a metal in strong acid.
   D. at high temperatures, copper may oxidize in a few minutes.
   E. all metals will burn in oxygen.

53. A heavy iron wire will burn in pure oxygen but not in air because

   A. in air, carbon dioxide present acts as a fire extinguisher.
   B. in air, there are too few collisions per second with oxygen molecules.
   C. in pure oxygen, the molecules move faster.
   D. in oxygen there is no water vapor present.

54. Another effective way to increase the number of molecular collisions besides that of increasing the concentration is to

   A. increase the velocity of the molecules.
   B. increase the mass of the molecules.
   C. reduce the temperature of the molecules.
   D. increase the size of the molecules.
   E. decrease the kinetic energy of the molecules.

55. Which one of the following is true in the comparison of a liquid and a solid at the same temperature?

   A. Liquid molecules have a greater degree of freedom.
   B. Heat must be applied to make the molecules of a solid move.
   C. Liquid molecules vibrate about a fixed position.
   D. There is less space between the molecules of a liquid.
   E. Liquid molecules are more dense.

56. For a reaction to take place it is necessary that

   A. the molecules be in the form of a gas.
   B. the substance must be under a high pressure.
   C. a force of attraction exists between them.
   D. the molecules must collide.
   E. the molecules move at their maximum speed.

57. Two substances which absorb heat when they react are heated until the reaction occurs at a fairly rapid rate. If the heat source is removed

    A. the speed of the reaction will increase due to the increase in concentration.
    B. the reaction will be explosive.
    C. the speed of the reaction will decrease.
    D. the speed of the reaction will remain unchanged.
    E. the temperature will rise.

58. If it took one hour for a certain chemical reaction at $100^{\circ}C.$, at $120^{\circ}C.$ it should take approximately

    A. 5 minutes.
    B. 10 minutes.
    C. 15 minutes.
    D. 30 minutes.
    E. 50 minutes.

59. Experimental evidence that a gas consists mostly of empty space is shown by which of the following?

    A. Gases exert pressure on the walls of their containers.
    B. The density of a gas becomes greater when it is liquified.
    C. Molecules are very small in comparison with the space between them.
    D. Gases are transparent.
    E. Heating a gas increases molecular motion.

60. Changes in pressure have only a slight effect on reactions between solids. The best explanation of this is that

    A. solids are only slightly reactive.
    B. in solids molecular freedom is limited.
    C. solids are not appreciably compressible.
    D. solid molecules move very slowly.

SAMPLE OF THE IOWA PLACEMENT CHEMISTRY APTITUDE EXAMINATION

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Constructed by

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Revised by

JACOB CORNOG AND D. B. STUIT

Name .... Date ....
(Print)   Last   First   Middle

Grade or Class.............. Age.................. Date of Birth... Sex.....................

School or College.. City...

GENERAL DIRECTIONS

This is a test to see how quickly and accurately you can think in the field of chemistry. The test consists of four parts with special directions for each part. Read the directions carefully and examine the samples so you will know exactly how to do the exercises. On page 2 an answer sheet is provided on which you are to place *all* of your responses. This answer sheet is to be torn from the booklet when you begin work. *Do not write any answers on the test booklets.*

The sample exercises indicate how your responses are to be recorded. When the signal is given, begin to work on Part 1 and stop when time is called. If you should finish before time is called you may go back over any previous part, but do not go on to the next part until told to do so.

Answer the questions in order as you come to them, but do not spend too much time on any one item. You should answer all questions on which you have some information, but *do not guess.* A certain proportion of your score will be deducted for wrong answers. If you make a mistake, erase your first mark completely. *Items for which more than one answer is checked will be scored wrong.*

Part	Time	Raw Score	Scale Score	Percentile
1. Mathematics	15			
2. Formulation	7			
3. Reading	18			
4. Information	7			
Total	47			

ANSWER SHEET
Chemistry Aptitude Test

Part 1
(25 items)

(1) (2) (3) (4) (5)

