THE RELATIVE EFFECTIVENESS OF THE SINGLE AND DOUBLE LABORATORY PERIODS IN PHYSICS AND CHEMISTRY

by

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CHAPTER I

INTRODUCTION.

During the past decade a number of experiments have been conducted in an attempt to determine the effectiveness of various methods of science teaching, but as far as the writer has been able to examine the literature no scientific experiment has been conducted to evaluate the effectiveness of the double-laboratory period as compared with the single laboratory period in high school physics and chemistry.* Nevertheless, the problems of the length of the laboratory period and the number of periods that are to be devoted to the subjects of physics and chemistry are problems of vital importance to the teachers and the pupils of classes in these subjects and to the administrators who, in the last analysis, are held responsible for the total cost of instruction as well as the success of the pupils in the high school.

If the single laboratory period might be found to be of about the same effectiveness as the double-laboratory period, there would be a direct saving of 28 percent of the

* Note: In this study the two-hour laboratory period will be called the double-period and the one-hour laboratory period will be called the single-period.

teacher's and pupil's time. If the pupils spend twice the amount of time in the laboratory surely the cost of supplies must be more. If the pupils would devote but two one-hour periods per week to laboratory instruction twice the number could be accommodated in the laboratory, and as the amount of space available for laboratory instruction usually determines the number of pupils that may enroll in the physics and chemistry classes, more pupils would be permitted to enroll in those classes if the single-period of laboratory instruction was followed.

If the use of the single-laboratory period will enable teachers and pupils to accomplish the desired results required by those who set up our standards in these subjects the problem of making class schedules would be greatly simplified. It is the purpose of this investigation to determine by means of standard test results, the comparative effectiveness of the double-laboratory period as compared with that of the single-laboratory period in teaching physics and chemistry.

CHAPTER II

RELATED LITERATURE

(A) History of the Development of the Double-Laboratory Period.

At the beginning of this study, one should make a brief survey of the various steps leading up to present laboratory methods of instruction in physics and chemistry. The subject of physics was introduced into the curriculum about 1850 under the name of Natural Philosophy while Chemistry was introduced about twenty-five years later. Natural Philosophy was taught more as a dogmatic subject and the laws were studied more than the related facts in science. "The laboratory feature of the secondary school treatment was not introduced until late in the seventies; a very few schools pretended in 1880 to give any laboratory instruction to their students."(1)

In 1886, Harvard was the first to make laboratory instruction in physics an entrance requirement. The experiment apparently was not a success for, in 1897, Harvard modified its entrance requirement and asked for more emphasis to be placed on text book discussions and lecture demonstrations.

At this time the requirements in physics had not been definitely standardized but the various teachers' associations began to ask for four periods per week for recitations, demonstra-

(1) Johnston, Charles H. and Others, High School Education, Chas. Scribners Sons, 1912, p. 151.

tions and problems and one period per week for laboratory work. In 1908, the North Central Association of Colleges and Secondary Schools gave the following definition of the unit in physics:

(1) "The unit in physics consists of at least one hundred and eighty periods of forty-five minutes each, (equal to one hundred and thirty-five hours) of assigned work."

(3) "It is very essential that double periods be arranged for laboratory work."(2)

In 1909, the College Entrance Examination Board set definitely the time to be given to the teaching of physics:

(1) "The unit in Physics consists of at least one hundred and twenty hours of sixty minutes each. Time spent in laboratory shall be counted at half its face value."

(2) "The Course of Instruction in Physics should include:

(c) "Individual laboratory work consisting of experiments requiring at least the time of thirty double periods."(3)

Thus we see where the "traditional double-period for laboratory instruction really had its beginning. As the secondary schools must prepare for the colleges and as the colleges were a "law unto themselves", the teachers of physics in the secondary schools could do no more than accept their decree. From 1910 to 1920 very little or no investigation had been done to prove the educational value of the above procedure.

(2) Johnston, Charles H. and Others, High School Education, Chas. Scribners Sons, 1912, p. 156-7.
(3) Ibid, p. 159-160.

In 1888, Harvard first included chemistry among the subjects that might be offered for admission.(4) Following the plan adopted for physics, the double-laboratory period was required in chemistry.

The amount of time to be devoted to laboratory instruction had, by 1910, been quite definitely fixed. In one of the reputable books, "The Teaching of Physics and Chemistry in the Secondary Schools" by Smith and Hall, we find: "The period for laboratory exercise should, by general agreement, be twice the length of the ordinary school period, as a rule."(5)

(B) Criticism Regarding the Amount of Time Spent in the Laboratory.

As early as 1912, E. L. Thorndike began to question the economy of the time spent in laboratory work. "Like any reform in education, the laboratory method has suffered at the hands of its friends, by being used indiscriminately and by being over used. It is not scientific to spend two hours in learning by manipulation of instruments something which could be better learned by thought."(6)

In his "Principles of Science Teaching", 1917, G. R. Twiss questioned the value of so much time spent in the laboratory.

(4) Johnston, Charles H. and Others, High School Education, Chas. Scribners Sons, 1912, p. 168.
(5) Hall, E. H. and Smith, A., The Teaching of Physics and Chemistry in the Secondary Schools, Longmans, Green & Co., 1910, p. 35.
(6) Thorndike, Edward L., Education, Macmillan Co., 1912, p. 178.

"The minimum amount of laboratory work for each science, according to prevailing ideals and standards is such as will require 30 to 35 double periods per year. In physics and chemistry, the double laboratory period has come to be an essential feature. ——— In the opinion of the writer, this is a larger proportion of time than most teachers can profitably use for laboratory work, and the practice results in many cases in neglecting to have principles and quizzes thoroughly threshed out in conferences. Unless the teaching becomes better than it is now usually found, probably better results could be obtained from four recitations and one double-laboratory period per week for each science." (7)

In the various books on "Science Teaching", the effectiveness of laboratory instruction was the subject of much thought. J. F. Woodhull said that "a well equipped course of lectures is more valuable than a well equipped laboratory." (8)

The economy of the time spent in the laboratory was questioned by S. C. Parker in 1920. "Unless careful steps are taken to avoid it, there is probably more time wasted in laboratory work than in any other type of high school exercise.

(7) Twiss, G. R., Principles of Science Teaching, Macmillan Company, 1917, p. 132-133.
(8) Woodhull, J. F., The Teaching of Science, Macmillan Co., 1918, p. 52.

If there is the least opportunity, many pupils will spend their time monkeying and fooling around instead of attending to business; and often, even when they seem to be attentively working, their minds are woolgathering in ways that would not be tolerated or even be possible in a recitation in mathematics or foreign language."(9)

(C) Studies Previously Made

Among the experiments first to be reported was that made by W. G. Bowers of the State Teachers' College, Greeley, Colorado. Here, for five years, the students were permitted to do optional work in the laboratory. In the beginning they might elect laboratory work for one double-period per week with one hour credit or, if they so elected, they might spend two double-periods per week and receive two hours credit. Ample supervision and help was provided for each laboratory group. All were to have the same class instruction and the same examinations.

