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The effects of different numbers of years of science study upon achievement in high school chemistry.

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Thesis

THE EFFECTS OF DIFFERENT NUMBERS OF YEARS OF SCIENCE STUDY UPON ACHIEVEMENT IN HIGH-SCHOOL CHEMISTRY

Submitted by

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CHAPTER I

THE PROBLEM

1. Major and Minor Problems

Purpose of study.-- The writer has observed that students enter high-school chemistry with different amounts of previous science instruction. Some of these students adapt themselves quite quickly to the new learning situations, and upon termination of the course have shown creditable achievement. Other students, however, who have evidenced marked achievement in scientific and non-scientific courses, fail to achieve well in their study of chemistry. Therefore, it is hoped that the investigations leading to the writing of this paper will illuminate the problem area of determining The Effects of Different Numbers of Years of Science Study upon Achievement in High-School Chemistry.

Justification for problem study.-- School administrators, guidance counselors, teachers, and parents desire information which will assist them to guide students into those science areas which will allow the student to acquire the maximum achievement according to their individual abilities. If years of science preparation prior to studying chemistry is a factor in student achievement in high-school chemistry, then this problem, and the minor problems contained herein, are justified.

Furthermore, other investigations into the science area have indicated that "....students who do not enroll in /science courses/ are denied guided and directed experiences which are intended to lead out to vital concepts, skills, attitudes and appreciations."[1/] It is hoped that the results of this problem will indicate, at least in part, to what extent previous science study assists students in gaining those concepts, attitudes, and skills, which are vital to achievement in high-school chemistry.

Assumptions.-- The writer's finances, time, and facilities available for the investigation of the problem forced the writer to establish certain assumptions to ensure validity. Those assumptions are:

1. Since the science courses in the seven schools differed with respect to content, difficulty, and time allotments, data gathered from all the schools and grouped together would be more reliable than analyzing each school separately.
2. For the purpose of grouping students into highest and lowest thirds in intelligence different forms of intelligence tests are equivalent.

[1/] Roy O. Billett, Fundamentals of Secondary-School Teaching, Houghton Mifflin Company, Boston, 1940, p. 256.

3. Although the science courses in the different schools may vary in title and content, students may be validly grouped as having none, one, two or more years of science preparation prior to studying chemistry.
4. In each of the seven schools, teacher marks are comparable with respect to indicating achievement in the different years of science preparation.

Minor problems.-- The major problem of this study was investigated by considering the following five minor problems:

1. The effects of academic aptitude upon achievement in high-school chemistry when years of science study are held constant.
2. The effects of mental age upon achievement in high-school chemistry when years of science study are constant.
3. The achievement of boys and girls with similar academic aptitude when years of science preparation are constant.
4. The achievement of students in high-school chemistry with two years of science study in the general science-biology sequence, compared to the achievement of those students with one year of science study in biology.

5. The correlation factor relating teacher marks of previous science study to achievement in high-school chemistry.

2. Scope of Problem

Schools.-- The different schools participating in this study totaled seven in number. Each of the seven schools was most happy to participate in the study and was very cooperative. Six of the cooperating schools are located in towns under ten thousand in population. The seventh school is located in the city of Attleboro, Massachusetts. All of the schools were within a fifteen-mile radius of the writer's own home, and are centered in the southeastern section of Massachusetts in the Norfolk and Bristol County areas. The population of six of the high schools was under five hundred students; the seventh school was a little larger than five hundred in population. Each of the high schools in the towns of Foxboro, Mansfield, Sharon, Franklin, North Attleboro, and Walpole, as well as the Attleboro High School, maintained a chemistry course in the junior year of studies.

Students.-- High-school chemistry students participating in the study totaled 333 in number. All of the students had three or less years of science study prior to enrolling in chemistry.

3. Data Gathering Methods

Selection of schools.-- The seven participating schools were selected on the bases of:

1. Chemistry course offering in junior year
2. Number of students enrolled in chemistry
3. Proximity of schools to writer's locale.

School principals, and in some instances the superintendent of schools, were interviewed to gain permission for using their school facilities for the conduct of the study. All of the interviewed administrators were cooperative and encouraged their science teachers to participate in the study. The cooperation of all the various school personnel was greatly appreciated by the writer.

Selection of students.-- All of the cooperating schools opened their student files to allow the writer to assemble those data which were considered necessary to the successful conduct of the problem. Each science teacher provided the writer with the names of those students currently enrolled in chemistry. The permanent records of each chemistry student were consulted to obtain the following personal student information:

1. Birth date
2. Intelligence quotient
3. Sex

4. Science preparation in number of years and courses taken
5. Teacher marks obtained in each year of science study.

Tables 1 and 2 contain distributions of boys and girls in participating schools with various amounts of science preparation prior to studying chemistry.

Participating boys.-- The number of boys taking part in this study totaled 171 or 51.4 per cent of the test group. Forty-two boys had no previous science study prior to chemistry; whereas, 31 boys had one year; 83 had two years; and 15 had three years of previous science study. Those boys who had two years of science preparation composed 48.5 per cent of the boy group.

Table 1. Distribution of Boys in Participating Schools, According to Years of Science Preparation

Years of Science Preparation	Participating Schools							Totals
	A	B	C	D	E	F	G	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
None...............	1	0	0	1	35	2	3	42
One................	7	0	1	7	0	11	5	31
Two................	16	7	21	12	0	8	19	83
Three..............	5	3	0	7	0	0	0	15
Total..........	29	10	22	27	35	21	27	171

<u>Participating girls</u>.-- Girls participating in this study, as indicated in Table 2, totaled 162 in number.

Table 2. Distribution of Girls in Participating Schools, According to Years of Science Preparation

Years of Science Preparation	Participating Schools							Totals
	A	B	C	D	E	F	G	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
None...............	7	0	0	1	36	3	3	50
One................	2	2	11	24	0	8	6	53
Two................	3	7	17	7	0	3	18	55
Three..............	1	3	0	0	0	0	0	4
Total..........	13	12	28	32	36	14	27	162

This group represented 48.6 per cent of the participating students. Fifty girls had no previous science study prior to chemistry. Fifty-three girls, however, had one year of previous study; 55 had two years; and only four had three years of preparation. As a group, the girls had less science study before enrolling in chemistry than the boys.

<u>Selection of standardized test</u>.-- The study was dependent upon the successful measurement of achievement in high-school chemistry. Many tests attempting to measure this factor have been constructed and published. Therefore, it was necessary to consult critical reviews of each chemistry test to obtain that test which appeared to guarantee the

truest measure of achievement. With the exception of the Anderson Chemistry Test, all of the reviewed chemistry tests contained no validation or reliability descriptions; and still others, such as the Minnesota and Iowa Achievement Tests, were designed by state departments of education to evaluate particular courses of study.[1] Tests such as these were thought not desirable for this study and were rejected.

Professor William Rieman, Chemistry Department, Rutgers University, reviewed the Anderson Chemistry Test and concluded that the "test" was as good as any similar test designed to measure achievement in high-school chemistry.[2] This review and the following test description caused the writer to accept the Anderson Chemistry Test as being suitable for this study.

Description of Anderson Chemistry Test.-- This test was constructed to measure the extent to which students achieved the important objectives of a high-school chemistry course. The test consisted of four parts, three parts devoted to the understanding of:

1. Functional concepts and skills (47 per cent)
2. Application of functional principles of chemistry (18 per cent)

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[1] Oscar K. Buros, The Fourth Mental Measurements Yearbook, Gynphon Press, Highland Park, New Jersey, 1953, pp. 617-621.

[2] Ibid., p. 632.

3. Application of the elements of the scientific method and associated attitudes in chemical situations (19 per cent).

The fourth section of the test was constructed to measure the student's "Ability to use basic chemistry skills" (16 per cent).

There are two comparable test forms, AM and BM, each containing 80 items, and requiring 40 minutes of working time. Only test form BM, however, was used in this problem study.

External and internal test validation.-- Publishers of the Anderson Chemistry Test reported that test items were "justified both in terms of frequency of inclusion in commonly used textbooks, and on the basis of expert judgment as to importance."[1/] Initial forms of the Anderson Chemistry Test were tried out in 35 high schools in 11 states on approximately 2,000 students. Validity indices of 0.49 and 0.50 were obtained for each of the two forms.[2/]

Test reliability.-- Coefficients of reliability of 0.90 and 0.93 were obtained on the test on students from two different communities. To better interpret the coefficients of reliability the standard error of measurement was computed and was reported to be 3.6 standard score points. This means that the student's score does not differ by more

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[1/] Kenneth Anderson, Anderson Chemistry Test, Manual of Directions, World Book Company, Chicago, Illinois, 1951, p. 2.

[2/] For a complete description see appendix - Anderson Chemistry Test, Manual of Directions.

than 3.6 points from his hypothetical "true" score.

4. Organization of Data

Collecting the data necessary to the problem of determining The Effects of Different Numbers of Years of Science Study Upon Achievement in High-School Chemistry consumed much time. Consequently, the more difficult task of grouping the voluminous data required greater time and closer attention to detail.

Experience groups.-- All of the students were first grouped according to their number of years of science preparation prior to studying chemistry. The determined experience groups totaled four in number and contained those students having none, one, two, and three years of science prior to studying high-school chemistry.

It is interesting to note that the entire chemistry class in school E, Table 3, had no science instruction beyond the eighth grade. All of the other schools apparently encouraged their students to participate in science courses because together they contributed only 21 of the 92 students in the group having no previous science experience. However, the fact remains that 27.6 per cent of the chemistry students had no science in high school before studying chemistry.

Of the 333 students surveyed, 84, or 25.2 per cent, as indicated in Table 4, column (5), had one year of science

Table 3. Number of Pupils in Each School Who Have Had No Previous Courses In Science

Schools	Number of Pupils
(1)	(2)
A..............	8
B..............	0
C..............	0
D..............	2
E..............	71
F..............	5
G..............	6
Total.......	92

before studying chemistry. Column (3), Table 4, indicates that biology, with 62 students, was the most popular one-year science study. General science, column (2), however,

Table 4. Number of Pupils in Each School Who Have Had One Year of Science Instruction, Distributed According to Course Taken

Schools	Course Taken			
	General Science	Biology	Physics	Totals
(1)	(2)	(3)	(4)	(5)
A...	2	7	0	9
B...	2	0	0	2
C...	0	12	0	12
D...	1	29	1	31
E...	0	0	0	0
F...	12	7	0	19
G...	4	7	0	11
Total	21	62	1	84

contributed only 21 out of the 84 students with one year of study.

The most popular science sequence in six of the seven schools, as indicated in Table 5, was the general science-biology sequence, which contributed 116 of the 138 students with two years of science instruction. Columns (3) and (4) indicate that the remaining 22 students divided their studies by taking physics and general science or biology.

Table 5. Number of Pupils in Each School, Who Have Had Two Years of Science Instruction, Distributed According to Course Taken

	Courses Taken			
Schools (1)	General Science Biology (2)	General Science Physics (3)	Biology Physics (4)	Totals (5)
A...	12	2	5	19
B...	9	5	0	14
C...	38	0	0	38
D...	9	0	10	19
E...	0	0	0	0
F...	11	0	0	11
G...	37	0	0	37
Total	116	7	15	138

Table 6 indicates that few students have three years of science instruction prior to studying chemistry. The nineteen students with three years of science experience

Table 6. Number of Pupils in Each School, Who Have Had Three Years of Science Instruction

Schools	Courses Taken		
	General Science	Biology	Physics
(1)		(2)	
A.....		6	
B.....		6	
C.....		0	
D.....		7	
E.....		0	
F.....		0	
G.....		0	
Total		19	

are all seniors who took physics in their high-school junior year.