1. ○ ○ ○ ○ ○
2. ○ ○ ○ ○ ○
3. ○ ○ ○ ○ ○
4. ○ ○ ○ ○ ○
5. ○ ○ ○ ○ ○
6. ○ ○ ○ ○ ○
7. ○ ○ ○ ○ ○
8. ○ ○ ○ ○ ○
9. ○ ○ ○ ○ ○
10. ○ ○ ○ ○ ○
11. ○ ○ ○ ○ ○
12. ○ ○ ○ ○ ○
13. ○ ○ ○ ○ ○
14. ○ ○ ○ ○ ○
15. ○ ○ ○ ○ ○
16. ○ ○ ○ ○ ○
17. ○ ○ ○ ○ ○
18. ○ ○ ○ ○ ○
19. ○ ○ ○ ○ ○
20. ○ ○ ○ ○ ○
21. ○ ○ ○ ○ ○
22. ○ ○ ○ ○ ○
23. ○ ○ ○ ○ ○
24. ○ ○ ○ ○ ○
25. ○ ○ ○ ○ ○

Score = No. Right

= [　　]

Part 2
(10 items)

(1) (2) (3) (4) (5)

1. ○ ○ ○ ○ ○
2. ○ ○ ○ ○ ○
3. ○ ○ ○ ○ ○
4. ○ ○ ○ ○ ○
5. ○ ○ ○ ○ ○
6. ○ ○ ○ ○ ○
7. ○ ○ ○ ○ ○
8. ○ ○ ○ ○ ○
9. ○ ○ ○ ○ ○
10. ○ ○ ○ ○ ○

Score = No. Right × 3

= [　　] × 3

= [　　]

Part 3
(30 items)

Section A

(1) (2) (3) (4) (5)

1. ○ ○ ○ ○ ○
2. ○ ○ ○ ○ ○
3. ○ ○ ○ ○ ○
4. ○ ○ ○ ○ ○
5. ○ ○ ○ ○ ○
6. ○ ○ ○ ○ ○
7. ○ ○ ○ ○ ○
8. ○ ○ ○ ○ ○
9. ○ ○ ○ ○ ○
10. ○ ○ ○ ○ ○

Section B

1. ○ ○ ○ ○ ○
2. ○ ○ ○ ○ ○
3. ○ ○ ○ ○ ○
4. ○ ○ ○ ○ ○
5. ○ ○ ○ ○ ○
6. ○ ○ ○ ○ ○
7. ○ ○ ○ ○ ○
8. ○ ○ ○ ○ ○
9. ○ ○ ○ ○ ○
10. ○ ○ ○ ○ ○

Section C

1. ○ ○ ○ ○ ○
2. ○ ○ ○ ○ ○
3. ○ ○ ○ ○ ○
4. ○ ○ ○ ○ ○
5. ○ ○ ○ ○ ○
6. ○ ○ ○ ○ ○
7. ○ ○ ○ ○ ○
8. ○ ○ ○ ○ ○
9. ○ ○ ○ ○ ○
10. ○ ○ ○ ○ ○

Score = No. Right

= [　　]

Part 4
(45 Items)

	T F		T F
1.	○ ○	24.	○ ○
2.	○ ○	25.	○ ○
3.	○ ○	26.	○ ○
4.	○ ○	27.	○ ○
5.	○ ○	28.	○ ○
6.	○ ○	29.	○ ○
7.	○ ○	30.	○ ○
8.	○ ○	31.	○ ○
9.	○ ○	32.	○ ○
10.	○ ○	33.	○ ○
11.	○ ○	34.	○ ○
12.	○ ○	35.	○ ○
13.	○ ○	36.	○ ○
14.	○ ○	37.	○ ○
15.	○ ○	38.	○ ○
16.	○ ○	39.	○ ○
17.	○ ○	40.	○ ○
18.	○ ○	41.	○ ○
19.	○ ○	42.	○ ○
20.	○ ○	43.	○ ○
21.	○ ○	44.	○ ○
22.	○ ○	45.	○ ○
23.	○ ○		

A =
R =
W (A-R) =

Score = R—W = [　　]

(Tear along this line)

— 2 —

PART 1. MATHEMATICS

(Time limit, 15 minutes)

Directions: The exercises in this part represent the most commonly used arithmetical and algebraic skills in first year chemistry. Solve each of the problems, find the answer among the five choices, and record your answer by making an $\times$ in the appropriate circle on the answer sheet. Study the samples.