A compilation of the students' grades was made at the end of ten quarters. The average of the grades made by the students that had the two double-periods was found to be 4.5 per cent more than the average made by the pupils taking one double-period.

(9)Parker, S. C., Methods of Teaching in the High School, Ginn and Company, 1920, p. 25.

In commenting on the results of the experiment, Bowers said: "Since the four-hour worker spent twice as much time in the laboratory and one-third more time on the subject as a whole it might seem as though at least 25 per cent of the time was unprofitably spent."(10)

A study of high school physics in the state of Kansas was made in 1923 by C. H. Watson, with special reference to the time spent in the classroom as well as the time spent in the laboratory. In 85 high schools having an enrollment above 300 pupils, the average time spent in classroom was found to be 140 minutes per week, and in the laboratory 137 minutes per week. In all the schools reporting, the average time spent in the classroom was 132.4 hours per year while the average time spent in the laboratory was 150 hours. The schools having the smaller enrollment usually gave more time to classroom work.(11)

Many colleges and universities will not put on the accredited list, high schools which do not have adequate laboratory facilities. They will not accept for entrance credit the work of students in high schools where the science has not been taught by the laboratory method of instruction. The colleges

(10) Bowers, W. G., School Science and Mathematics, 24: 6, 606-13, June 1924.
(11) Watson, C. H., A Critical Study of High School Physics, Unpublished Master's Thesis, University of Kansas, 1923, pp. 88-92.

and universities under the College Entrance plan of admission continue to set definite standards of time to be spent in the laboratory as well as the experiments to be performed.(12)

The colleges and universities of the Central Association and the Western Association are less arbitrary in their requirements for admission. In many of the state universities, the graduates from approved high schools must be accepted regardless of the methods used in science teaching. This gives more freedom in the method of instruction and several high school teachers have conducted experiments in the teaching of high school sciences.

The three methods usually followed in the experiments are the laboratory method, the lecture-demonstration method, and the combination method. In the laboratory method, the pupils meet in the classroom where the subject matter is discussed and then they go to the laboratory where they attempt to perform the required experiments. In the lecture-demonstration method the teacher does most of the reciting and performs all of the required experiments before the class. The combination method simply means a combination of the laboratory and the lecture-demonstration

(12) College Entrance Examination Board, Document 120, Dec. 1927, pp. 61-79.

methods.

Nash and Phillips made a study of three methods of teaching science: "The pupil method", where the pupil did most of the work; "the instructor method", where the teaching was done by the lecture-demonstration method; and "the combination method", where the pupils had class instruction and lecture-demonstration and then performed their experiments in the laboratory. The pupils were divided into three groups of equal mental ability and were given the same subject matter and the same examinations. The number of pupils in the "pupil group" was 18, and in each of the other two groups 22. This would seem to be very small numbers with which to conduct a worthwhile experiment.

The results reported by the experimenters show very little difference in the accomplishment, though the instructor method led the other two.(13)

An experiment in teaching physics was conducted by Kiebler and Woody in the Hillsdale, Michigan, high school for the purpose of comparing and evaluating the merits of the individual laboratory method and the lecture-demonstration method of teaching physics. The pupils in each group had the same subject matter and the same experiments. No mention

(13) Nash, H. B. and Phillips, M. J. W., Journal of Educational Research, 7: 1, pp. 50-59, January, 1923.

was made of the giving of initial tests though both classes had the same final examinations. The observations noted by the experimenters are as follows:

1. "The results secured through the use of the demonstration method were as good if not superior in the three types of tests."

2. "The individual method tended to be superior in those experiments that are especially difficult to perform, or in which great care must be exercised to see the exact procedure."

3. "When the demonstration method gives equal or superior results, it is to be preferred to the individual laboratory method because it saves about one-half of the time usually devoted to performing experiments and permits the instructor to use the time thus saved in relating the facts and principles to allied phenomena."

4. "The results of the experiment suggest that in the smaller high schools, at least, better teaching would result and much money would be saved if the laboratories could be arranged and equipped so as to facilitate demonstration of many experiments instead of trying to provide apparatus for the individual performance of all of them." (14)

(14) Kiebler, E. W., and Woody, Clifford, Journal of Educational Research, 7:1, pp. 50-59, Jan., 1923.

Experiments have been conducted in order to test the value of the lecture-demonstration method of teaching chemistry. This method has been advocated by E. R. Downing of the School of Education, University of Chicago. In his articles in the school journals and in his book "The Teaching of Science in Schools"[15] he has reported the results of some experiments made to compare the lecture-demonstration and the laboratory methods of teaching chemistry. In School and Society, on the "Relative Value of Laboratory Instruction" he says: "In view of the results of investigations, the students waste an inordinate amount of time in the laboratory. General courses in science which aim to impart information, stimulate appreciation and establish a point of view rather than to develop a point of skill, both in the secondary schools and colleges may well rely chiefly on the lecture-demonstration or the developmental method of instruction."[16]

The experiments on the lecture-demonstration method of teaching chemistry made previous to 1925 have been summarized by Downing in the School Review.[17] Among the list of experimentors are the names of Anibal, Cooprider, and Cunningham. In his discussion of the investigations, Downing says:

(15) Downing, Elliot R., Teaching Science in the Schools, University of Chicago Press, 1925, Chapter I.
(16) Downing, Elliot R., School and Society, 19: 496, pp. 769-70 June 1924.
(17) Downing, Elliot R., The School Review. 33: pp. 688-97, November 1925.

"These investigators have noted in general that there is a marked saving of time in doing work by the lecture-demonstration method. Cooprider estimates it at about 50 per cent. Anibal estimates that to teach chemistry to a class of thirty pupils by lecture-demonstration method cost about 7 per cent as much as to teach by the laboratory method."

In making a summary of the report, Downing says: "The lecture-demonstration method of instruction yields better results than the laboratory method in imparting the essential knowledge and is more economical of time and expense. The lecture-demonstration method appears to be the better method for imparting skill in laboratory technique in its initial stage and for developing ability to solve new problems."

A review of the various reported experiments of the lecture-demonstration method has been made by F. A. Riedel, Supervisor of Science, Oread Training School, University of Kansas.(18) While the previous reviews have generally approved of the experiments, Riedel questions the conclusions of the experimentors

(18) Riedel, F. A., School Science and Mathematics, 27:5, pp. 515-16, May, 1927.

on very justifiable grounds. Among the questionable points are the number of students of each group; the frequent use of objective tests; the identical method was not used by other teachers or in other schools; the modern statistical precautions were not used by more than one author.

In general, from the review given by Riedel, one would conclude that the lecture-demonstration experiments do not really prove anything but that they are very valuable in that they open the way for a more complete and more scientific study of the problem of time spent in laboratory work.