Intelligence groups.-- Students in each of the experience groups were placed into subgroups on an intelligence quotient and mental age basis. The intelligence quotient of each student was obtained from the permanent record and arranged from highest to lowest in intelligence. The range of each of the intelligence groups was determined to aid in dividing the subgroups into levels of highest and lowest thirds in intelligence.

Division of the range of intelligence quotients, however, did not produce groups with similar frequencies. In order to produce such groups it was necessary to divide the range of students into thirds and accept the corresponding intelligence levels as representing points of highest and lowest thirds in intelligence. Table 7 contains information pertaining to the range and number of students in the lowest third in intelligence for each year of science preparation.

Table 7. Intelligence Quotient Ranges and Frequencies of Students Grouped According to (1) Lowest Third in Intelligence and (2) Various Years of Science Preparation

Years of Preparation	Lowest Third	
	IQ Range	F
(1)	(2)	(3)
None...........	83-105	28
One............	83-104	26
Two............	80-108	49

When Table 7 is compared with Table 8, it is evident that the numbers of students in the lowest and highest thirds in intelligence for each year of science preparation are not

Table 8. Intelligence Quotient Ranges and Frequencies of Students Grouped According to (1) Highest Third in Intelligence and (2) Various Years of Science Preparation

Years of Preparation	Highest Third	
	IQ Range	F
(1)	(2)	(3)
None...........	117-130	25
One............	112-127	22
Two............	117-130	35

equal. These groups, nevertheless, were the best groupings that the assembled data permitted. All other attempts to group these students proved to be more unsatisfactory than the accepted ones and were rejected.

Mental-age groups.-- The experience groups were again divided into the second subgroup according to mental age. The range of mental ages was divided into thirds to determine levels of highest and lowest thirds in mental age. Division of the mental age range, however, failed to produce subgroups with similar frequencies, and it was again necessary to divide the range of students into thirds and accept their mental ages as determining points of highest and lowest thirds in mental age. The mental age range and number of students in the lowest third in mental age for each year of science preparation are arranged in Table 9 for the convenience of the reader.

Table 9. Mental Age Ranges and Frequencies of Students Grouped According to (1) Lowest Third in Mental Age and (2) Various Years of Science Preparation

Years of Preparation	Lowest Third	
	Range (MA)	F
(1)	(2)	(3)
None.........	160-210	30
One..........	180-214	22
Two..........	160-214	39

When Table 9 is contrasted with Table 10, it is apparent that students in the lowest and highest thirds in mental age, for each year of science preparation, are more alike in number than students grouped similarly according to intelligence quotient.

Table 10. Mental Age Ranges and Frequencies of Students Grouped According to (1) Highest Third in Mental Age and (2) Various Years of Science Preparation

Years of Preparation	Highest Third	
	Range (MA)	F
(1)	(2)	(3)
None........	233-270	27
One.........	235-272	23
Two.........	240-290	38

Sex groups.-- The boys and girls in each experience group were separated into two subgroups, one consisting of boys only and the other of girls. Absenteeism on test day and deficient permanent records caused the frequencies of each of the subgroups in Table 11 to be smaller than originally expected. Nevertheless, the number of boys in each preparation group was thought to be sufficient for the purposes of this study.

Table 11. Mean Intelligence Quotients and Frequencies of Boys Grouped According to Years of Science Preparation

Years of Preparation	Boys	
	Mean IQ	F
(1)	(2)	(3)
None........	115	39
One.........	111	21
Two.........	108	72

Table 12 contains data on girls grouped according to years of preparation. In each of the preparation groups the mean intelligence quotient of girls, column (2), is within five points of the boys' intelligence quotient. Such a small difference in intelligence quotients indicates that boys and girls participating in this study are approximately equal in aptitude.

Table 12. Mean Intelligence Quotients and Frequencies of Girls Grouped According to Years of Science Preparation

Years of Preparation	Girls	
	Mean IQ	F
(1)	(2)	(3)
None........	110	44
One.........	106	47
Two.........	112	52

Teacher marks.-- All of the boys and girls in each of the experience groups had their marks in each year of science instruction averaged together so that the average science mark could be compared with their Anderson Test score. This method was employed to assist in determining a correlation between science-teacher marks and achievement scores obtained on the Anderson Chemistry Test. All of the schools participating in the study graded upon a five-point basis; hence, there was no difficulty in transposing the different marking systems onto a five-point numerical scale--five points indicating highest achievement and one point lowest achievement.

Biology versus general science-biology sequence.-- Since those students who had one year of science preparation in biology and those who had two years of science preparation in the general science-biology sequence comprised two fairly popular groups, it was thought to be of interest to compare the achievement of these two groups. Students in the general science group had a mean intelligence quotient of 108, as compared to the mean intelligence quotient of 112 for students in the general science-biology sequence.

5. Test Administration

Testing.-- All of the cooperating science teachers proctored their own chemistry classes during the actual test periods. Each teacher was interviewed by the writer one week before the actual test day to ensure constant test procedures within all schools. None of the participating students was aware of the testing program until test day. On this day each student was handed a typewritten statement, prepared by the writer, which informed all students of the testing program's scope and purpose. A copy of this statement may be found in the appendix.

Each teacher retained copies of the Anderson Test to be administered to students who were absent on test day.

Test schedule.-- Establishing a test schedule to satisfy all schools proved to be a difficult task. During the month of October all cooperating science teachers agreed to participate in the testing program during the first two weeks in May. Late in April, however, some teachers believed that their students would not perform well upon the Anderson Chemistry Test and desired to postpone testing until the last week in June. The science teachers required much evidence to support the writer's claim that a loss of one month's study in chemistry would not act adversely to the problem study.

Testing began Tuesday, May 1, 1956, and ended Thursday, May 10, 1956.

CHAPTER II

PROBLEM FINDINGS

With the completion of the last test administration all efforts were turned towards the task of correcting the tests and readying the material for statistical analysis.

Unfortunately test results were affected by factors which influenced the median and mean Anderson Test scores. Two of these factors, absenteeism and improper test administration, were anticipated and controls were established to minimize their effects.[1]

The third obstacle to the testing pattern was the uncontrolled number of students having three years of science study. It was thought that the nineteen students were too small in number to warrant full statistical treatment. The mean intelligence quotient and mean test score, therefore, were the only measures computed. Students with three years of science study had a mean intelligence quotient of 115 and obtained a mean score of 43 points.

The findings of each of the other preparation groups are discussed in the divisions of this chapter.

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[1] See Chapter I, Section 5.

1. Intelligence Groupings

Median scores.-- The results of the Anderson Chemistry Test administered to students grouped in highest and lowest thirds in intelligence are presented in tables for the reader's ready reference.

The lowest level of achievement, in terms of Anderson Test scores, was obtained by students in the lowest third in intelligence with no previous science preparation. These students, Table 13, column (2), had a median score of 33 points which placed them at the 22 percentile of the standardized test group. The median scores of those students with one and two years of science preparation were 34 and 38 points, respectively. The maximum difference in scores of students in the lowest third occurred between students with no preparation, column (2), and students with two years of preparation, column (4). The maximum difference was five points.

Table 13. Distribution of Median Anderson Test Scores According to (1) Years of Science Preparation and (2) Highest and Lowest Thirds of Students in Intelligence

Intelligence Group	Years of Science Preparation		
	None	One	Two
(1)	(2)	(3)	(4)
Highest Third	41.5	45.25	49
Lowest Third	33	34	38

Students in the highest third in intelligence, Table 13, with none, one, and two years of science preparation had median scores of 41 1/2, 45 1/4, and 49 points. Here again, the maximum difference in achievement occurred between students with no science preparation, column (2), and students with two years of preparation, column (4). This difference was approximately eight points. Students in the lowest third in intelligence with no science preparation, column (2), and students in the highest third in intelligence with two years of science preparation, column (4), displayed the greatest difference in performance. The two groups differed by 16 points.

Percentile ratings.-- Table 14 offers the reader another perspective on the relative growth of students grouped according to intelligence. The percentile scores,

Table 14. Percentile Ratings of Students in Highest and Lowest Thirds in Intelligence with Various Amounts of Science Preparation

Intelligence Group	Years of Science Preparation			
	None	One	Two	Maximum Difference
(1)	(2)	(3)	(4)	(5)
Highest Third	44	52	62	18
Lowest Third	22	24	33	11
Difference	22	28	29	--

based upon the norm group of the Anderson Chemistry Test illuminated the various raw score differences occurring between groups, and indicated that the maximum relative growth of students in the highest third was 18 percentile points as compared to 11 percentile points for students in the lowest third in intelligence. The difference between students in the highest and lowest third in intelligence for each year of science preparation was 22, 28, and 29 percentile points, respectively.

Standard deviations.-- The performance of students grouped according to intelligence can be better understood by observing the deviations as grouped in Table 15. Students in the lowest third in intelligence, Table 15, tended to be more homogeneous in their variation of performance than did students in the highest third who displayed a continuous increase in variation of performance for each year of science

Table 15. Standard Deviations of Anderson Test Scores According to (1) Years of Science Preparation and (2) Highest and Lowest Thirds in Intelligence

IQ Groups	Years of Preparation None	 One	 Two
(1)	(2)	(3)	(4)
Highest Third	7.8	10.9	11.8
Lowest Third	8.8	6.2	9.0

study. The difference in standard deviations of students in the highest third, columns (2) and (4), was four points as compared to a difference of three points for students in the lowest third, columns (3) and (4).

The reader can perhaps gain a clearer picture of the performance and overlapping of students grouped according to intelligence by observing Figure 1. The bar graph is