SAMPLE: A. $3x = 15$; what does x equal?

(1) 2   (2) 3   (3) 5   (4) 7   (5) 10

a. (with circle 3 marked $\otimes$, columns 1 2 3 4 5)

B. $4a + 7 = 35$; what does a equal?

(1) 3   (2) 4   (3) 5   (4) 6   (5) 7

b. (with circle 5 marked $\otimes$)

For the first sample, 5 is the correct answer so circle three in marked with an $\times$. The answer for the second sample is 7, so circle five has been checked.

---

1. $v^2 = 2gs$; what does s equal?

(1) $v^2 - 2g$ (2) $v^2 + 2g$ (3) $\dfrac{v^2}{2g}$ (4) $\dfrac{v}{g}$ (5) $\dfrac{2g}{v^2}$

2. $bx = 2$; what does b equal?

(1) $2x$ (2) $\dfrac{x}{2}$ (3) $\dfrac{2}{x}$ (4) $x-2$ (5) $2-x$

3. $s = vt$; what does t equal?

(1) sv (2) $\dfrac{v}{s}$ (3) $s-v$ (4) $v-s$ (5) $\dfrac{s}{v}$

4. What is the square root of 1156.00?

(1) 26   (2) 34   (3) 36   (4) 289   (5) 578

5. $m-n = a-b$; what does n equal?

(1) $a-b+m$ (2) $a-b-m$ (3) $a+b-m$ (4) $b-a+m$ (5) $a+b+m$

6. Reduce to a common denominator: $\dfrac{1}{a} - \dfrac{1}{b}$.

(1) $\dfrac{2}{a-b}$ (2) $\dfrac{2}{ab}$ (3) $\dfrac{b-a}{ab}$ (4) $a-b$ (5) $\dfrac{b-a}{a-b}$

7. What is 14% of .06?

(1) .84   (2) .084   (3) .0084   (4) .233   (5) .0233

8. Solve for x: $\dfrac{12.2}{18.3} = \dfrac{x}{21.9}$

(1) 2/3   (2) 2   '3) 13.6   (4) 14.6   (5) 32.8

9. Solve for x: $\dfrac{x}{3} = 2y^2$.

(1) $\dfrac{2y^2}{3}$ (2) $\dfrac{2y^2}{-3}$ (3) $2y^2-3$ (4) $3-2y^2$ (5) $6y^2$

10. Divide: $.0024 \div .0004$.

(1) 6   (2) .6   (3) .06   (4) .006   (5) .0006

11. Simplify: $\sqrt{x^2y^2}$.

(1) xy (2) $(xy)^2$ (3) x^2y^2 (4) $\sqrt{x^2} \cdot \sqrt{y^2}$ (5) $(-xy)(xy)$

Turn to Page 4.

12. What is the reciprocal of $\frac{a}{2b}$?

    (1) $\frac{2b}{a}$ (2) 2ab   (3) ab   (4) $4a^2b^2$ (5) $\frac{4b^2}{a^2}$

13. $a^2 - b^2 = c^2$; what does b equal

    (1) $\sqrt{a^2-c^2}$ (2) $(a-c)(a+c)$ (3) $\sqrt{c^2-a^2}$ (4) $a-c$ (5) $c+a$

14. $c^2 - 1 = -d^2$; if d is ½, what is c^2?

    (1) .50   (2) .75   (3) −.75   (4) 1.25   (5) −1.25

15. $\frac{a}{y} = b$; what does y equal?

    (1) ab   (2) $\frac{a}{b}$ (3) $a-b$ (4) $b-a$ (5) $\frac{b}{a}$

16. $\frac{a}{3b} = \frac{x}{y}$, what does b equal?