(D) Present Tendencies

While the lecture-demonstration method of teaching science has made some progress, there is a tendency to give less time to laboratory work either by the use of one double-period per week or by two single-periods per week. In "Supervision of Instruction" H. W. Nutt says, "The number and length of recitation periods per week should be determined by the size of the

class, the experience and skill of the teacher, the amount of individual attention given each pupil and the number of subjects the pupil is taking."(19)

The reducation of the time spent in the laboratory has sometimes been made necessary for the arrangement of the class schedule. If the laboratory periods would be two one-hour periods much trouble might be avoided. This has been suggested by F. W. Johnson in his book "The Administration and Supervision of the High School." If the double-laboratory periods are used as in most schools, they present considerable difficulty of adjustment. The increasing practice of single laboratory periods which is based on other considerations than those related to schedule making simplifies this troublesome factor.(20)

The Oregon State Course of Study for High School Science, 1922-24, says that "laboratory work should not be over-estimated."(21)

In the Indiana State Course of Study for Secondary Schools, 1924, we find "Too much time is spent in laboratory

(19) Nutt, Herbert W., The Supervision of Instruction, Houghton Mifflin, 1920, pp. 124-25.
(20) Johnson, Franklin W., The Administration and Supervision of High Schools. Ginn and Co., 1925, p. 255.
(21) Oregon State Course of Study for High Schools, 1922: p. 81.

work. Two periods per week will suffice for laboratory work. If too much time is spent in the laboratory the students are almost certain to get into drifting habits."(22)

L. A. Kalbach, chief clerk in the United States Bureau of Education writes: "We know of no evaluative study of the length of periods and number of periods per week devoted to physics and chemistry."

The Supervisor of Physical Science, C. N. Cable, of the New York State Department of Education, in response to the question regarding the number and length of laboratory periods in the science classes of that state writes, "The regular procedure for the schools of this state is to devote four periods per week to demonstration and recitation, these periods varying from forty to sixty minutes each and two periods to laboratory work. This procedure is modified to some extent in certain cases. In certain large cities where the schools are overcrowded the laboratory time is somewhat shorter, only one period being available, according to the school schedule."

(22) Indiana State Department of Public Instruction, Bul. 65; 168.

From the foregoing, we can readily see that the educational value of the time spent in laboratory work is questionable. One would naturally expect better results from the double-period than from the single-period. If less time in the laboratory will adequately prepare pupils for the higher institutions, why should so much time be spent in laboratory instruction? There seem to be no definite aims in the teaching of physics and chemistry. Should the great aim be only to prepare the pupils for the higher institutions?

If the double-laboratory period does not show any appreciable effectiveness, why should it be continued? If the double-laboratory period is essential, why should not all classes follow this method? To answer these questions we should do more than philosophize. In order to ascertain answers to these questions the accomplishment made by pupils under each method of instruction should be measured as accurately as possible.

CHAPTER III

STATEMENT OF THE PROBLEM

This thesis has to do with the effectiveness of the double-laboratory period as compared with that of the single-laboratory period in science teaching. Our conclusions will be based on the results achieved by the pupils in the physics and chemistry classes in the high schools of Kansas City, Missouri, during the school year 1924-1925, as measured by standardized tests. Through this experiment an answer will be sought for the following questions:

1. Will the use of the double-laboratory period in high school physics and chemistry show a greater accomplishment at the end of the school year than will the use of the single period?

2. Will pupils that spend two one-hour periods per week during the year in the laboratory show results in physics and chemistry equal to results of pupils that devote two two-hour periods to the same subjects?

3. If there is any difference in the effectiveness of these laboratory periods, which one will produce the greater effectiveness when the results are measured by standardized tests?

At the time the data were collected for this study, Kansas City had four high schools. In one high school, the

Northeast, two two-hour periods per week were devoted to laboratory work in physics and chemistry, and in other high schools, Manual Training, Westport and Central, two-one-hour periods per week were given to the same subjects. Here we find an interesting situation and one that makes our experiment possible. The four high schools in the same system, under the same general supervision, organized so as to accomplish the same definite ends, with one high school following the double-laboratory method of instruction and three following the single method. Some definite reason should be given to show why it was necessary for one high school to devote twice the amount of time to laboratory instruction.

As the writer was an instructor in the Junior College of Kansas City, and as the student body of this college was made up principally of the graduates of these high schools, the question often asked was whether there might be an appreciable difference in the students of the physics and chemistry classes regarding their preparation for and ability to do advanced work in the subjects of physics and chemistry. An investigation of the grades made by the students in Junior College was begun but the results were not deemed sufficient for a scientific study as no

standardized tests had been given.

The writer of the thesis with the approval of Superintendent I. I. Cammack and under the supervision of G. E. Melcher, Director of Research, carried on the investigation reported in the following chapters.

CHAPTER IV

THE METHOD OF PROCEDURE

(A) The Groups Studied

This study will include all of the pupils in the physics and chemistry classes in four schools of Kansas City, Missouri, during the school year 1924-1925. When the experiment was begun in September, 1924 nearly 500 pupils were enrolled in each subject making a total of about 1000 pupils. The teacher of physics in the Central High School did not give one of the tests and for that reason the pupils in physics in that school are not included in the findings.

In order to ascertain the intelligence of the groups studied, the "Otis Self-Administering Test of Mental Ability", Higher Examination, Form A, was given during the first month of the school year.* The measure of achievement made during the school year was determined by the "Starch Physics Test", as an initial test given to the pupils of the physics classes during the second week of the school term. About the same time the chemistry classes were given the Rich Chemistry Test, for their initial test.

During the last month of the school year, as a final test, the Starch Physics Test and the Rich Chemistry Test, Epsilon,

* Samples of all tests are found in the Appendix.

were repeated.

These tests contained directions to the teachers for administering the tests. In addition to these instructions, the Director of Research gave typewritten directions so that the procedure might be as uniform as possible.

All the tests were graded by the writer's wife, Erma D. Spitler, who was an experienced teacher, by a skilled clerk and by the writer. In order to test the accuracy of the grading, an inspection was made by random sampling and this proved the work to be very accurate.

A number of the pupils missed one or more tests and these incomplete sets of tests were thrown out. All questionable papers were discarded. When a tabulation was made of the final results, the following numbers were available for consideration in our report.

Table A.

Distribution of Cases in Report

	Northeast	Manual Training	Westport	Central
Physics	65	52	80	
Chemistry	84	50	85	100
Total	149	102	165	100

It will be observed that the Northeast high school, the school with the double-laboratory period has 149 cases to be compared with the other high schools.

(B) All Cases Considered.

In order to answer the questions stated in Chapter III, we have made a study of all the pupils according to Table I and compared the gains made by the pupils in the double-laboratory classes with the gains made by the pupils in the single-laboratory classes. We did not expect to find that the mental ability of the pupils of any one school, as measured by the Otis Tests to be comparable to the mental ability of each of the other three schools. But we have tabulated the Otis Scores * so that the reader may easily compare the mental ability of the groups. We have given the mean and the standard deviation of the mean for each group in each subject.