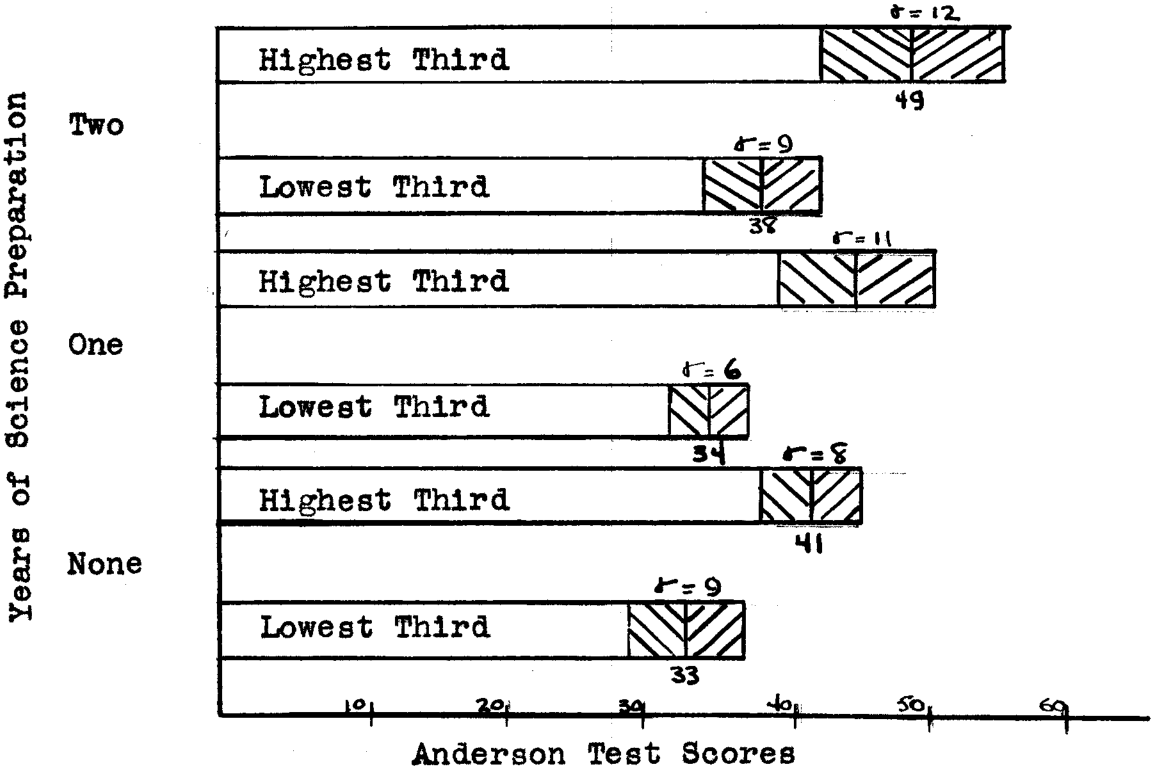

Figure 1. Median Test Scores and Standard Deviations of Students Grouped According to (1) Highest and Lowest Thirds in Intelligence and (2) Years of Science Preparation

drawn to scale and offers a visual comparison of median scores and deviation of students grouped according to intelligence with different amounts of science preparation. A close examination of the graph reveals that the students in the lowest third, regardless of preparation, never performed as well as students in the highest third with similar preparation. There was, however, an overlap in performance between students in the lowest third with (n) years of preparation and students in the highest third with (n-1) years of preparation.

2. Mental Age Groups

The similarity of data existing between students grouped according to mental age and intelligence was so great that the writer hesitated to engage in any discussion pertaining to mental age groups in fear of being redundant. Yet, the absence of such a discussion would tend to obscure the remarkable relationship of these two groups.

Median scores.-- The median scores of students in the mental age groups are tabulated in Table 16 for easy comparison. The maximum difference in scores of students in the highest third in mental age occurred between students with no previous science preparation, column (2), and students with two years of science preparation, column (4). This difference was 6 1/2 points as compared to 4.9 points for students in the lowest third with similar preparation.

Table 16. Distribution of Median Anderson Test Scores According to (1) Years of Science Preparation and (2) Highest and Lowest Thirds of Pupils in Mental Age

Mental Age Groups	Years of Science Preparation		
	None	One	Two
(1)	(2)	(3)	(4)
Highest Third	41.0	44.2	47.5
Lowest Third	33.0	34.0	37.9

At this point the reader will find it interesting to compare the scores of Table 16 with scores earned by students grouped according to intelligence, Table 13. As mentioned previously, the scores are so nearly alike that their similarities are best analyzed by directly comparing each table with the other.

Standard deviations.-- Table 17 contains the standard deviations of students grouped according to mental age and indicates that students in the highest and lowest third with no previous science preparation, column (2), had standard deviations which for all practical purposes were identical. Students with one and two years of preparation, columns (3) and (4), displayed a difference of approximately two points. When viewed with respect to years of preparation, students in the lowest third showed little variation in performance as compared to a variation of approximately four points for students in the highest third.

Table 17. Standard Deviations of Anderson Test Scores According to (1) Years of Science Preparation and (2) Highest and Lowest Thirds in Mental Age

Mental Age Groups	Years of Science Preparation		
	None	One	Two
(1)	(2)	(3)	(4)
Highest Third	8.6	12.6	12.1
Lowest Third	8.7	8.9	10

Figure 2 graphically portrays the performance of students grouped according to mental age and shows that

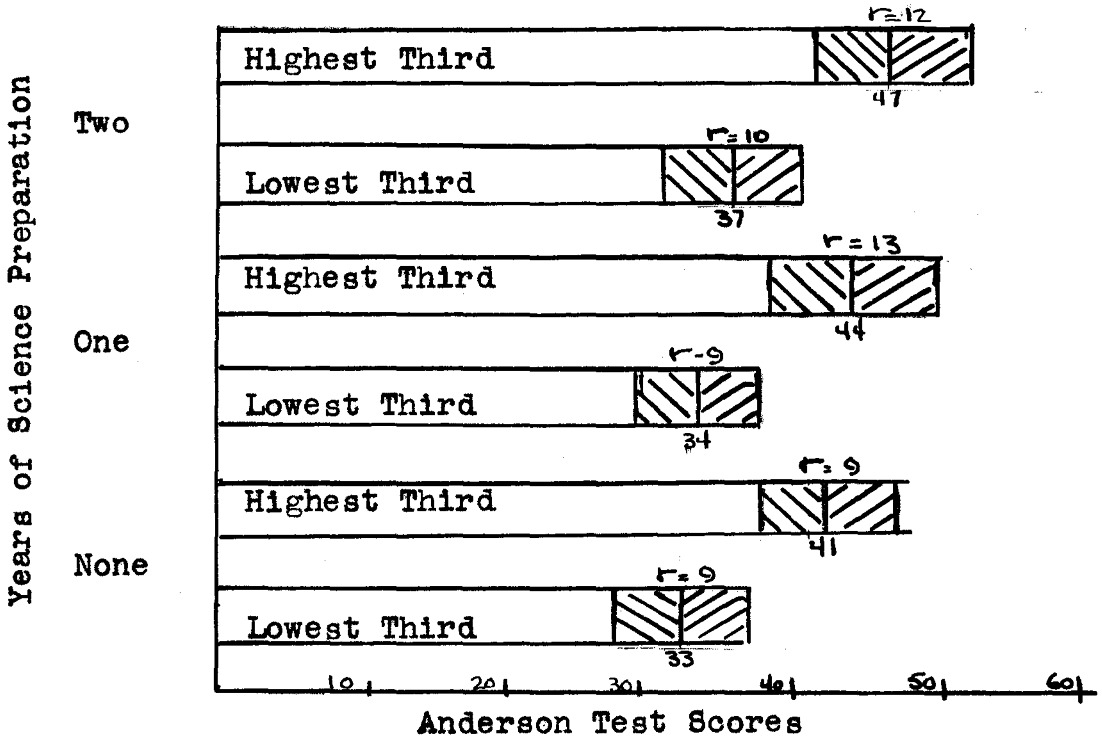

Figure 2. Median Test Scores and Standard Deviations of Students Grouped According to (1) Highest and Lowest Thirds in Mental Age and (2) Years of Science Preparation

students in the lowest third tended to overlap students in the highest third in performance. This overlapping in performance was not so prevalent when the students were grouped in terms of highest and lowest third in intelligence. This point is better understood by comparing the findings of these groups as presented in Figures 1 and 2.

3. Sex Groups

When the students were placed into boy and girl groups according to years of preparation, it was interesting to see that although the groups were similar in intelligence, boys consistently averaged a higher mean score than the girls. Columns (2) and (3), Table 18, show that boys tested for each year of science preparation had a mean score higher than girls with similar science preparation. The boys' average mean score was 42.8; whereas, the girls had an average mean score of 36.6 points. Boys and girls with two years of preparation tended to be more similar in performance than did students in any other preparation group. The mean score for boys with two years of preparation was 45.6 as compared to 42.3 points for the girls. The difference in scores of boys and girls in each of the remaining preparation groups was approximately seven and eleven points for none and one year of preparation.

The relative growth of boys, column (2), Table 18, as compared to the relative growth of girls, column (3), was

Table 18. Distribution of Mean Anderson Test Scores of Boys and Girls with Different Amount of Science Preparation

Years of Science Preparation	Mean Anderson Test Scores	
	Boys	Girls
(1)	(2)	(3)
None...........	39.1	32.6
One............	43.7	34.8
Two............	45.6	42.3
Average Scores	42.8	36.6

approximately seven and ten points. Although boys consistently averaged a higher score, the girls displayed greater relative achievement for each year of science preparation.

4. Biology Students Compared with General Science-Biology Students

The information contained in Tables 4 and 5, Chapter I, indicated that students who had two years of preparation in general science and biology composed a group which was approximately twice as large as the group with one year of preparation in biology. The findings of each of these two groups, however, are thought to be valid for comparison purposes, and are presented for the singular purpose of attempting to describe the effects of different numbers of years of science preparation upon achievement in high-school chemistry.

Biology students.-- Those students who had one year of study in biology had a mean intelligence quotient of 108 and obtained a median score of 36 points. The standard deviation was computed to be approximately eleven points.

General science-biology students.-- In contrast to the above group, students who had two years of science preparation in general science and biology had a mean intelligence quotient of 112 and a median Anderson Test score of 43. The standard deviation of the group was 12 points.

5. Correlation of Teacher Marks with Anderson Test Scores

Scatter diagrams relating Anderson Test scores to teacher marks of students with one and two years of science preparation were constructed to offer the reader the advantage of visual relationships. Students obtaining the highest teacher mark in a five-point qualitative marking system were grouped in column five (5), and students receiving lower teacher marks were grouped in columns with decreasing numerical values. These columns represent marking systems of A, B, C, D, E, or F and A, B, C+, C-, and F.

<u>One-year preparation</u>.-- Table 19 is a scatter diagram relating test scores to teacher marks of students with one year of science preparation. The computation of the coefficient of correlation by the product moment method was 0.51,which for predictive purposes is not too significant. Yet, when the mean Anderson Test score of students in each column was computed, it was discovered that those students having a teacher mark of "A" had the highest mean score, and students having lower teacher marks obtained lower group mean scores. The mean scores of students having teacher marks corresponding to grades of A, B, or C were 47 1/2, 39 1/2, and 32 points, respectively.

<u>Two-year preparation</u>.-- When the scatter diagram relating test scores and marks of students with two years of preparation

Table 19. Scatter Diagram Relating Anderson Test Scores to Teacher Marks of Students with One Year of Science Preparation

Marks Scores	1 F	2 D	3 C	4 B	5 A
75					
70					2
65					
60				1	1
55				1	
50			1	4	2
45			1	4	2
40			5	2	2
35		1	7	7	2
30			7	5	1
25			7	2	
20			1		
15			1		

$r = 0.51$

was constructed, it was thought advisable to include those point scores which were part of a five-point qualitative marking system. Therefore, both the whole number and fractional values of the average marks are included in Table 20. The qualitative scale included in the table is

Table 20. Scatter Diagram Relating Anderson Test Scores to Average Teacher Marks of Students with Two Years of Science Preparation

Marks / Scores	D		C		B		A
	2	2.5	3	3.5	4	4.5	5
75							2
70						1	1
65					3		2
60							3
55				1		5	3
50			1	4	4	3	1
45			1	9	8	7	2
40		1	3	5	4	6	1
35	1		4	8	2	1	
30	1	2	7	3	3	2	
25		1		1	4		
20	1		1				
15			1	1			
10							

$r = 0.59$

illustrative of the marking system in most of the participating schools.

When the mean score of students in each column was computed, it was again discovered that students having the higher average mark obtained the higher mean group score. The mean Anderson Test score of students grouped from highest to lowest in teacher marks was 57, 45.8, 48.7, 39.6, 33.3, 32.3, and 28.3 points.

Computation of the coefficient of correlation by the product moment method was 0.59. This correlation factor was slightly larger than the one computed for students with one year of preparation and is not too significant for predictive purposes.