    (1) $\frac{ay}{3x}$ (2) $\frac{3b}{ay}$ (3) 3aby   (4) $\frac{3by}{a}$ (5) $\frac{3ay}{b}$

17. Combine: $x-(x-a) =$

    (1) $2x+a$ (2) $2x-a$ (3) $a-2x$ (4) a   (5) $-a$

18. Write with an exponent $\sqrt[3]{a+b}$.

    (1) $(a+b)^{1/3}$ (2) a^3+b^3 (3) $(a+b)^{-3}$ (4) $(a+b)^3$ (5) $(a+b)^{-1/3}$

19. If $x = y+z$, how much less than x is z?

    (1) $x-y$ (2) $x+y$ (3) x   (4) y   (5) $y-x$

20. What kind of proportion is represented by the statement "the larger the diameter the greater the area"?

    (1) Direct   (2) indirect   (3) inverse   (4) variable   (5) squared

21. If $\frac{W_2}{W} = \frac{W}{W_1}$, what is the value of W?

    (1) W_2W_1 (2) $\frac{W_2}{W_1}$ (3) $\sqrt{\frac{W_2}{W_1}}$ (4) $\sqrt{W_2W_1}$ (5) $-W_2W_1$

22. What is the mean of 3, 8, 0, 7, and 2?

    (1) 0   (2) 4   (3) 5   (4) 20   (5) 336

23. Simplify $\frac{\frac{x}{2}}{x}$.

    (1) $\frac{x^2}{2}$ (2) $2x^2$ (3) $\frac{x}{2}$ (4) 2   (5) $\frac{1}{2}$

24. A man judged a distance of 20 yards to be 25 yards. What was his per cent of error?

    (1) .20%   (2) 20%   (3) .25%   (4) 25%   (5) .80%

25. Find the numerical value for x: $x = \frac{6 \times 10^2 \times 2 \times 10^3}{3 \times 10^4}$.

    (1) 4   (2) 40   (3) 400   (4) 4000   (5) 40,000

End of Part 1.

PART 2. FORMULATION
(Time limit, 7 minutes)

Directions: In this part you are to read each statement or short paragraph and do what it tells you to do. In most cases this involves writing an algebraic expression for what the statement says. As in Part 1, select the correct answer from among the five choices and mark the appropriate circle on the answer sheet with an ×. Study the samples.

SAMPLE: A. If x is a number, twice that number would be expressed algebraically as:

(1) x   (2) x²   (3) 2x   (4) 2x²   (5) 4x

a. ⃝ ⃝ ⊗ ⃝ ⃝ (1 2 3 4 5)

B. If x and y represent two numbers, their sum would be expressed as:

(1) x+y   (2) xy   (3) x—y   (4) x²y²   (5) $\frac{x}{y}$

b. ⊗ ⃝ ⃝ ⃝ ⃝

---

1. Letting x represent the length of an edge of a cube, write the *simplest* algebraic expression which represents the volume of the cube.

   (1) x²   (2) x³   (3) 9x   (4) 3x   (5) $\sqrt[3]{x}$

2. The length of a certain rectangle is twice its width. Letting w represent the width, write an algebraic expression for the perimeter of the rectangle.

   (1) 4w   (2) 8w   (3) 6w   (4) 2w²   (5) 4w+2

3. If a barrel of gasoline containing x gallons will propel an automobile y miles in 5 hours, what is the mileage travelled per gallon of gasoline?

   (1) $\frac{x}{y}$ (2) $\frac{y}{x}$ (3) xy   (4) $\frac{5x}{y}$ (5) $\frac{5y}{x}$

4. An airplane travels at a uniform velocity of m miles per hour for one hour and consumes x gallons of gasoline during that time. How many gallons of gasoline will be needed to travel a distance of y miles?

   (1) $\frac{xy}{m}$ (2) $\frac{xm}{y}$ (3) $\frac{x}{my}$ (4) $\frac{y}{mx}$ (5) $\frac{m}{xy}$

5. Bill and Bob row a boat across a lake. Bob rows y miles, and Bill rows the rest of the distance. If Bill rows three miles farther than Bob, how wide is the lake.

   (1) y—3   (2) 3y+2   (3) 2y+3   (4) y+3   (5) 2y+6

6. The electrical output of the larger of two dynamos is five units more than three times the smaller. What is the output of the larger dynamo if the output of the smaller is represented by x?