(C) Pairing

In order to make a study of pupils having the same mental ability, we have collected the gains made by the pupils in physics and chemistry and have tabulated them by pairs, taking only those cases wherein the Otis scores of each pair are alike. To illustrate, we have taken a case from the Manual Training group in physics where the Otis Score is 36 and have paired it with a case in the Northeast group in physics that

* Note: In this paper we will use the term "Otis Scores" for scores made on the Otis Tests of Mental Ability.

has the same Otis Score. In this way we have been able to pair the following number of cases:

Table B.

Cases Paired According to Otis Scores

	Northeast and Manual Training	Northeast and Westport	Northeast and Central
Physics	37	53	0
Chemistry	38	67	57
Total	75	120	57

By this pairing, we have eliminated the factor of differences in gains due to differences in mental ability and any difference in the gains will be assumed to be due, mainly, to the differences in the length of the laboratory period.

CHAPTER V.

PRESENTATION AND INTERPRETATION OF FINDINGS.

All data collected in this study have been arranged in tabualr form in this chapter. The reader should keep in mind that the Northeast high school has two double-laboratory periods per week and the other high schools have two single-laboratory periods per week.

(A) The Mental Ability and Achievement of All Students as Measured by the Tests.

Table I shows a frequency distribution of the Otis Scores made by all the students in the physics classes. It can be seen that the Northeast and Westport groups are quite similar as to mental ability and that the Manual Training group is somewhat inferior.

Table II shows the frequency distribution of gains made by the students in the physics classes with the mean and standard deviation of each group. The gains are obtained by taking the difference between the scores made by each student in the initial test and the final test. The mean of each group will enable the reader to compare the achievement of each group.

In Table III, we have a frequency distribution of the Mental Ability of the students in Chemistry, with the mean and standard deviation of each group. The reader will note that the mean of the Manual Training group is the lowest, the Northeast group is second, the Westport group is third, and the Central group is fourth. This is necessary in order to make a comparison of the gains given in Table IV.

Table IV gives a frequency distribution of the gains made in chemistry by the students in each of the groups, with the mean and standard deviation of each group. It will be noted that the order of the mean of gains does not follow the same order of the mean of mental ability given in Table III.

The reliability of the difference in the means is given in Tables V and VI. The reliability of an average depends upon the number of cases and the variability of the measures within the sample. We assume that we have made a random sampling of the groups. Are these samples representative? To answer this question we refer to tables V and VI. If the chances are 100 in 100, we have true reliability. As the chances in 100 become less than 100, the reliability becomes less.

(B) The Achievement Made by the Students of Equal Mental Ability as Measured by the Tests.

In order to eliminate the factor of differences in mental ability, we have taken the Otis Scores of the Northeast group and paired with them, score by score, students in each of the other three groups. These scores are called "paired scores". We find from Table VII that 37 students in the Manual Training physics group have the same Otis score that 37 students have in the Northeast group; and 53 students in Westport physics group have the same Otis score that 53 students have in the Northeast physics group.

Now, suppose we take two groups of students, A. and B, having the same mental ability. Each group will have the same course of study but a different method of instruction. At the end of a specified period, we administer to each group the same test. If the achievement of group A is greater than the achievement of group B, one would say that the method used in instructing group A is superior - more effective - than the method used in instructing group B.

Table VIII gives the achievement of groups of equal mental ability under different methods of instruction. The achievement in physics of Manual Training group, with the single-laboratory method of instruction, is nearly equal to

the achievement in physics of the Northeast group, with the double-laboratory method of instruction; and the achievement in physics of the Westport group, with the single-laboratory method of instruction is higher than the achievement in physics of the Northeast group with the double-laboratory method of instruction.

From Table IX, in the chemistry groups, 38 in the Northeast and Manual Training groups have the same Otis score, 67 in Northeast and Wesport, and 57 in Northeast and Wesport, and 57 in Northeast and Central. These paired groups were obtained according to scores made on the Otis tests.

Table X gives the achievement, the mean, and the standard deviation of the achievement of the paired groups in chemistry. Here we find the achievement of the Northeast chemistry group higher than that of the Manual Training chemistry group, and also higher than the achievement of the Central chemistry group. The mean of the achievement of the Westport chemistry group is higher than the achievement of the Northeast chemistry group.

Tables XI and XII show the reliability of the means of the achievement made by the students of equal mental ability. These tables show a perfect reliability in each of the paired groups. For an explanation of the reliability, refer to page 26.

TABLE I

DISTRIBUTION OF OTIS SCORES FOR STUDENTS IN THE PHYSICS CLASSES OF THE THREE KANSAS CITY, MISSOURI, HIGH SCHOOLS.

Scores	Northeast	Manual Training	Westport
30-34	3	2	1
35-39	3	2	1
40-44	6	9	5
45-49	8	14	12
50-54	11	15	14
55-59	15	9	24
60-64	12	2	11
65-69	5	1	7
70-74	2	0	5
Total	65	52	80
M	54.12	49.62	56.13
S. D.	9.61	7.41	8.40

This table reads:

Out of the 65 cases in Northeast, 3 made an Otis score between 30 and 35, 3 made an Otis score between 35 and 40, etc. The 65 scores made by the Northeast group were between 30 and 75.

TABLE II

DISTRIBUTION OF THE GAINS MADE BY THE STUDENTS IN THE PHYSICS CLASSES OF THE THREE KANSAS CITY, MISSOURI HIGH SCHOOLS.

Scores	Northeast	Manual Training	Westport
1 - 4	0	1	0
5 - 9	2	9	0
10 - 14	3	10	9
15 - 19	12	6	7
20 - 24	20	10	23
25 - 29	20	7	15
30 - 34	7	5	14
35 - 39	1	3	9
40 - 44	0	1	3
Total	65	52	80
M	23.50	19.91	24.94
S. D.	6.09	9.74	8.22

This table reads:

If we find the difference between the scores made in the initial test and final test by the students in the Northeast physics classes, no pupil would have a gain of less than 5 points, 2 pupils would have a gain between 5 and 10 points, 3 pupils would have a gain between 10 and 15 points, ect.

TABLE III

DISTRIBUTION OF OTIS SCORES FOR STUDENTS IN THE CHEMISTRY CLASSES OF THE FOUR KANSAS CITY, MISSOURI, HIGH SCHOOLS.

Scores	Northeast	Manual Training	Westport	Central
30-50	4	2	2	1
35-39	7	12	3	2
40-44	10	17	5	6
45-49	14	7	17	11
50-54	13	8	14	13
55-59	16	3	23	28
60-64	10	0	13	22
65-69	9	1	8	15
70-74	1	0	0	2
Total	84	50	85	100
M	52.26	44.60	54.79	57.10
S. D.	9.97	7.49	8.16	8.18

See explanation under Table I.