The writer believes that the statistics presented in this section and in the preceding sections were sufficient in their attempt to describe the effects of different numbers of years of science preparation upon achievement in high-school chemistry. If such were not the case, the conclusions presented in Chapter III would not be valid.

CHAPTER III

SUMMARY OF FINDINGS AND TENTATIVE CONCLUSIONS

A summary of the findings of each minor problem is presented in this section. Before presenting each summary the minor problems are restated to offer the reader the opportunity of becoming re-acquainted with the problem as originally stated.

1. Restatement and Summary of Minor Problems

First minor problem.-- The effects of academic aptitude upon achievement in high-school chemistry when years of science study are held constant.

The findings related to the first minor problem are:

1. Students in the lowest third in intelligence with no previous science study obtained the lowest achievement score as measured by the Anderson Chemistry Test.
2. Students in the highest third in intelligence with two years of science study obtained the highest achievement score.
3. Students in the highest third in intelligence displayed a greater gain in achievement for each year of study than students in the lowest third with similar preparation.

4. Students in the highest third in intelligence with one and two years of preparation tended to display a greater variation in performance than students in the lowest third with similar preparation.
5. Students in the lowest third in intelligence with one and two years of science study had a tendency to be equal in achievement with students in the highest third in intelligence with one less year of science preparation.

Second minor problem.-- The effects of mental age upon achievement in high-school chemistry when years of science study are constant.

The findings related to the second minor problem are:

1. Students in the lowest third in mental age with no previous science study obtained the lowest median achievement score.
2. Students in the highest third in mental age with two years of science study obtained the highest median achievement score.
3. Students in the highest third in mental age with one and two years of science study tended to display a greater variation in performance than did students in the lowest third with similar preparation.

Third minor problem.-- The achievement of boys and girls with similar academic aptitude when years of science preparation are constant.

The findings related to the third minor problem are:

1. For each year of science study boys obtained a higher mean score than girls.
2. Girls displayed a greater relative gain in achievement after two years of science study than boys.

Fourth minor problem.-- The achievement of students in high-school chemistry with two years of science study in the general science-biology sequence compared to the achievement of those students with one year of science study in biology.

The findings related to the fourth minor problem are:

1. Students who had two years of science study in general science and biology had a median score which was higher than the median score of students with one year of study in biology.
2. Both preparation groups displayed approximately equal variation in scores.
3. Students who had two years of science study in general science and biology had a mean intelligence quotient which was four points higher than the intelligence quotient of students with one year of study in biology.

Fifth minor problem.-- The correlation factor relating teacher marks of previous science study to achievement in high-school chemistry.

The findings related to the fifth problem are:

1. The correlation factor relating Anderson Test scores to teacher marks of students with one year of science study was 0.51.
2. The correlation factor relating Anderson Test scores to the teacher marks obtained by students with two years of science study was 0.59.
3. Those students who obtained the higher teacher mark, as a group, also obtained the higher mean test score.

2. Tentative Conclusions

The necessary consequences resulting from the findings of the problem of determining The Effects of Different Numbers of Years of Science Study upon Achievement in High-School Chemistry are recorded below as tentative conclusions. Perhaps other studies directed towards the investigation of the major problem will yield findings which are not identical to the findings presented herein. Until that time arrives, however, the following statements are offered as conclusions arising from this problem study.

The conclusions are:

1. Achievement in high-school chemistry is directly associated to the independent variables of intelligence and years of previous science study.
2. Students in the highest third in intelligence display greater achievement gains for each year of study

than students in the lowest third with similar preparation.

3. Students in the lowest third in intelligence tend to be more homogeneous in achievement than students in the highest third in intelligence with similar preparation.
4. Students in the lowest third in intelligence tend to perform as well as students in the highest third in intelligence with one less year of science preparation.
5. Students grouped according to mental age and intelligence display similar achievement patterns.
6. When years of science study and academic aptitude are similar, boys tend to achieve more in their study of high-school chemistry than girls.
7. Students who have had two years of science study in general science and biology achieve more in their study of chemistry than students with one year of science study in biology.
8. For predictive purposes, the correlation factors relating teacher marks to achievement in high-school chemistry were not significant.

<u>Concluding statement</u>.-- If the conclusions presented in this writing were synthesized into one statement, they could well indicate that students who elect chemistry,

regardless of academic aptitude, stand to achieve more in their study if they have a background in selected high-school science courses.

Undoubtedly, the facts causing such a statement indicate the necessity of requiring students to participate in elementary high-school science courses so that they might have the opportunity to acquire the attitudes, ideas, appreciations, and skills which are essential to maximum achievement in the advanced science of high-school chemistry.

APPENDIX

EVALUATION AND ADJUSTMENT SERIES

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COÖRDINATOR FOR SCIENCE TESTS: **VICTOR H. NOLL**, MICHIGAN STATE COLLEGE

ANDERSON CHEMISTRY TEST

BY **KENNETH E. ANDERSON**
SCHOOL OF EDUCATION, UNIVERSITY OF KANSAS

MANUAL OF DIRECTIONS

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NATURE AND CONTENT

The *Anderson Chemistry Test* has been constructed to measure the extent to which students have achieved the important objectives of a high school course in chemistry. There are two comparable forms, AM and BM, each comprising 80 test items carefully selected on the basis of curricular validity and satisfaction of statistical requirements.

The time required for administration of this test is one class period. Test booklets are non-expendable, all student responses being recorded on separate answer sheets. The answer sheets may be scored easily either by hand or by machine.

The *Anderson Chemistry Test* is divided into the following parts in the proportions given: Part A — Understanding of functional facts and concepts (47%); Part B — Understanding and application of functional principles of chemistry (18%); Part C — Understanding and application of the elements of the scientific method together with its associated attitudes in chemical situations (19%); Part D — Ability to use the basic skills in chemistry (16%).

The following outline indicates the scope of the test and the relative emphasis given the various aspects measured:

1. Chemical changes — 8%
2. Chemical solutions — 9%
3. Symbols, equations, problems — 20%
4. Atomic structure — 10%
5. Ionization — 10%

The *Anderson Chemistry Test* is one of the tests in the *Evaluation and Adjustment Series* of high school tests.

The achievement tests in this series cover a variety of subjects in the fields of mathematics, science, social studies, and the language arts. Each test in the series contributes toward a complete, integrated evaluation program for secondary schools. These tests are designed specifically to evaluate the outcomes of instruction in the various subjects as they are being taught in the typical schools of our country.

The series also includes the following tests in the field of science:

Dunning Physics Test *Engle Psychology Test* *Kilander Health Knowledge Test*
Nelson Biology Test *Read General Science Test*

Published by World Book Company, Yonkers-on-Hudson, New York, and Chicago, Illinois

PRINTED IN U.S.A. ACT : M-1

6. Study of the elements, individually and by families — 22%
7. Organic chemistry — 14%
8. Applications of chemistry — industrial and personal — 7%

DEVELOPMENT OF THE TEST

The *Anderson Chemistry Test,* like the other tests in the *Evaluation and Adjustment Series,* was constructed and validated according to rigid standards.

The procedures followed in selecting the content of this test to measure important outcomes consisted of (1) determining in the soundest manner possible the objectives to be measured; (2) determining the proper emphases and weights to be assigned to the various objectives; (3) deciding upon suitable methods of measuring these objectives; and (4) developing test items calculated to furnish the desired measurements.

The items were constructed only after a thorough analysis of varied instructional materials and authoritative pronouncements in the science field. Most elements measured may be justified both in terms of frequency of inclusion in commonly used textbooks and on the basis of expert judgment as to importance.

In determining the objectives and content of this test the following sources were utilized:

1. Approximately 20 widely used textbooks.
2. Representative curricula and state courses of study.
3. National Society for the Study of Education. Forty-fifth Yearbook, Part I. *The Measurement of Understanding.* University of Chicago Press; 1946.
4. National Society for the Study of Education. Forty-sixth Yearbook, Part I. *Science Education in American Schools.* University of Chicago Press; 1947.
5. Progressive Education Association. *Science in General Education.* (Report of the Committee on the Functions of Science in General Education for the Commission on Secondary School Curriculum.) D. Appleton-Century Company; 1938.
6. Kenneth E. Anderson, "The Relative Achievements of the Objectives of Secondary School Science in a Representative Sampling of Fifty-six Minnesota Schools," Doctor's Dissertation, Minneapolis: University of Minnesota, 1949.

Initial tryout. After the curriculum research outlined in the preceding paragraphs had been completed, three experimental forms of the *Anderson Chemistry Test* were developed. Each preliminary form of the test comprised 105 items. Thus, almost twice as much material was tried out as was ultimately included in the final forms of these tests. These experimental forms were administered near the close of school in 1949 to groups of students in 35 high schools in 11 states. Approximately 2000 students took the experimental forms of the test. Their mean IQ was 113, according to results on the *Terman-McNemar Test of Mental Ability,* given at the same time as the experimental forms.

Construction of final forms. The results of the preliminary tryout were analyzed during the summer of 1949. Difficulty and validity indices[1] were computed for each item in the test. The mean validity index of the test items in Form AM is .49; and in Form BM, .50. Difficulty values for each item are given in Table 1. On the basis of these difficulty and validity data, items were selected in such fashion as to yield two final forms of the test precisely balanced in difficulty, of suitable range of difficulty, and composed of items known to be of significant discriminating power.

In selecting material for the final forms of the test, consideration was given not only to the statistical evidences of suitable difficulty and validity, but also to the construction of a test which, from a content standpoint, would correspond to the original outline or blueprint and which would, therefore, represent a balanced coverage of objectives.

All teachers who administered the preliminary forms in this initial experimentation were asked to criticize these forms, particularly with respect to coverage of topics, clarity of questions, difficulty of the materials, adequacy of directions, etc. Thus, in effect, the test was subjected to the critical review of many classroom teachers prior to publication; these criticisms have been taken into account in developing the final forms of the test.

RELIABILITY AND EQUIVALENCE OF FORMS

For a proper evaluation of a test it is necessary to have relevant information pertaining to the stability, or consistency, of the test scores, and to the degree of comparability among the forms. Such information for the *Anderson Chemistry Test* is given below.

Reliability. Corrected split-half reliability coefficients of .90 and .93 were obtained on the *Anderson Chemistry Test* based on 162 chemistry students in one community and 151 in two communities combined. Inasmuch as this test is essentially a power test, these reliability coefficients may be regarded as good estimates of the reliability of the instrument itself. An alternate-form reliability of .87 was found based on administration of both Forms AM and BM to 128 students in one community with an interval of less than a week between the successive administrations.

It is somewhat difficult even for the statistically trained user of tests to interpret the practical significance of a reliability coefficient in terms of the fluctuation in the test results of an individual student that may be expected from one testing to another. For this reason it is often more meaningful to use the *standard error of measurement,*[2] which is an estimate of the amount by which an individual's obtained score is

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[1] Difficulty values for each item were computed by averaging the per cent passing each item in the upper and lower 27 per cent of the item-analysis population. Validity indices are approximations of the item-total score correlation obtained from the upper-lower 27 per cent groups by means of the Flanagan table.

[2] S.E. Meas. = $\sigma_1\sqrt{1 - r_{11}}$ when σ_1 = S.D. of total score and r_{11} is corrected split-half reliability coefficient.