   (1) 15x   (2) 5x+3   (3) x+8   (4) x+15   (5) 3x+5

7. The force (f) required to break a new manila rope is equal to the product of a constant (m) and the square of the circumference (c) of the rope. Express in equation form.

   (1) f = cm   (2) f = $\frac{m}{c}$ (3) f = m²c   (4) f = mc²   (5) f = m²c²

8. The specific gravity of a substance is defined as the ratio of the weight of any volume of the substance to the weight of an equal volume of water. Letting *s.g.* represent the specific gravity of the substance, x the weight of the substance and w the weight of an equal volume of water, express the above relationship in equation form.

   (1) s.g. = $\frac{w}{x}$ (2) s.g. = $\frac{x}{w}$ (3) s.g. = xw   (4) w = s.g.x   (5) x = $\frac{w}{s.g.}$

9. In a cylindrical tumbler filled with water the total force F against the bottom is equal to the weight of the column of liquid resting on the bottom. The weight is determined by the area (A) of the bottom, the depth h of the water, and the weight d of a unit volume of the water. Express the force F in terms of area, depth and density.

   (1) F = $\frac{Ah}{d}$ (2) F = Ahd   (3) F = $\frac{hd}{A}$ (4) F = $\frac{Ad}{h}$ (5) F = A²hd

10. If a quantity of gas is subjected to a temperature change, the ratio of the original volume V_1 to the new volume V_2 is the same as the ratio of the original absolute temperature T_1 to the new temperature T_2, the pressure P remaining constant. Express in equation form.

   (1) $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ (2) $\frac{T_1}{V_1} = \frac{T_2}{V_2}$ (3) $\frac{V_2}{V_1} = \frac{T_1}{T_2}$ (4) $\frac{V_1}{V_2} = \frac{T_1}{T_2}$ (5) $P\frac{V_1}{V_2} = \frac{T_1}{T_2}$

End of Part 2.

(Time limit, 18 minutes)

Directions: This is a test of your ability to read thoroughly and comprehensively in the field of chemistry. Read the materials below carefully as you will be asked to apply the facts in various ways.

SECTION A

The chemical name of ordinary table salt is sodium chloride. It is represented by the symbol NaCl. "Na" stands for the Latin word for sodium and "Cl" for chlorine or chloride. Thus the formula NaCl indicates that table salt is composed of sodium and chlorine. When sodium chloride or a similar substance is dissolved in water the resulting solution will carry an electric current. This conductivity of salt solutions is best explained by the ionization theory.

According to this theory, sodium chloride exists in water solution as a very large number of very small separate pieces of sodium and an equally large number of very small separate pieces of chlorine. Each individual piece of sodium carries a unit positive charge of electricity and is called a positive ion. It is indicated by the symbol Na+. Similarly each separate piece of chlorine is a negative ion carrying a unit negative charge and is indicated by the symbol Cl−. When solid sodium chloride is caused to form by evaporation of the solution or by other means, the positive Na+ and the negative Cl− ions join in equal numbers to form solid NaCl. In any solid or solution the total number of positive charges must always equal the total number of negative charges. Hence it would be impossible to have sodium chloride in which there were twice as many pieces of Cl− as there were of Na+ and the formula NaCl₂ would be *incorrect*.

But the smallest pieces into which some substances divide when dissolved may carry more than one unit charge. Copper chloride ($CuCl_2$) solution contains copper ions and chloride ions. *Each* copper ion carries *two* positive unit charges and is indicated by the symbol Cu++ while each chloride ion as in sodium chloride solution carries one negative charge and is represented by Cl−. Thus in a copper chloride solution there are twice as many chloride ions as there are copper ions but each copper ion carries twice as many charges and the *total number of positive charges equals the total number of negative charges* in the solution. Different kinds of ions may carry as many as four positive or negative charges each. Chemical formulas must be written so as to indicate that the positive and negative charges are equal in number.

In the following exercises the correct number of charges + or − is given for the ions indicated by the formulas. Select from among the five choices the formula which has the correct set of sub-numbers, making an × in the circle corresponding to your choice on the answer sheet.