TABLE IV.

DISTRIBUTION OF THE GAINS MADE BY THE STUDENTS IN THE CHEMISTRY CLASSES OF THE FOUR KANSAS CITY, MISSOURI HIGH SCHOOLS.

Scores	Northeast	Manual Training	Westport	Central
1 - 2	5	6	0	7
3 - 4	4	10	1	27
5 - 6	12	16	2	35
7 - 8	21	10	8	14
9 - 10	18	4	12	8
11 - 12	17	2	21	8
13 - 14	6	1	17	1
15 - 16	1	1	16	0
17 - 18	0	0	8	0
Total	84	50	85	100
M	8.43	5.86	12.32	5.84
S. D.	3.17	3.01	3.19	2.53

See explanation under Table II.

TABLE V.

COMPARISON OF GAINS MADE BY THE STUDENTS IN THE PHYSICS CLASSES OF THE THREE KANSAS CITY, MISSOURI HIGH SCHOOLS.

	N. E.	M. T.	Wp.
Frequencies	65	52	80
M	23.50	19.91	24.94
S. D.	6.09	9.74	8.22

Northeast and Manual Training

N. E. M - M. T. M	3.59
S. D. of Difference of Mean	2.27
Chances in 100 that the true N. E. mean is greater than the true M. T. Mean	99.8

Northeast and Westport

W. P. M - N. E. M	1.44
S. D. of Difference of Mean	1.21
Chances in 100 that the true W. P. mean is greater than the true N.E. mean	88.2

The above results are determined by the formula*

$$\sigma\,(\text{dif.}) = \sigma^2\,(\text{av}_1) + \sigma^2\,(\text{av}_2)$$

By the solution of the formula and by the use of the Table XIV, page 134, Garrett, we find the chances of a true difference.

* Garrett, Henry E., Statistics in Psychology and Education, Longmans, Green Co., 1926, 128-34.

TABLE VI

COMPARISON OF GAINS MADE BY

THE STUDENTS IN THE CHEMISTRY

CLASSES OF THE FOUR KANSAS CITY,

MISSOURI HIGH SCHOOLS.

	N.E.	M.T.	W.P	C.
Frequencies	84	50	85	100
M	8.43	5.86	12.32	5.85
S. D.	3.17	3.01	3.19	2.53

Northeast and Manual Training

N. E. M - M. T. M	2.57
S. D. of Difference of Mean	.475
Chances in 100 that the true N.E. mean is greater than the true M.T. mean	68

Northeast and Westport

W. P. M - N.E. M	3.89
S. D. of Difference of Mean	7.95
Chances in 100 that the true W. P. mean is greater than the true N.E. mean	100

Northeast and Central

N. E. M - C. M.	2.59
S. D. of Difference of Mean	605
Chances in 100 that the true N.E. mean is greater than the true C. Mean	100

See explanation under Table V.

TABLE VII

DISTRIBUTION OF OTIS SCORES FOR PAIRED STUDENTS IN THE PHYSICS CLASSES OF THE THREE KANSAS CITY, MISSOURI HIGH SCHOOLS.

Scores	Northeast and Manual Training	Northeast and Westport.
30 - 34	2	1
35 - 39	2	2
40 - 44	5	4
45 - 49	7	8
50 - 54	10	9
55 - 59	8	15
60 - 64	2	8
65 - 69	1	4
70 - 74	0	2
Total	37	53
M	50.34	54.86
S. D.	8.02	8.72

By paired students we mean that we collected as a pair students having the same Otis score. The table reads that 2 students in Northeast and 2 students in Manual Training had a score between 30 and 35. The true scores are : one from each school had an Otis score of 30 and one fwom each school had an Otis score of .32, etc.

See explanation under Table VIII.

TABLE VIII

DISTRIBUTION OF THE GAINS MADE BY THE PAIRED STUDENTS IN THE PHYSICS CLASSES OF THE THREE KANSAS CITY, MISSOURI HIGH SCHOOLS.

Scores	N.E.	M.T.	N.E.	W.P.
1 - 4	0	0	0	0
5 - 9	2	5	1	0
10 - 14	2	7	3	5
15 - 19	7	4	9	3
20 - 24	10	7	19	17
25 - 29	12	6	16	11
30 - 34	4	5	5	9
35 - 39	0	1	0	6
40 - 44	0	2	0	2
Total	37	37	53	53
M	22.77	21.69	23.35	26.46
S. D.	6.41	9.83	7.61	7.44

To read this table the reader must keep in mind that these scores are made by pupils of equal mental ability as determined by the Otis tests. A copy from the working tabulation may make this more easily understood.

Gains Made by Paired Students in Physics.

Otis Score	N.E. Gain	M.T. Gain
30	32	5
32	17	8
36	20	14
38	15	31
39	12	41
42	27	9

TABLE IX

DISTRIBUTION OF THE OTIS SCORES FOR PAIRED STUDENTS IN THE CHEMISTRY CLASSES OF THE FOUR KANSAS CITY, MISSOURI HIGH SCHOOLS.

Scores	Northeast and Manual Training	Northeast and Westport	Northeast and Central
30 - 34	2	2	1
35 - 39	7	3	2
40 -44	10	5	6
45 - 49	8	12	8
50 - 54	7	14	9
55 - 59	3	14	12
60 - 64	0	9	10
65 - 69	1	8	8
70 - 74	0	0	1
Total	38	67	57
M.	45.74	53.77	55.13
S. D.	5.54	8.83	9.14

This table reads:

In the Northeast and Manual Training groups, 2 students made an Otis score between 30 and 35, a students made an Otis score between 35 and 40. However, it must be kept in mind that each pair of students had the same Otis score.

TABLE X.

DISTRIBUTION OF THE GAINS MADE BY PAIRED STUDENTS IN THE CHEMISTRY CLASSES OF THE FOUR KANSAS CITY, MISSOURI HIGH SCHOOLS.

Scores	Northeast and Manual Training		Northeast and Westport		Northeast and Central	
	N.E.	M.T.	N.E.	W.P	N.E.	C.
1 - 2	0	4	5	0	3	4
3 - 4	1	4	3	0	4	11
5 - 6	6	14	8	2	7	18
7 - 8	11	7	13	5	16	11
9 - 10	10	5	15	10	9	7
11 - 12	8	2	17	16	13	6
13 - 14	2	1	5	12	5	0
15 - 16	0	1	1	15	0	0
17 - 18	0	0	0	7	0	0
Total	38	38	67	67	57	57
M.	8.76	6.55	8.66	12.61	8.41	6.34
S. D.	2.40	3.17	3.34	3.12	3.18	2.78

See explanation inder Table VIII.

TABLE XI

COMPARISON OF GAINS MADE BY PAIRED STUDENTS IN THE PHYSICS CLASSES OF THE THREE KANSAS CITY, MISSOURI HIGH SCHOOLS.