TABLE 1. ITEM-DIFFICULTY VALUES

Item No.	Form AM	Form BM	Item No.	Form AM	Form BM
1	80	81	41	62	67
2	78	76	42	59	30
3	78	75	43	55	59
4	76	75	44	40	53
5	74	74	45	66	54
6	72	71	46	40	73
7	70	70	47	49	49
8	69	70	48	42	43
9	69	68	49	47	43
10	68	67	50	39	32
11	67	67	51	20	24
12	67	67	52	26	33
13	66	67	53	75	73
14	66	67	54	61	64
15	63	64	55	57	54
16	63	67	56	52	51
17	62	62	57	48	50
18	62	62	58	45	48
19	61	62	59	67	72
20	60	60	60	66	70
21	59	58	61	64	63
22	57	57	62	32	30
23	57	56	63	80	91
24	55	55	64	56	66
25	55	54	65	46	56
26	54	54	66	81	37
27	54	53	67	42	81
28	53	53	68	68	49
29	53	51	69	29	36
30	52	50	70	54	60
31	49	48	71	52	41
32	49	48	72	70	68
33	49	47	73	68	57
34	48	47	74	65	55
35	46	45	75	64	54
36	44	44	76	58	54
37	44	43	77	57	53
38	42	29	78	57	52
39	75	82	79	51	46
40	66	56	80	29	34
			Mean Diff.	57	57

likely to vary from his "true" score. The standard error of measurement is more meaningful, also, because it is less a function of the variability of the group on which it is based and is more comparable from test to test than is the reliability coefficient. The standard error of measurement on the *Anderson Chemistry Test* is 3.6 standard score points. This means that there are two chances in three that an individual's score on the test does not differ by more than 3.6 points from his hypothetical "true" score.

It is necessary to keep constantly in mind the fact that the obtained score on this test, as on any test, is not an absolutely accurate measure of an individual's achievement, but that it involves certain measurement errors, the approximate magnitude of which is suggested by the standard error of measurement. It is especially important that this concept of measurement error be given consideration in connection with the interpretation of differences between scores of any two tests.

Equivalence of forms. Forms AM and BM are comparable in content in the sense that their respective items cover in approximately equal proportions the various aspects of the subject with which the test is concerned. In both forms there is approximately the same amount of emphasis devoted to any given aspect of the subject. The forms are, moreover, of equal difficulty. On the basis of item-difficulty values derived in the initial tryout of the materials, items were allocated to the final forms in such a manner as to result in two forms precisely balanced not only with respect to average difficulty, but also with respect to distribution of item difficulties. Furthermore, the items in the two forms were balanced with respect to validity indices.

As an additional check on the equivalence of forms, a study was undertaken involving the administration of both forms of the test in a rotation-type experiment. A randomly determined half of the group took Form AM first; the other half, Form BM first. Comparison of the distributions of scores of the two forms for the groups tested indicated that the two forms are almost directly comparable at all points along the scale, even in terms of raw score.

Thus, any differences found between results of administration of the two forms are accurate reflections of changes that have taken place from one administration to the other, within the limits of the reliability of the test, and are not consequences of any systematic differences between the forms.

GENERAL DIRECTIONS TO THE EXAMINER

This test may be given by the regular classroom teacher, without any extensive previous training. Students may be tested in the usual instructional groups or in larger groups if sufficient proctors are provided. Before attempting to administer this test the examiner should become thoroughly familiar with the directions governing its administration. The usual physical standards for good test administration — e.g., lighting, desk space, quiet, etc. — should be met.

Time schedule. The actual working time which must be allotted to this test is 40 minutes. To the working time must be added approximately 10 minutes for the examiner to distribute and collect testing materials, for the students to fill in the identifying information on the answer sheet, and for the examiner to give the directions. Testing periods should be so arranged that the full working time is available.

Materials needed by each student. Each student taking the test will need a copy of the test booklet, a copy of the separate answer sheet, scratch paper, two soft-lead pencils, and an eraser. If the answer sheets are to be scored by machine, a special electrographic pencil must be furnished to each student.

SPECIFIC DIRECTIONS FOR ADMINISTERING

Be sure that each student has two soft-lead pencils, scratch paper, and an eraser, and that the desks are cleared of all other materials.

If the students are not familiar with the use of separate answer sheets, and particularly if the tests are to be scored on an International Business Machines Scoring Machine, the students should have special practice in marking their answers before they start on this test.[1] *The special practice answer sheets should be inspected to be certain that each student is making one glossy black response for each item. The blackened area should not extend either above or below the pair of dotted lines, but it may extend approximately $\frac{1}{16}$ inch to either side. Two up-and-down strokes over each other usually are adequate.*

Begin the specific instruction period for this test by saying: **"You will now be given your materials for the *Anderson Chemistry Test*."**

Give each student an answer sheet and say: **"Now fill in your name and the other information called for on the left-hand side of the answer sheet. Be sure to fill in all the information accurately. The date of testing is . . . . . ."** (Give the date.) **"Be sure to record your birth date — the year, month, and day of your birth. Now look farther to the right. It says, 'FORM OF TEST AM, BM (CIRCLE ONE).' Now put circle around . . .** (whichever form is used)."

Allow sufficient time for each student to fill in th required data. When all information has been filled in on the answer sheet, say: **"I am now going to distribute the test booklets. Do not open them. You are not to make any marks whatever on these test booklets."** (Pass out the test booklets.) Then say: **"Now study the directions on the cover page of the test booklet."**

If tests are to be scored by the International Business Machines Scoring Machine, the following additional directions should be read:

"Your papers are going to be scored by an electrical scoring machine. If your papers are to be scored fairly, it is essential that you remember the following rules: (1) Use only the special pencil. (2) Make heavy black marks as long as the pairs of lines on the answer sheet by moving your pencil up and down several times. (3) Do not make any stray marks. (4) Do not mark more than one answer for a question. (5) Erase carefully any answer you wish to change. Failure to follow these instructions is apt to reduce your score as read by the machine."

While the students are reading the directions, move about the room in order to make sure that everyone knows how to handle the answer sheet and has marked the samples correctly. When this has been done, say: **"Are there any questions about how you are to take the test? No questions will be answered after the examination starts."** (Allow time for questions.)

Then say: **"You will have 40 minutes in which to complete this test. When you have finished checking your answers, close your booklet and leave it on your desk until you are given further instructions. Remember, do not make any marks on your test booklet. Now open your test booklet and fold it so that only page 2 is showing. Always keep the booklet folded so that you have only one page in front of you at a time. Start work now."** (Record time in hours and minutes on the blackboard.)

During the testing period, move quietly about the room, making sure that the students are marking the answer sheets properly.

At the end of 40 minutes, say: **"Stop! Close you booklets."**

Collect the test booklets, answer sheets, electrographic pencils (if furnished), and used scratch paper. Count booklets and answer sheets to make sure that all are returned.

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[1] IBM Form ITS 1100–S288, "General Directions to Pupils Using Special Answer Sheets for Machine-Scored Tests," can be obtained through the nearest IBM branch office; or the Division of Test Research and Service, World Book Company, will provide suggested practice materials, which may be adapted and mimeographed locally.

DIRECTIONS FOR SCORING

The score on this test is the number of right answers.

Hand scoring. Hand scoring is accomplished accurately and rapidly by means of a perforated stencil type of scoring key. To score an answer sheet by hand, proceed as follows:

1. Scan each answer sheet and, with a colored pencil, draw a line through any row of spaces in which more than one answer has been marked by the student. Count multiple-marked items as omitted. Do not count multiple-marked items as right even though the right answer is one of those marked.
2. Place the scoring key over the answer sheet so that the heavy black arrows in the center of the answer sheet show through the openings on the key and the arrows on the answer sheet and those on the key are point to point, thus: $\boxed{\rightarrow}\leftarrow$. Adjust the key, if necessary, with a slight rotary motion so that the answer spaces on the answer sheet show through the openings on the key.
3. To obtain the score on the test, count the number of marks appearing through the holes punched in the stencil. This is the number right, or *raw score,* for this test. Encircle the standard score corresponding to this raw score in the table at the left margin of the answer sheet, like this example for a student whose raw score on Form AM of a test is 21:

20	21	22	23
149	⑮	152	154

Machine scoring. It is assumed that all persons attempting to score this test by means of the International Test Scoring Machine will have familiarized themselves thoroughly with the scoring techniques described in the various International Business Machines publications, particularly as they concern the manipulation of the machine itself. To insure satisfactory accuracy in scoring, the following steps are suggested:

1. Be sure that the machine is properly adjusted according to IBM directions.
2. Scan each answer sheet carefully, completely erasing all double-marked items and stray marks, no matter how slight, which fall within the sensing spaces. Darken all faint marks with an electrographic pencil. If answer sheets are badly marked, it frequently is easier to score them by hand than to scan and clean them.
3. The same stencil which serves as the hand-scoring key may be used as the machine-scoring stencil. Field holes must be punched in the spaces indicated by black circles at the top and bottom of the key.

Note which form is encircled on the answer sheet and make sure that the proper machine-scoring key is used. Then, with the master switch on field A, the A formula switch in the RIGHTS position, and the B and C formula switches in any position but A, read the raw score (number right) on the RIGHTS circuit of the A field. Locate this raw score in the raw score-standard score table. The numbers which appear below the raw score are the corresponding standard scores for Forms AM and BM. Draw a circle around or otherwise mark the appropriate standard score.

INTERPRETATION OF RESULTS

Raw scores on most tests are in themselves of but limited significance. They do permit an objective ranking of students in accordance with achievement status, but for maximum significance of results it is necessary that there be some basis for comparison and interpretation of the scores. In the case of this test meaningful interpretation of scores is made possible by standard scores and percentile norms. The nature and uses of these two types of interpretative scores are described below.

Standard scores. Raw scores on the *Anderson Chemistry Test,* as on all the tests in the *Evaluation and Adjustment Series,* are converted to a scale of normalized standard scores. These standard scores have the property of constituting a scale of more nearly equal units than do the raw scores and are, hence, better suited to the measurement of growth. They have the further great advantage of representing a uniform mode of interpretation for all tests in the series. The standard scores for all tests in the series are comparable in the sense of being derived according to a uniform method, relating them all to scores on the *Terman-McNemar Test of Mental Ability.* The raw scores on the *Anderson Chemistry Test* are converted to standard scores having a mean of 113 and a standard deviation of 13.5, these values having been chosen because they represented the median and standard deviation, respectively, of the distribution of *Terman-McNemar* IQ's of the students in the chemistry test standardization population. Thus, automatically, provision is made for taking account of the ability level of students by virtue of the fact that the mean standard score for the norm group is assigned a value corresponding to the median IQ for these students. The standard scores are particularly useful in connection with comparison of results on two or more tests in the series.

Percentile norms. Expression of scores in terms of percentile norms is the most common mode of interpretation of test results at the secondary level. Table 2 presents percentile norms corresponding to standard scores on the *Anderson Chemistry Test.* These norms are end-of-year norms and are to be used in interpreting the results of tests administered at the end of one year of instruction in chemistry. The percentile rank corresponding to a given standard score indicates the per cent of the national normative group which had scores equal to or less than a given standard score. The relative standing of a student in various tests in the *Evaluation and Adjustment Series* may be compared in terms of his percentile rank in the several tests; but such comparison suffers from the fact that the percentile scale is not a scale of equal units, and from the more serious limitation that the standardization populations for the various tests differ in ability level one from another.