SAMPLES:
A. Na+   Cl−
  (1) NaCl   (2) Na₂Cl   (3) NaCl₂   (4) Na₂Cl₂   (5) Na₃Cl₂

B. Cu++   Cl−
  (1) CuCl   (2) CuCl₂   (3) Cu₂Cl   (4) Cu₂Cl₂   (5) CuCl₃

	1	2	3	4	5
a.	⊗	○	○	○	○
b.	○	⊗	○	○	○

In Sample A, the correct formula is NaCl so the first circle is marked with an ×. In Sample B, the correct formula is CuCl₂ so the second circle is marked with an ×.

---

1. K+   Cl−
  (1) K₂Cl   (2) KCl   (3) KCl₂   (4) K₂Cl₄   (5) K₂Cl₃

2. Ba++   Cl−
  (1) BaCl₂   (2) BaCl   (3) Ba₂Cl₂   (4) Ba₂Cl   (5) Ba₃Cl₃

3. K+   S−−
  (1) K₃S₄   (2) KS   (3) K₄S₂   (4) K₂S   (5) KS₂

4. Sb+++   Cl−
  (1) Sb₃Cl   (2) Sb₂Cl   (3) Sb₃Cl₃   (4) Sb₂Cl₄   (5) SbCl₃

5. Sb+++   S−−
  (1) SbS₂   (2) SbS₃   (3) Sb₃S   (4) Sb₂S₃   (5) Sb₃S₂

6. Mg++   S−−
  (1) Mg₂S₄   (2) Mg₃S₂   (3) MgS   (4) Mg₂S₃   (5) Mg₂S

7. Sn++++   Cl−
  (1) Sn₃Cl₄   (2) SnCl   (3) SnCl₄   (4) Sn₄Cl   (5) SnCl₃

8. Sn++++   S−−
  (1) SnS₂   (2) Sn₃S₄   (3) SnS₄   (4) Sn₂S   (5) SnS

9. Sn++++   X−−−
  (1) SnX₂   (2) Sn₃X₄   (3) Sn₄X₃   (4) SnX   (5) Sn₂X₂

10. K+   X−−−
  (1) K₃X   (2) K₂X₂   (3) KX₃   (4) K₃X₄   (5) K₂X₄

At times an ion may contain more than one kind of element. For example, the formula for silver nitrate is $Ag(NO_3)$. As one nitrate (NO_3) ion combines with one silver (Ag) ion which has $1+$ charge, the (NO_3) group must have $1-$ charge, in order for the charges to balance.

In the following exercise, select from among the five choices the formula which has the correct set of sub-numbers, making an $\times$ in the circle corresponding to your choice on the answer sheet. Keep in mind the fact that the number of charges $+$ and $-$ must always balance.

A table of ions and the number of charges is provided below:

$Zn^{++} = 2+$	$Fe^{+++} = 3+$	$(SO_4)^{--} = 2-$	$(PO_4)^{---} = 3-$
$K^+ = 1+$	$H^+ = 1+$	$(NO_3)^- = 1-$	$S^{--} = 2-$
$Ag^+ = 1+$		$(OH)^- = 1-$	

SAMPLE: (1) $Ag(SO_4)$ (2) $Ag(SO_4)_2$ (3) $Ag_2(SO_4)$ (4) $Ag_2(SO_4)_2$ (5) $Ag_3(SO_4)_2$ 1 2 3 4 5 ◯ ◯ ⊗ ◯ ◯

1. (1) $Zn_2(SO_4)$ (2) $Zn(SO_4)_2$ (3) $Zn(SO_4)$ (4) $Zn_3(SO_4)_2$ (5) $Zn_2(SO_4)_3$

2. (1) $K_2(SO_4)$ (2) $K(SO_4)$ (3) $K_3(SO_4)_2$ (4) $K_2(SO_4)_3$ (5) $Zn_2(NO_3)_3$

3. (1) $Zn(OH)$ (2) $Zn_3(OH)_2$ (3) $Zn(OH)_3$ (4) $Zn(OH)_2$ (5) $Zn_2(OH)_3$

4. (1) $Fe(NO_3)_2$ (2) $Fe_3(NO_3)_2$ (3) $Fe_2(NO_3)_3$ (4) $Fe(NO_3)$ (5) $Fe(NO_3)_3$