	Northeast and Manual Training		Northeast and Westport	
	N.E.	M.T.	N.E.	M.P.
Frequencies	37	37	53	53
M	22.77	21.69	23.25	26.46
S. D.	6.41	9.83	5.53	7.71

Northeast and Manual Training

N.E. M - M.T. M	1.08
S. D. of Difference of Mean	.56
Chances in 100 that the true N.E. mean is greater than the true M.T. mean	64.2

Northeast and Westport

W. P. M - N.E. M	3.21
S. D. of Difference of Mean	2.45
Chances in 100 that the true W.P. mean is greater than the true N.E. mean	99.3

See explanation under Table V.

TABLE XII.

COMPARISON OF GAINS MADE BY PAIRED STUDENTS IN THE CHEMISTRY CLASSES OF THE FOUR KANSAS CITY, MISSOURI HIGH SCHOOLS.

	Northeast and Manual Training		Northeast and Westport		Northeast and Central	
	N.E.	M.T	N.E.	W.P.	N.E.	C.
Frequencies	58	38	67	67	57	57
M.	8.76	6.55	8.66	12.61	8.41	6.34
S. D.	2.40	3.17	3.34	3.12	3.18	2.78

Northeast and Manual Training.

N.E. M - M.T. M	2.19
S. D. of Difference of Mean	3.39
Chances in 100 that true N.E. M is greater than true M.T. M.	100

Northeast and Westport

W. P. M - N.E. M	3.95
S. D. of Difference of Mean	7.07
Chances in 100 that true N.E. M. is greater than the N.E. M.	100

Northeast and Central

N.E. M- C. M	2.07
S. D. of Difference of Mean	3.70
Chances in 100 that true N.E. M is greater than true C. M	100

See explanation under Table V.

CHAPTER VI

CONCLUSIONS

In the analysis of our problem in Chapter III, we stated three specific questions which we believed our experiment would answer. On the basis of the data presented, we are now ready to answer them. It is not to be presumed that these conclusions are applicable to all classes in physics and chemistry, whether they follow the single-laboratory method or the double-laboratory method. Our answers to these questions are based on the achievement made by the students in the physics and chemistry classes of the four Kansas City, Missouri high schools during the school year 1924-1925.

In the physics classes, the double-laboratory method was more effective than the single-laboratory method when we compare the Northeast group with the Manual Training group but less effective when we compare the Northeast group with the Westport group.

In the chemistry classes, the double-laboratory method was more effective when we compare the Northeast group

with the Manual Training group and also when we compare the Northeast group with the Central group. The double-laboratory method is less effective when we compare the Northeast with the Westport group. These conclusions, derived from the findings under Tables II, and VIII, for physics and Tables IV and X, for chemistry, are the same whether the groups are paired or not paired according to mental ability as measured by the Otis Test.

The following general conclusion is based on the data of this study:

When we measure the results by standardized tests, the effectiveness of the teaching of physics and chemistry is not determined by the length of the laboratory period.

APPENDIX

(A) Bibliography

(B) Samples of Tests

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OTIS SELF-ADMINISTERING TESTS OF MENTAL ABILITY

By ARTHUR S. OTIS

Formerly Development Specialist with Advisory Board, General Staff, United States War Department

HIGHER EXAMINATION: FORM A

20 Score.....

Read this page. Do what it tells you to do.

Do not open this paper, or turn it over, until you are told to do so. Fill these blanks, giving your name, age, birthday, etc. Write plainly.

Name.....Age last birthday.....years
First name, initial, and last name

Birthday..... Class..... Date.....192...
Month Day

School or College..... City.....

This is a test to see how well you can think. It contains questions of different kinds. Here is a sample question already answered correctly. Notice how the question is answered:

Which one of the five words below tells what an apple is?

1 flower, 2 tree, 3 vegetable, 4 fruit, 5 animal.....(*4*)

The right answer, of course, is "fruit"; so the word "fruit" is underlined. And the word "fruit" is No. 4; so a figure 4 is placed in the parentheses at the end of the dotted line. This is the way you are to answer the questions.

Try this sample question yourself. Do not write the answer; just draw a line under it and then put its number in the parentheses:

Which one of the five words below means the opposite of north?

1 pole, 2 equator, 3 south, 4 east, 5 west.....( )

The answer, of course, is "south"; so you should have drawn a line under the word "south" and put a figure 3 in the parentheses. Try this one:

A foot is to a man and a paw is to a cat the same as a hoof is to a—what?

1 dog, 2 horse, 3 shoe, 4 blacksmith, 5 saddle.....( )

The answer, of course, is "horse"; so you should have drawn a line under the word "horse" and put a figure 2 in the parentheses. Try this one:

At four cents each, how many cents will 6 pencils cost?..... ( )

The answer, of course, is 24, and there is nothing to underline; so just put the 24 in the parentheses.

If the answer to any question is a number or a letter, put the number or letter in the parentheses without underlining anything. Make all letters like printed capitals.

The test contains 75 questions. You are not expected to be able to answer all of them, but do the best you can. You will be allowed half an hour after the examiner tells you to begin. Try to get as many right as possible. Be careful not to go so fast that you make mistakes. Do not spend too much time on any one question. No questions about the test will be answered by the examiner after the test begins. Lay your pencil down.

Do not turn this page until you are told to begin.

Published by World Book Company, Yonkers-on-Hudson, New York, and 2126 Prairie Avenue, Chicago
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OSATMA: HE: A-7

EXAMINATION BEGINS HERE:

1. The opposite of hate is (?)
   1 enemy, 2 fear, 3 love, 4 friend, 5 joy ..... ( )
2. If 3 pencils cost 5 cents, how many pencils can be bought for 50 cents? ..... ( )
3. A bird does not always have (?)
   1 wings, 2 eyes, 3 feathers, 4 a nest, 5 a bill ..... ( )
4. The opposite of honor is (?)
   1 glory, 2 disgrace, 3 cowardice, 4 fear, 5 defeat ..... ( )
5. A fox most resembles a (?)
   1 wolf, 2 goat, 3 pig, 4 tiger, 5 cat ..... ( )
6. Quiet is related to sound in the same way that darkness is related to (?)
   1 a cellar, 2 sunlight, 3 noise, 4 stillness, 5 loud ..... ( )
7. A party consisted of a man and his wife, his two sons and their wives, and four children in each son's family. How many were there in the party? ..... ( )
8. A tree always has (?)
   1 leaves, 2 fruit, 3 buds, 4 roots, 5 a shadow ..... ( )
9. The opposite of economical is (?)
   1 cheap, 2 stingy, 3 extravagant, 4 value, 5 rich ..... ( )
10. Silver is more costly than iron because it is (?)
    1 heavier, 2 scarcer, 3 whiter, 4 harder, 5 prettier ..... ( )
11. Which one of the six statements below tells the meaning of the following proverb? "The early bird catches the worm." ..... ( )

    1. Don't do the impossible.
    2. Weeping is bad for the eyes.
    3. Don't worry over troubles before they come.
    4. Early birds like worms best.
    5. Prompt persons often secure advantages over tardy ones.
    6. It is foolish to fret about things we can't help.