TABLE 2. END-OF-YEAR PERCENTILE NORMS

Stand. Score	%-ile	Stand. Score	%-ile	Stand. Score	%-ile	Stand. Score	%-ile
148+	99+	**125**	81	**105**	28	**85**	2
147	99	**124**	79	**104**	26	**84**	2
146	99	**123**	76	**103**	24	**83**	1
145	99	**122**	74	**102**	22	**82**	1
144	99	**121**	72	**101**	19	**81**	1
142	98	**120**	70	**100**	18	**80**	1
141	98	**119**	67	**99**	16	**79**	1
140	98	**118**	65	**98**	14	**78**	1−
138	97	**117**	62	**97**	13		
137	96	**116**	60	**96**	11		
136	95	**115**	55	**95**	10		
135	94	**114**	52	**94**	9		
134	93	**113**	49	**93**	8		
132	92	**112**	47	**92**	7		
131	91	**111**	44	**91**	6		
130	89	**110**	41	**90**	5		
129	87	**109**	38	**89**	4		
128	86	**108**	36	**88**	3		
127	84	**107**	33	**87**	3		
126	83	**106**	31	**86**	2		

Standardization. The *Anderson Chemistry Test* is one of eleven tests in the *Evaluation and Adjustment Series* standardized in the spring of 1950 in a comprehensive national standardization program. This test was administered to 3539 students in 76 schools representing 24 states throughout the country.

It is now generally recognized that it is practically impossible to demonstrate that any normative group is truly representative of a hypothetical national school population. At best the test author and publisher can only present data on certain characteristics of the normative group which are known to be related to achievement; this information permits the test user to compare his own students with the normative group with respect to these characteristics. Two such characteristics which may be defined easily are age and intelligence. The median chronological age of the students on whom this test was standardized is 17 yrs.–6 mos., and their median IQ on the *Terman-McNemar Test of Mental Ability* is 113. If a teacher or administrator knows that his school deviates appreciably from the normative group in average ability or in age-for-grade, he should, of course, take account of such deviations when interpreting results for the school.

All tests in the standardization program were administered by the classroom teacher or the principal; all scoring was checked and the statistical work and analysis of results were done by the Division of Test Research and Service.

USING THE TEST RESULTS

Some of the uses which may be made of the results on the *Anderson Chemistry Test* are described below.

Evaluating individual achievement. The primary function of this test is to provide a valid, objective measure of achievement in chemistry for the individual student. This measure of the student's accomplishment permits the teacher to determine how well the student has succeeded in mastering those objectives of the course which are covered by the test. The percentile rank corresponding to the score tells the teacher how the student compares with the normative group of other students taking the same course throughout the country.

The concept of "evaluating" a student's achievement implies more than a mere measurement of status. It suggests an appraisal of his performance, presumably in relation to his ability, and a judgment as to whether or not his achievement is in line with what may be expected from him in light of his ability. The standard scores for the *Anderson Chemistry Test* are such as to permit ready comparison of achievement with mental ability level, since the scores have been equated to IQ's derived from the *Terman-McNemar Test of Mental Ability*.[1] Thus, a direct comparison of the student's standard score on the test with his *Terman-McNemar* IQ will indicate the direction and extent of the difference between his ability and achievement in this field. There has also been prepared an expectancy table indicating the level of achievement on the *Anderson Chemistry Test* associated with varying levels of IQ for a random sample of students in the normative group.

Individual guidance. Every achievement test result which is obtained for a student during his school career has significance not only as a measure of what he has accomplished in a given course, but also as a predictor of what he is likely to do in the future, particularly in closely related fields. Thus, results on the test reasonably may be assumed to be prognostic of success in later work in the field of science.

Every test result has potential usefulness in the guidance of the individual student with respect to future educational and vocational plans. A common difficulty in the use of results from a variety of tests for guidance purposes is that the several results are not comparable, either because of different systems of interpreting scores on the various tests or because of lack of comparability among the groups on which the tests are standardized

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[1] Similar comparisons may also be made with results from th *Otis Quick-Scoring Mental Ability Test: Gamma*, and the *Pintn, General Ability Test: Advanced*, by means of tables of comparable scores on these three intelligence tests available upon application to World Book Company.

Thus, relative strengths and weaknesses of the individual are not accurately portrayed. One of the advantages of the *Anderson Chemistry Test*, as one of the tests in the *Evaluation and Adjustment Series*, is that its results are comparable with those of all other tests in the series, since scores on all tests are expressed in terms of a common standard score system.

By virtue of this comparability it is possible to obtain accurate comparisons of a student's standing in various areas; it is possible, in a given area such as science, to determine whether a student is consistently strong in the field, or whether he tends to manifest greater or less proficiency in this area as he progresses through school. The utilization of these comparative test results is simplified by the preparation of a cumulative profile chart for the student on which his standing in various tests in the *Evaluation and Adjustment Series* may be recorded, all in terms of the common standard score system.

Evaluating group achievement. Inasmuch as this test will be administered, as a rule, very close to the end of the school year, the results have limited usefulness for instructional purposes for the particular groups of students tested. The test may be administered a month or so before the end of the school year and efforts made in the remaining time to review or reteach the areas where weaknesses are revealed. The test, however, is not designed as a diagnostic instrument; it does not furnish analytical measures of the individual student's mastery of various aspects of the subject. The interested teacher can make effective use of the results in the analysis of the achievement of a whole class, looking toward the improvement of instruction.

The first step in the study of performance of the class as a whole is, of course, the determination of the average standing of the class on the test which, like the results for an individual student, may be evaluated in relation to the ability level of the class. Beyond this simple appraisal of achievement as a whole, however, it will be profitable to make a question-by-question study of the results for the class. This may be done by determining the number of students who answered each question correctly, converting these values to per cents of the class passing each question (which are really local difficulty values), and then comparing these local difficulty values with the item-difficulty values reported in Table 1. The teacher can determine for each question whether the class is achieving as high a level of success as the students on whom the item-difficulty values are based. By grouping the questions according to topic, perhaps in accordance with the outline given on pages 1–2 of this Manual, and summarizing the item values for each topic, the teacher can determine which topics, if any, seem to be mastered less well by the local group than by the typical students.

Information on the topics or areas in which students are relatively weak will prompt the teacher to give thought either to devoting greater time to the topics in question, or to revising the instructional program in some other appropriate way. It is possible, of course, that the teacher will conclude that the areas in which the students do not do well are not particularly important and that no change in the instructional program need be made. The important thing, in either case, is that the teacher's attention has been focused on objective evidence as to relative mastery of various topics.

The proper use of any achievement test involves a careful consideration of the extent to which the test really covers the objectives which are considered to be the important outcomes of the course. Because of the nature of standardized tests designed for national use, it sometimes happens that they cannot give to all objectives the same relative emphases as an individual teacher might consider to be appropriate; indeed, certain admittedly important objectives may not be covered at all in the standardized test. The teacher who is interested in a complete evaluation, therefore, may consider it desirable to supplement the standardized test with measures designed to cover the specific local outcomes which are not properly represented in the standardized test. Such comprehensive evaluation can be made by listing the local objectives, determining which of them are covered in the standardized test and which must be covered separately, and developing test questions or other measurement techniques for the objectives not covered in the standardized test. The results on the standardized tests and the local test may, if desired, be combined by appropriate methods into a single over-all achievement measure.

GENERAL EDITOR: **WALTER N. DUROST**, SCHOOL OF EDUCATION, BOSTON UNIVERSITY
COÖRDINATOR FOR SCIENCE TESTS: **VICTOR H. NOLL**, MICHIGAN STATE COLLEGE

ANDERSON CHEMISTRY TEST

BY **KENNETH E. ANDERSON**
SCHOOL OF EDUCATION, UNIVERSITY OF KANSAS

FORM BM

DIRECTIONS:

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

This is a test of your knowledge of chemistry. For each question there are five possible answers. You are to decide which answer is the best one. You may answer a question even when you are not perfectly sure that your answer is correct, but you should avoid wild guessing. Do not spend too much time on any one question.

Study the sample questions below, and notice how the answers are marked on the separate answer sheet.

Sample A. H_2O is the formula for —

1. hydrogen.
2. carbon.
3. oxygen.
4. water.
5. salt.

For Sample A the answer, of course, is "water," which is answer **4**. Now look at your answer sheet. At the top of the page in the left-hand column is a box marked SAMPLES. In the five answer spaces after Sample A, a heavy black mark has been made filling the space (the pair of dotted lines) marked **4**.

Sample B. Which one of the following terms does not belong with the other four?

6. NaCl
7. H_2O
8. Fe
9. KOH
10. H_2SO_4

The correct answer for Sample B is "Fe," because "Fe" is an element while the other four are compounds. "Fe" is answer **8**, so you would answer Sample B by making a heavy black mark that fills the space under the number **8**. Do this now.

Read each question carefully and decide which one of the answers is best. Notice what number your choice is. Then, on the separate answer sheet, make a heavy black mark in the space under that number. In marking your answers, always be sure that the question number in the test booklet is the same as the question number on the answer sheet. Erase completely any answer you wish to change, and be careful not to make stray marks of any kind on your answer sheet or on your test booklet. When you finish a page, go on to the next page. If you finish the entire test before the time is up, go back and check your answers. Work as rapidly and as accurately as you can.

When you are told to do so, open your booklet to page 2 and begin. The working time for this test is 40 minutes.

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b

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Part A

1. Water solutions of acids contain —
   1. hydrogen ions.
   2. oxygen.
   3. a metal.
   4. chlorine.
   5. the carboxyl radical.

2. The chemical substance making up the cell wall of plants is —
   6. an acetate.
   7. cellulose.
   8. sugar.
   9. a non-carbon compound.
   10. similar to coal in composition.

3. When calcium acts on water, the gas given off is —
   1. oxygen.
   2. chlorine.
   3. argon.
   4. hydrogen.
   5. ozone.

4. A property of hydrogen is that it is —
   6. pale green.
   7. very soluble in water.
   8. denser than air.
   9. a monatomic gas.
   10. less dense than air.

5. Hydrogen sulfide solution is a weak acid because it —
   1. turns litmus red.
   2. tastes sour.
   3. forms relatively few hydrogen ions.
   4. is a solution.
   5. does not contain oxygen.

6. "Dry Ice" is —
   6. solid carbon.
   7. solid carbon dioxide.
   8. solid carbon monoxide.
   9. anhydrous ice.
   10. an isotope of water.

7. Sulfur dioxide is used in —
   1. gas ranges.
   2. gas mantles.
   3. heating plants.
   4. refrigerators.
   5. gas lamps.

8. An example of a non-electrolyte is —
   6. sugar solution.
   7. hydrochloric acid.
   8. sodium hydroxide.
   9. sodium chloride.
   10. sulfuric acid.

9. The most common halogen salt is —
   1. calcium fluoride.
   2. barium chloride.
   3. sodium chloride.
   4. ammonium chloride.
   5. potassium iodide.

10. The decaying of fruit is an example of —
    6. deoxidation.
    7. chemical change.
    8. physical change.
    9. transmutation.
    10. hydrogenation.

11. Water and kerosene are —
    1. mutually soluble.
    2. a tincture.
    3. a "true solution."
    4. immiscible.
    5. miscible.

12. Soft water is used in preference to hard water for domestic purposes because —
    6. it has a better taste.
    7. it is purer.
    8. it contains fewer bacteria.
    9. it boils at a lower temperature.
    10. it does not react with soap.

13. The usual laboratory method of preparing hydrogen is by using —
    1. zinc and hydrochloric or dilute sulfuric acid.
    2. zinc and acetic acid.
    3. water and sending an electric current through it.
    4. sodium and hydrochloric acid.
    5. calcium and sulfuric acid.