5. (1) FeS (2) Fe_3S_2 (3) Fe_2S_3 (4) FeS_3 (5) Fe_3S

6. (1) $Zn(NO_3)$ (2) $Zn_3(NO_3)_2$ (3) $Zn(NO_3)_2$ (4) $Zn_2(NO_3)$ (5) $Zn_2(NO_3)_3$

7. (1) $Zn(PO_4)$ (2) $Zn_3(PO_4)_2$ (3) $Zn(PO_4)_2$ (4) $Zn_2(PO_4)$ (5) $Zn_2(PO_4)_3$

8. (1) $Fe(SO_4)$ (2) $Fe(SO_4)_2$ (3) $Fe_3(SO_4)_2$ (4) $Fe_2(SO_4)_3$ (5) $Fe_2(SO_4)$

9. (1) $K_2(PO_4)_3$ (2) $K_2(PO_4)$ (3) $K(PO_4)$ (4) $K_3(PO_4)$ (5) $K_2(PO_4)_3$

10. (1) $Fe_3(PO_4)_2$ (2) $Fe_2(PO_4)$ (3) $Fe(PO_4)_2$ (4) $Fe_3(PO_4)_4$ (5) $Fe(PO_4)$

SECTION C

The chemical name of a compound is based upon the ions of which it is composed. You have already found that ions unite in proportion to charges carried, i.e., an ion with $2+$ charges will unite with 2 ions with $1-$ charge, or a single ion with $2-$ charges, etc.

Using the table of ions and names given below, select the correct formula for each of the compounds from among the five choices, note its number and make a cross $\times$ in the corresponding circle on the answer sheet.

Potassium $K^+ = 1+$	Lead $Pb^{++} = 2+$	Arsenate $(AsO_4)^{---} = 3-$
Aluminum $Al^{+++} = 3+$	Chloride $Cl^- = 1-$	
Barium $Ba^{++} = 2+$	Carbonate $(CO_3)^{--} = 2-$	

SAMPLE: Lead chloride   1 2 3 4 5
(1) $PbCl$ (2) $PbCl_2$ (3) Pb_2Cl (4) Pb_2Cl_3 (5) Pb_3Cl_2 ◯ ⊗ ◯ ◯ ◯