12. Which statement above tells the meaning of this proverb? "Don't cry over spilt milk." .... ( )
13. Which statement above explains this proverb? "Don't cross a bridge till you get to it." .... ( )
14. An electric light is related to a candle as an automobile is to (?)
    1 a carriage, 2 electricity, 3 a tire, 4 speed, 5 glow ..... ( )
15. If a boy can run at the rate of 6 feet in $\frac{1}{4}$ of a second, how far can he run in 10 seconds? .... ( )
16. A meal always involves (?)
    1 a table, 2 dishes, 3 hunger, 4 food, 5 water ..... ( )
17. Of the five words below, four are alike in a certain way. Which is the one not like these four?
    1 bend, 2 shave, 3 chop, 4 whittle, 5 shear ..... ( )
18. The opposite of never is (?)
    1 often, 2 sometimes, 3 occasionally, 4 always, 5 frequently ..... ( )
19. A clock is related to time as a thermometer is to (?)
    1 a watch, 2 warm, 3 a bulb, 4 mercury, 5 temperature ..... ( )
20. Which word makes the truest sentence? Men are (?) shorter than their wives.
    1 always, 2 usually, 3 much, 4 rarely, 5 never ..... ( )
21. One number is wrong in the following series. What should that number be?
    1 4 2 5 3 6 4 7 5 9 6 9 ..... ( )
22. If the first two statements following are true, the third is (?) All members of this club are Republicans. Smith is not a Republican. Smith is a member of this club.
    1 true, 2 false, 3 not certain ..... ( )
23. A contest always has (?)
    1 an umpire, 2 opponents, 3 spectators, 4 applause, 5 victory ..... ( )
24. Which number in this series appears a second time nearest the beginning?
    6 4 5 3 7 8 0 9 5 9 8 8 6 5 4 7 3 0 8 9 1 ( )
25. The moon is related to the earth as the earth is to (?)
    1 Mars, 2 the sun, 3 clouds, 4 stars, 5 the universe ..... ( )
26. Which word makes the truest sentence? Fathers are (?) wiser than their sons.
    1 always, 2 usually, 3 much, 4 rarely, 5 never ..... ( )

27. The opposite of awkward is (?)
1 strong, 2 pretty, 3 short, 4 graceful, 5 swift..... ( )

28. A mother is always (?) than her daughter.
1 wiser, 2 taller, 3 stouter, 4 older, 5 more wrinkled..... ( )

29. Which one of the six statements below tells the meaning of the following proverb? "The burnt child dreads the fire."..... ( )

1. Frivolity flourishes when authority is absent.
2. Unhappy experiences teach us to be careful.
3. A thing must be tried before we know its value.
4. A meal is judged by the dessert.
5. Small animals never play in the presence of large ones.
6. Children suffer more from heat than grown people.

30. Which statement above explains this proverb? "When the cat is away, the mice will play." ( )

31. Which statement above explains this proverb? "The proof of the pudding is in the eating." ( )

32. If the settlement of a difference is made by mutual concession, it is called a (?)
1 promise, 2 compromise, 3 injunction, 4 coercion, 5 restoration..... ( )

33. What is related to disease as carefulness is to accident?
1 doctor, 2 surgery, 3 medicine, 4 hospital, 5 sanitation..... ( )

34. Of the five things below, four are alike in a certain way. Which is the one not like these four?
1 smuggle, 2 steal, 3 bribe, 4 cheat, 5 sell..... ( )

35. If 10 boxes full of apples weigh 400 pounds, and each box when empty weighs 4 pounds, how much do all the apples weigh?..... ( )

36. The opposite of hope is (?)
1 faith, 2 misery, 3 sorrow, 4 despair, 5 hate..... ( )

37. If all the odd-numbered letters in the alphabet were crossed out, what would be the tenth letter not crossed out? Print it. *Do not mark the alphabet.*..... ( )
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

38. What letter in the word SUPERFLUOUS is the same number in the word (counting from the beginning) as it is in the alphabet? Print it..... ( )

39. What people say about a person constitutes his (?)
1 character, 2 gossip, 3 reputation, 4 disposition, 5 personality..... ( )

40. If 2½ yards of cloth cost 30 cents, what will 10 yards cost?..... ( )

41. If the words below were arranged to make a good sentence, with what letter would the second word of the sentence begin? Make it like a printed capital.
same means big large the as..... ( )

42. If the first two statements following are true, the third is (?) George is older than Frank. James is older than George. Frank is younger than James.
1 true, 2 false, 3 not certain..... ( )

43. Suppose the first and second letters in the word CONSTITUTIONAL were interchanged, also the third and fourth letters, the fifth and sixth, etc. Print the letter that would then be the twelfth letter counting to the right..... ( )

44. One number is wrong in the following series. What should that number be?
0 1 3 6 10 15 21 28 34..... ( )

45. If 4½ yards of cloth cost 90 cents, what will 2½ yards cost?..... ( )

46. A man's influence in a community should depend upon his (?)
1 wealth, 2 dignity, 3 wisdom, 4 ambition, 5 political power..... ( )

47. What is related to few as ordinary is to exceptional?
1 none, 2 some, 3 many, 4 less, 5 more..... ( )

48. The opposite of treacherous is (?)
1 friendly, 2 brave, 3 wise, 4 cowardly, 5 loyal..... ( )

49. Which one of the five words below is most unlike the other four?
1 good, 2 large, 3 red, 4 walk, 5 thick..... ( )

50. If the first two statements following are true, the third is (?) Some of Brown's friends are Baptists. Some of Brown's friends are dentists. Some of Brown's friends are Baptist dentists.
1 true, 2 false, 3 not certain..... ( )

51. How many of the following words can be made from the letters in the word LARGEST, using any letter any number of times?
great, stagger, grasses, trestle, struggle, rattle, garage, strangle..... ( )

52. The statement that the moon is made of green cheese is (?)
1 absurd, 2 misleading, 3 improbable, 4 unfair, 5 wicked..... ( )

Do not stop. Go on with the next page.