14. Limestone is essentially —
    6. calcium oxide.
    7. strontium carbonate.
    8. calcium sulfate.
    9. calcified chalk.
    10. calcium carbonate.

15. A physical change occurs when —
    1. water is electrolyzed.
    2. wood is sandpapered.
    3. wood burns.
    4. sulfur dioxide unites with water.
    5. food is digested.

16. If a quantity of blue-black smoke issues from the exhaust pipe of a moving automobile, it means that —
    6. no carbon monoxide is being formed.
    7. the car has leaky valves.
    8. a poor grade of oil is being used.
    9. the carburetor is set too lean.
    10. there is incomplete combustion in the cylinders.

Go on to the next page.

17. The reaction between aluminum and hydrochloric acid represents —
    1. synthesis.
    2. double displacement.
    3. analysis.
    4. single (simple) displacement.
    5. catalysis.

ulfur dioxide at standard conditions of temperature and
ressure is —
    6. an acid.
    7. a base.
    8. a solid.
    9. a salt.
    10. an acid anhydride.

19. Substances which do NOT break up into ions when in solution are called —
    1. electrolytes.
    2. aqueous.
    3. hydrates.
    4. non-electrolytes.
    5. isotopes.

20. Protons are —
    6. the nucleus of the atom for all elements.
    7. planetary electrons.
    8. particles of positive electricity.
    9. particles of negative electricity.
    10. neutral.

21. "Carborundum" is —
    1. a boron compound.
    2. a colloid.
    3. quartz.
    4. a silicon compound.
    5. diamond.

22. Oxygen is obtained commercially chiefly from —
    6. potassium chlorate.
    7. liquid air.
    8. manganese dioxide.
    9. mercuric oxide.
    10. sodium hydroxide.

23. The adsorbing material in gas masks is —
    1. activated charcoal.
    2. calcium chloride.
    3. sodium phenylate.
    4. copper sulfate.
    5. precipitated chalk.

24. Aluminum resists corrosion chiefly because there is formed on the surface a layer of —
    6. aluminum oxide.
    7. aluminum carbonate.
    8. aluminum nitride.
    9. aluminum sulfide.
    10. aluminum sulfate.

25. Sour milk contains —
    1. acetic acid.
    2. citric acid.
    3. lactic acid.
    4. tartaric acid.
    5. ethyl alcohol.

26. Carbon combines with oxygen to form —
    6. peroxides.
    7. hydroxides.
    8. carbonides.
    9. oxides.
    10. carbides.

27. The best way of preparing a quantity of oxygen in the laboratory is by heating —
    1. potassium chlorate.
    2. iron oxide.
    3. hydrogen peroxide.
    4. mercuric oxide.
    5. water.

28. Hydrogen is used extensively in the production of —
    6. solid fats.
    7. salad oil.
    8. gelatine.
    9. ham.
    10. olive oil.

29. What happens when zinc is heated in a sealed tube containing hydrogen?
    1. An oxide is formed.
    2. Water is formed.
    3. The zinc gains in weight.
    4. Monatomic hydrogen is formed.
    5. Nothing happens.

30. The mineral bauxite contains the metallic element —
    6. sulfur.
    7. nickel.
    8. aluminum.
    9. copper.
    10. silver.

31. Fluorine can displace chlorine, bromine, and iodine from their compounds; chlorine can displace bromine and iodine from their compounds; and bromine can displace iodine from its compounds. The foregoing statement is evidence that of the four halogen acids —
    1. HBr is the most stable.
    2. HI is the least stable.
    3. HF and HCl are the least stable.
    4. HBr and HI are the most stable.
    5. All are equally stable.

Go on to the next page.

32. The element found in proteins, but not in fats or carbohydrates, is —
    6. nitrogen.
    7. carbon.
    8. hydrogen.
    9. oxygen.
    10. iron.

33. Silver nitrate is —
    1. an acid.
    2. a base.
    3. a salt.
    4. a hydride.
    5. a mixture.

34. What form of sulfur is stable at room temperature?
    6. prismatic
    7. monoclinic
    8. amorphous
    9. rhombic
    10. milk of sulfur

35. The electrolyte in a lead storage battery is —
    1. nitric acid.
    2. hydrochloric acid.
    3. ammonium chloride.
    4. sulfuric acid.
    5. manganese dioxide.

36. Isotopes of an element have different —
    6. numbers of external electrons.
    7. atomic weights.
    8. chemical properties.
    9. symbols.
    10. formulas.

37. The weight of one gram-molecular volume of acetylene, C_2H_2, is —
    1. 14 grams.
    2. 25 grams.
    3. 26 grams.
    4. 28 grams.
    5. 30 grams.

38. When a substance is reduced, it —
    6. always loses oxygen.
    7. becomes an uncombined element.
    8. loses electrons.
    9. requires hydrogen as a reducing agent.
    10. gains electrons.

Part B

There are 7 sets of 2 questions each in this part of the test. The first question in each set is an information question and the second is a question on the chemical principle that best explains the answer to the preceding question. In each case, on your answer sheet, opposite the number of the question, make a heavy black mark under the number of your answer.

39. Which one of the following compounds is non-existe
    1. CaO
    2. SO_2
    3. Al_2O_3
    4. NeO
    5. MnO_2

40. Which one of the following statements gives the principle that best explains the answer to question 39?
    6. Atoms that are inert chemically are thought to have the outer shell completely full of electrons.
    7. Some atoms are electrically neutral.
    8. Oxygen unites with most of the other elements.
    9. Incomplete outer shells make elements chemically active.
    10. Metals will unite with non-metals.

- -

41. Almost all explosives contain a compound of the element —
    1. fluorine.
    2. chlorine.
    3. sulfur.
    4. nitrogen.
    5. hydrogen.

42. Which one of the following statements gives the principle that best explains the answer to question 41?
    6. A large volume of gas is necessary for an effective explosion.
    7. Relatively inactive elements form unstable compounds when combined with other elements.
    8. Very rapid burning results in an explosion.
    9. Compounds with high heats of formation are unstable.
    10. Compounds with low heats of formation are stable.

- -

43. The addition of manganese dioxide to potassium chlorate with the application of heat will result in —
    1. less oxygen per unit of time than when potassium chloride is used alone.
    2. more oxygen per unit of time than when potassium chloride is used alone.
    3. no change in the rate of production of oxygen.
    4. the production of manganese chloride.
    5. the production of potassium dioxide.

44. Which one of the following statements gives the principle that best explains the answer to question 43?
    6. Positive elements change places with negative [illegible]ments in chemical reactions.
    7. Oxidation and reduction take place at the same time.
    8. A catalytic agent may or may not change the speed of a chemical reaction.
    9. Manganese dioxide furnishes oxygen in this and other chemical reactions.
    10. A catalytic agent may speed up or slow down a chemical reaction.

Go on to the next page.

45. What is a chemical compound that has the following characteristics: a gram-molecular weight of 98; a good dehydrating agent; a good oxidizing agent; and a high boiling point?
    1. sodium hydroxide
    2. calcium chloride
    3. plaster of paris
    4. sulfuric acid
    5. hydrochloric acid

46. Which one of the following statements gives the principle that best explains the answer to question 45?
    6. Fractional distillation makes use of differences in boiling points.
    7. Substances that lose water are said to be efflorescent.
    8. Each substance has a definite point above and below which they absorb or lose water.
    9. Some salts absorb water in the formation of crystals.
    10. Substances have specific physical and chemical properties by which they may be identified.

47. Which one of the following is the best conductor of electricity?
    1. iron
    2. silver
    3. lead
    4. nickel
    5. tungsten

48. Which one of the following statements gives the principle that best explains the answer to question 47?
    6. Good conductors have low atomic weights.
    7. Good conductors have low densities.
    8. Good conductors hold their electrons loosely.
    9. Good conductors are malleable.
    10. Good conductors are ductile.

49. Precipitators are often placed in chimneys of factories to —
    1. conserve fuel.
    2. reduce fire hazards.
    3. reduce smoke and recover solids.
    4. increase the draft.
    5. increase the heat output per ton of fuel.

50. Which one of the following statements gives the principle that best explains the answer to question 49?
    6. Finely divided particles burn rapidly.
    7. Reduced pressure increases the flow of air.
    8. Air reduction results in slower burning.
    9. Colloidal particles carry electrical charges.
    10. Forced drafts increase the supply of oxygen available for burning fuels.

51. Which one of the following organic compounds is probably the most active?
    1. CH_4
    2. C_4H_{10}
    3. C_2H_6
    4. C_2H_4
    5. C_2H_2

52. Which one of the following statements gives the principle that best explains the answer to question 51?
    6. The greater the number of carbon atoms, the greater the chemical activity.
    7. The smaller the number of carbon atoms, the greater the chemical activity.
    8. Saturated hydrocarbons are very active chemically.
    9. Unsaturated hydrocarbons are more active than saturated hydrocarbons, and the degree of activity is proportional roughly to the degree of unsaturation.
    10. Saturated hydrocarbons are chemically inactive.

Part C

Each of questions 53 through 58 consists of five terms, one of which does NOT belong with the other four. You are to select the term which does NOT belong. Mark its number in the proper space on your answer sheet.

53.
    1. cesium
    2. krypton
    3. helium
    4. neon
    5. argon

54.
    6. silica
    7. charcoal
    8. graphite
    9. lampblack
    10. diamond

55.
    1. malleable
    2. strong
    3. lustrous
    4. combustible
    5. ductile

56.
    6. bauxite
    7. cuprite
    8. hematite
    9. diamond
    10. quartz

57.
    1. acetic acid
    2. lactic acid
    3. tartaric acid
    4. nitric acid
    5. citric acid

58.
    6. bronze
    7. brass
    8. solder
    9. nichrome
    10. iron

Go on to the next page.

Questions 59 through 62 are based on the following table:

RESULTS OF THREE EXPERIMENTS TO DETERMINE WHAT FACTORS, IF ANY, AFFECT THE SOLUBILITY OF SOLIDS

EXPERIMENT	KIND AND AMOUNT OF SOLVENT	TEMPERATURE OF SOLVENT	PRESSURE	KIND OF SOLUTE	AMOUNT OF SOLUTE DISSOLVED
I	100 cc H_2O 100 cc H_2O	20° C. 60° C.	600 mm 800 mm	$CuSO_4$ $CuSO_4$	22 grams 39 grams
II	100 cc H_2O 100 cc H_2O	20° C. 20° C.	700 mm 700 mm	$CuSO_4$ KCl	22 grams 34 grams
III	100 cc H_2O 100 cc CCl_4	10° C. 10° C.	700 mm 700 mm	Sulfur Sulfur	.1 gram 15 grams

Constant factors are those which are kept the same in an experiment. Varied factors are those which are not kept the same in an experiment. You are to assume that if a factor was found NOT to affect the solubility of solids in any one experiment, it would not do so in any other experiment. The number of grams of solute dissolved in the given volume of solvent produced saturation.

Read each question and study the table carefully. Decide which answer is best and mark its number in the proper space on your answer sheet.