1. Lead carbonate
     (1) $Pb(CO_3)$ (2) $Pb(CO_3)_2$ (3) $Pb_2(CO_3)$ (4) $Pb_2(CO_3)_3$ (5) $Pb_3(CO_3)_2$

2. Barium chloride
     (1) Ba_2Cl_3 (2) $BaCl_2$ (3) Ba_2Cl_2 (4) $BaCl$ (5) Ba_3Cl_2

3. Aluminum chloride
     (1) $AlCl$ (2) $AlCl_2$ (3) Al_2Cl (4) Al_2Cl_3 (5) $AlCl_3$

4. Aluminum arsenate
     (1) $Al(AsO_4)_2$ (2) $Al_2(AsO_4)$ (3) $Al_2(AsO_4)_3$ (4) $Al(AsO_4)$ (5) $Al_3(AsO_4)_2$

5. Aluminum carbonate
     (1) $Al(CO_3)$ (2) $Al(CO_3)_2$ (3) $Al_2(CO_3)$ (4) $Al_3(CO_3)_2$ (5) $Al_2(CO_3)_3$

6. Lead arsenate
     (1) $Pb(AsO_3)$ (2) $Pb(AsO_4)_2$ (3) $Pb_2(AsO_4)$ (4) $Pb_2(AsO_4)_3$ (5) $Pb_3(AsO_4)_2$

7. Potassium carbonate
     (1) $K(CO_3)$ (2) $K(CO_3)_2$ (3) $K_2(CO_3)$ (4) $K_2(CO_3)_3$ (5) $K_3(CO_3)_2$

8. Barium arsenate
     (1) $Ba(AsO_4)$ (2) $Ba(AsO_4)_2$ (3) $Ba_2(AsO_4)$ (4) $Ba_2(AsO_4)_3$ (5) $Ba_3(AsO_4)_2$

9. Barium carbonate
     (1) $Ba(CO_3)$ (2) $Ba(CO_3)_2$ (3) $Ba_2(CO_3)$ (4) $Ba_2(CO_3)_3$ (5) $Ba_3(CO_3)_2$

10. Potassium arsenate
     (1) $K(AsO_4)$ (2) $K_3(AsO_4)$ (3) $K(AsO_4)_3$ (4) $K_2(AsO_4)_3$ (5) $K_3(AsO_4)_3$

End of Part 3.

(Time limit, 7 minutes)

Directions: Examine each statement below and decide whether it is true or false. If the statement is true, place an X in the appropriate circle of the first or "true" column on the answer sheet; if the statement is false, place an X in the second circle, this being in the "false" column.

If you do not know the answer to an item, skip it and go on to the next one.

SAMPLE: A. Gold is a metal.
B. Copper is a compound.

T F
a. ⊗ ◯
b. ◯ ⊗

1. Rusting and burning involve the same kind of chemical reaction.
2. Hydrochloric acid is used in automobile batteries.
3. The smallest unit into which a substance may be divided and still retain its chemical properties is the electron.
4. Helium is preferable to hydrogen for use in zeppelins chiefly because it is more buoyant.
5. Application of heat tends to speed up most chemical reactions.
6. Pure water conducts electricity better than a solution containing common salt.
7. Water is an element.
8. The essential chemical reaction in photography is called photosynthesis.
9. The feeling of discomfort experienced in a crowded room is primarily due to a deficiency of oxygen.
10. Oxygen is the gas given off from a bottle of pop.
11. Freezing of water is a physical rather than a chemical change.
12. At normal room temperatures all metals are solids.
13. The molecules of a gas are always in motion.
14. A substance which cannot be decomposed by chemical means is known as an element.
15. The number of elements is now thought to be eighty-seven.
16. If a burning splinter is placed in a bottle of carbon dioxide gas it wil be extinguished.
17. Increasing the pressure lowers the boiling point of water.
18. Oxygen is more abundant than other gases in the earth's atmosphere.
19. The total amount of energy in the universe is constantly changing.
20. A thermometer measures the quantity of heat in a substance.
21. Acid solutions turn red litmus paper blue.
22. If a solution of chlorine in water is exposed to sunlight, hydrochloric acid is formed.
23. If a gas flame under a pan of boiling water is increased, the temperature of the water remains the same.
24. All the chemical elements found in living organisms are also found in non-living matter.
25. The boiling point of distilled water is lower than the boiling point of sea water.
26. One of the chief causes of hardness in water is calcium bicarbonate.
27. Cream has less density than skim milk.
28. A kiloliter is equal to 10,000 liters.
29. The density of water, in its liquid state, is independent of its temperature.
30. The sun was the original source of the energy obtained from gasoline.
31. The bubbles emerging from a diver's suit become smaller as they approach the surface.
32. Energy is furnished to the body by the oxidation of food.
33. The chemical name for common table salt is sodium chlorate.
34. Carbon monoxide gas has a distinctive odor.
35. Diamonds and charcoal are both composed of the same element.
36. Other things being equal, a piece of iron will rust more rapidly at 40° F. than at 100° F.
37. Solidified carbon monoxide gas is commonly known as "dry ice".
38. When a candle is burned, one of the products formed is water.
39. Hydroflouric acid attacks glass containers.
40. The element helium was discovered to exist on the sun before it was discovered on the earth.
41. Vinegar should be used to neutralize hydrochloric acid spilled on the skin or clothing.
42. Water at 2° C. is less dense than water at 4° C.
43. Vinegar is a dilute solution of acetic acid.
44. The essential function of a baking powder is to liberate carbon dioxide.
45. Green plants, when exposed to sunlight, remove oxygen from the air and restore carbon dioxide.

End of Part 4. End of test.