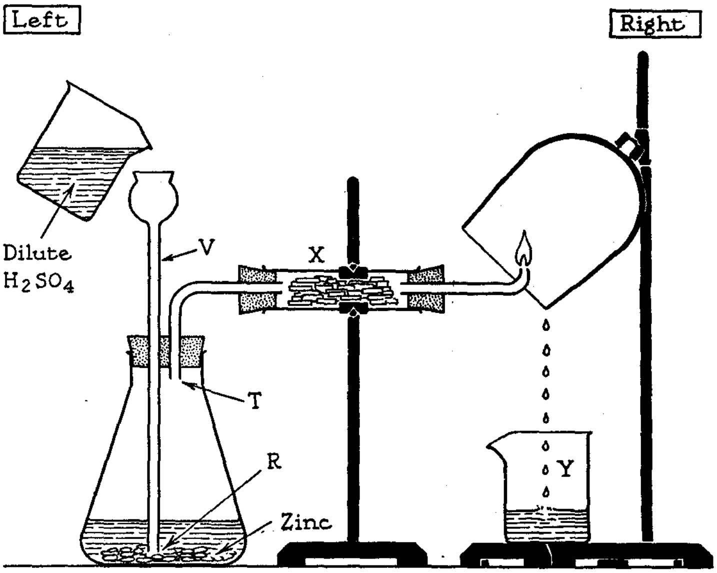
59. What factor or combination of factors in Experiment III produced the observed difference in the amount of solute dissolved?
    1. temperature of solvent
    2. kind of solvent
    3. kind of solute
    4. pressure; temperature of solvent
    5. kind of solute; pressure

60. What factor or combination of factors was varied in Experiment II?
    6. kind of solute
    7. kind of solvent
    8. temperature
    9. temperature of solvent; pressure
    10. kind of solvent; kind of solute

61. What factor or combination of factors was kept constant in Experiment I?
    1. kind of solute
    2. temperature of solvent; pressure
    3. kind of solvent; kind of solute
    4. kind of solvent; pressure
    5. kind of solvent; kind of solute; pressure

62. In these experiments, what factors definitely affect the solubility of solids?
    6. kind of solute; pressure
    7. kind of solvent; temperature of solvent
    8. pressure; kind of solvent
    9. kind of solvent; kind of solute
    10. temperature of solvent; pressure; kind of solute

Questions 63 through 67 are based on the figure below. Study the figure and read each question carefully. Then, on your answer sheet, make a heavy black mark in the space under the number of the best answer.



63. The piece of apparatus marked V is called a —
    1. funnel.
    2. pneumatic trough.
    3. thistle tube.
    4. graduate.
    5. U-tube.

64. The products of the chemical reaction to the left of X will be —
    6. hydrogen and zinc sulfate.
    7. hydrogen and sulfur dioxide.
    8. sulfur trioxide and zinc sulfate.
    9. sulfur dioxide and zinc sulfate.
    10. hydrogen sulfide and zinc sulfate.

65. The product of the chemical reaction to the right of X will be —
    1. carbon dioxide.
    2. carbon monoxide.
    3. hydrogen sulfide.
    4. hydrogen.
    5. water.

66. To be certain that the substance in beaker Y is a result of the chemical reaction to the right of X, a substance must be placed in the tube at X. The substance which would do the job is —
    6. glass wool.
    7. calcium chloride.
    8. aluminum sulfate.
    9. sodium chloride.
    10. water.

67. The glass-tube openings T and R should —
    1. be reversed in their relative positions.
    2. both be far above the liquid.
    3. both be in the liquid.
    4. remain as they are.
    5. both be just above the liquid.

Go on to the next page.

Part D

Questions 68 and 69 are based on the equation for the preparation of oxygen by heating potassium chlorate. (Atomic weights: K = 39, Cl = 35.5, O = 16.)

68. To balance the equation, the coefficient of the oxygen is —

1. 1
2. 2
3. 3
4. 4
5. 5

69. If 490 grams of potassium chlorate are used, how many liters of oxygen will be obtained?

6. 22.4 liters
7. 44.8 liters
8. 67.2 liters
9. 89.6 liters
10. 134.4 liters

Questions 70 and 71 are based on the equation for the preparation of hydrogen using zinc and hydrochloric acid. (Atomic weights: Zn = 65, H = 1, Cl = 35.5.)

70. If 65 grams of zinc are used, how many liters of hydrogen will be formed?

1. 1
2. 2
3. 22.4
4. 44.4
5. 88.8

71. What is the equation or reacting weight of hydrochloric acid?

6. 35.5
7. 36.5
8. 70
9. 73
10. 146

---

72. When CuO is reduced to metallic copper, the copper gains how many electrons per atom?

1. 1
2. 2
3. 3
4. 4
5. 5

73. Which is the correct formula for aluminum hydroxide?

6. $Al(OH)_3$
7. $Al(OH)_2$
8. $Al(OH)_4$
9. $Al_2(OH)_3$
10. $Al_3(OH)_2$

74. Which is the correct formula for potassium sulfite?

1. K_2SO_4
2. KSO_4
3. $K_2(SO_4)_2$
4. K_2S
5. K_2SO_3

75. What is one of the products in the completely balanced equation $CaC_2 + H_2O \longrightarrow$?

6. C_2H_5OH
7. CO_2
8. C_2H_2
9. H_2
10. H_2O_2

76. Which is the correct formula for barium nitrate?

1. Ba_2NO_3
2. $BaNO_3$
3. $Ba(NO_3)_2$
4. $Ba(NO_2)_2$
5. $BaNO_2$

77. Which is the correct formula for normal calcium phosphate?

6. $Ca_3(PO_4)_2$
7. $Ca_2(PO_4)_3$
8. $CaPO_4$
9. $Ca_4(PO_3)_2$
10. $Ca(PO_4)_2$

78. The equation $Fe + S \longrightarrow FeS$ represents which one of the following chemical changes?

1. synthesis
2. analysis
3. simple replacement
4. double replacement
5. catalysis

79. What will be one of the ions in the ionic representation of $Ca(OH)_2$?

6. Ca^+
7. CaO^+
8. OH^-
9. OH^{--}
10. Ca^{+++}

80. Which one of the following contains the greatest percentage of oxygen by weight? (Atomic weights: K = 39, Cl = 35.5, Na = 23, O = 16, Ca = 40, Hg = 200.)

1. $KClO_3$
2. $NaClO_3$
3. Na_2O_2
4. CaO
5. HgO

Go back and check your answers.

STATEMENT TO STUDENTS

You are about to take a test in chemistry which may help us to determine how well other science courses have aided you in your chemistry. Approximately 360 students in seven different schools are taking this same test.

Your test score will become a part of your high school record, however, your score on this test will not affect your grade in this chemistry class. Your teacher has other means of grading you. We hope you will do your best.

RAW SCORE	1	2	3	4	5	6	7	8	9	10
Stand. Score Forms AM and	69	70	71	72	73	74	75	77	78	79
RAW SCORE	11	12	13	14	15	16	17	18	19	20
Stand. Score Forms AM and	80	81	82	83	84	85	86	87	88	89
RAW SCORE	21	22	23	24	25	26	27	28	29	30
Stand. Score Forms AM and	90	91	92	93	94	95	96	97	98	99
RAW SCORE	31	32	33	34	35	36	37	38	39	40
Stand. Score Forms AM and	100	101	102	103	104	105	106	107	108	109
RAW SCORE	41	42	43	44	45	46	47	48	49	50
Stand. Score Forms AM and	110	111	112	113	114	[illegible]	115	116	117	118

RAW SCORE (Cont'd)	51	52	53	54	55	56	57	58	59	60
Stand. Score Forms AM and BM	119	120	121	122	123	124	125	126	127	128
RAW SCORE (Cont'd)	61	62	63	64	65	66	67	68	69	70
Stand. Score Forms AM and BM	129	130	130	131	132	134	135	136	137	138
RAW SCORE (Cont'd)	71	72	73	74	75	76	77	78	79	80
Stand. Score Forms AM and BM	140	141	142	144	145	146	147	148	149	150

ANDERSON CHEMISTRY TEST

ANSWER SHEET

NAME ______ SEX: M ___ F ___ GRADE ___ DATE OF TESTING ______ YEAR ______ MONTH ______ DAY

SCHOOL ______ CITY AND STATE ______ DATE OF BIRTH ______ YEAR ______ MONTH ______ DAY

TEACHER ______ CLASS OR SECTION ______ STUDENT'S AGE ______ YEARS ______ MONTHS ______ DAYS

%ILE ☐

FORM OF TEST

AM BM

(CIRCLE ONE)

HIGH SCHOOL COURSE (CHECK): ACADEMIC ___ COMMERCIAL ___ GENERAL ___ SCIENTIFIC ___ OTHER (SPECIFY) ______

In the following spaces indicate the number of years (one semester is ½ year), since the end of the 8th grade, that you will have studied each of the subjects by the end of the present semester.

	GENERAL SCIENCE	BIOLOGY	CHEMISTRY	PHYSICS	PHYSICAL SCIENCE	HEALTH	PHYSIOLOGY	OTHERS
YEARS OF STUDY								

BE SURE YOUR MARKS ARE HEAVY AND BLACK.
ERASE COMPLETELY ANY ANSWER YOU WISH TO CHANGE.

SAMPLES

A 1 2 3 ▮4 5

B 6 7 8 ▮9 10

PART A

1 1 2 3 4 5
2 6 7 8 9 10
3 1 2 3 4 5
4 6 7 8 9 10
5 1 2 3 4 5
6 6 7 8 9 10
7 1 2 3 4 5
8 6 7 8 9 10
9 1 2 3 4 5
10 6 7 8 9 10
11 1 2 3 4 5
12 6 7 8 9 10
13 1 2 3 4 5
14 6 7 8 9 10
15 1 2 3 4 5
16 6 7 8 9 10
17 1 2 3 4 5
18 6 7 8 9 10
19 1 2 3 4 5
20 6 7 8 9 10
21 1 2 3 4 5

PART B

22 6 7 8 9 10
23 1 2 3 4 5
24 6 7 8 9 10
25 1 2 3 4 5
26 6 7 8 9 10
27 1 2 3 4 5
28 6 7 8 9 10
29 1 2 3 4 5
30 6 7 8 9 10
31 1 2 3 4 5
32 6 7 8 9 10
33 1 2 3 4 5
34 6 7 8 9 10
35 1 2 3 4 5
36 6 7 8 9 10
37 1 2 3 4 5
38 6 7 8 9 10
39 1 2 3 4 5
40 6 7 8 9 10
41 1 2 3 4 5
42 6 7 8 9 10

PART C

43 1 2 3 4 5
44 6 7 8 9 10
45 1 2 3 4 5
46 6 7 8 9 10
47 1 2 3 4 5
48 6 7 8 9 10
49 1 2 3 4 5
50 6 7 8 9 10
51 1 2 3 4 5
52 6 7 8 9 10
53 1 2 3 4 5
54 6 7 8 9 10
55 1 2 3 4 5
56 6 7 8 9 10
57 1 2 3 4 5
58 6 7 8 9 10
59 1 2 3 4 5
60 6 7 8 9 10
61 1 2 3 4 5
62 6 7 8 9 10
63 1 2 3 4 5

PART D

64 6 7 8 9 10
65 1 2 3 4 5
66 6 7 8 9 10
67 1 2 3 4 5
68 1 2 3 4 5
69 6 7 8 9 10
70 1 2 3 4 5
71 6 7 8 9 10
72 1 2 3 4 5
73 6 7 8 9 10
74 1 2 3 4 5
75 6 7 8 9 10
76 1 2 3 4 5
77 6 7 8 9 10
78 1 2 3 4 5
79 6 7 8 9 10
80 1 2 3 4 5

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