53. Of the five things following, four are alike in a certain way. Which is the one not like these four?
1 tar, 2 snow, 3 soot, 4 ebony, 5 coal..... ( )

54. What is related to a cube in the same way in which a circle is related to a square?
1 circumference, 2 sphere, 3 corners, 4 solid, 5 thickness..... ( )

55. If the following words were seen on a wall by looking in a mirror on an opposite wall, which word would appear exactly the same as if seen directly?
1 OHIO, 2 SAW, 3 NOON, 4 MOTOR, 5 OTTO..... ( )

56. If a strip of cloth 24 inches long will shrink to 22 inches when washed, how long will a 36-inch strip be after shrinking?..... ( )

57. Which of the following is a trait of character?
1 personality, 2 esteem, 3 love, 4 generosity, 5 health..... ( )

58. Find the two letters in the word DOING which have just as many letters between them in the word as in the alphabet. Print the one of these letters that comes first in the alphabet..... ( )
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

59. Revolution is related to evolution as flying is to (?)
1 birds, 2 whirling, 3 walking, 4 wings, 5 standing..... ( )

60. One number is wrong in the following series. What should that number be?
1 3 9 27 81 108..... ( )

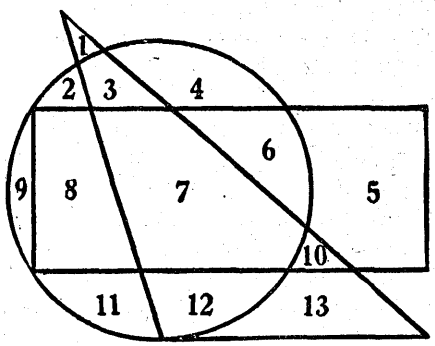
61. If Frank can ride a bicycle 30 feet while George runs 20 feet, how far can Frank ride while George runs 30 feet?..... ( )

62. Count each N in this series that is followed by an O next to it if the O is not followed by a T next to it. Tell how many N's you count.
N O N T Q M N O T M O N O O N Q M N N O Q N O T O N A M O N O M ..... ( )

63. A man who is averse to change and progress is said to be (?)
1 democratic, 2 radical, 3 conservative, 4 anarchistic, 5 liberal..... ( )

64. Print the letter which is the fourth letter to the left of the letter which is midway between O and S in the alphabet..... ( )

65. What number is in the space which is in the rectangle and in the triangle but not in the circle? ( )



66. What number is in the same geometrical figure or figures as the number 8?..... ( )

67. How many spaces are there that are in any two but only two geometrical figures?..... ( )

68. A surface is related to a line as a line is to (?)
1 solid, 2 plane, 3 curve, 4 point, 5 string..... ( )

69. If the first two statements following are true, the third is (?) One cannot become a good violinist without much practice. Charles practices much on the violin. Charles will become a good violinist.
1 true, 2 false, 3 not certain..... ( )

70. If the words below were arranged to make the best sentence, with what letter would the last word of the sentence end? Print the letter as a capital.
sincerity traits courtesy character of desirable and are..... ( )

71. A man who is influenced in making a decision by preconceived opinions is said to be (?)
1 influential, 2 prejudiced, 3 hypocritical, 4 decisive, 5 impartial..... ( )

72. A hotel serves a mixture of 2 parts cream and 3 parts milk. How many pints of cream will it take to make 15 pints of the mixture?..... ( )

73. What is related to blood as physics is to motion?
1 temperature, 2 veins, 3 body, 4 physiology, 5 geography..... ( )

74. A statement the meaning of which is not definite is said to be (?)
1 erroneous, 2 doubtful, 3 ambiguous, 4 distorted, 5 hypothetical..... ( )

75. If a wire 20 inches long is to be cut so that one piece is $\frac{2}{3}$ as long as the other piece, how long must the shorter piece be?..... ( )

PHYSICS TEST

Prepared by Daniel Starch, University of Wisconsin

Directions for administering and scoring the test.

The test may be given at the end of the year or the various sections may be given after the completion of the different topics.

Allow the pupils as much time as they reasonably need to complete as many of the statements or problems as they can.

Score the test by determining the number of statements completed or solved correctly. The number, not the percentage, of the statements finished correctly is the score.

The results of a class should then be tabulated to show the name of each pupil and his score in each of the divisions of the test.

Standard	Mechanics	Heat	Sound	Light	Magnetism and Electricity	Total
Scores	17.	4.5	5.5	7.0	16.	50

MECHANICS

1. The_____is the absolute unit of force that, acting upon_____of mass will give to it an acceleration of_____per second per second.

2. The erg is the work done by a force of_____acting through a distance of_____

3. In the equation $s=\frac{1}{2}a't^2$, s means_____, a means_____, t means_____

4. The point of application of the resultant of all the parallel forces that make up the weight of a body is its _____

5. The law of _____means that no energy is created and none destroyed.

6. The smallest stress that will cause a permanent set in a body is called_____

7. The energy of an elevated body is an example of_____energy. The energy of a descending hammer is an example of_____ energy.

8. If two forces are represented by two adjacent sides of a parallelogram, their resultant is represented by_____

9. If a stone, dropped from the top of a cliff, strikes the bottom in 5 seconds, the cliff is_____ feet high.

10. If a man draws a ton of mortar up in buckets a distance of 10 feet, he does_____ foot-pounds of work.

11. Any two bodies in the universe attract each other with a force which is_____proportional to the product of_____ and_____ proportional to_____

_____

12. A boy pulls a loaded sled weighing 200 lbs. up a hill which rises 1 ft. in 5 measured along the slope. Neglecting friction, he exerts_____ pounds of force.

13. The mechanical advantage of any lever is the ratio of_____ to _____

14. The tendency of a body to retain its condition of rest or motion is_____

15. The rate of change of momentum is proportional to_____and takes place in the direction in which_____

16. To every action there is_____reaction in_____direction.

17. The periods of pendulums of equal lengths swinging through short arcs are independent of_____

_____ and also independent of_____

18. The period of a pendulum is directly proportionall to_____

19. A cord must pass_____times to and from a movable pulley in order that a 50 lb. weight may support a 200 lb. weight.

20. The absorption of ink by a blotter is an illustration of_____action.

21. Pressure exerted upon any part of an enclosed liquid is transmitted_____ in all directions and acts with_____force on all_____ surfaces and at right angles to them.

22. The pressure per square foot in a swimming tankfilled with water to a depth of 10 ft. is_____ pounds. The weight of a cubic foot of water is 62.4 lbs.

23. The ratio between the weight of a body and the weight of_____ is its specific gravity.

24. The specific gravity of a wooden ball that floats two thirds under water is_____

25. The fact that liquids take a spherical form is an illustration of the phenomenon of_____

26. A barometer is an instrument for measuring_____

27. The temperature remaining the same, the volume of a given mass of gas varies_____

28. The pressure of the atmosphere at sea level is_____lb. per square inch.

How many weeks have you studied Mechanics?

HEAT

1. A temperature of 50 degrees centigrade is the same as_____degrees Fahrenheit.

2. The point_____degrees below_____degrees centigrade is called absolute zero.

3. The quantity of heat required to raise_____of water through_____centigrade is called_____

4. The process by which heat is carried from hotter bodies to colder bodies by a moving fluid is called _____ The process by which it is transferred through substances that are at rest is called _____

5. The coefficient of expansion is the ratio of the increase in volume to the original volume produced by _____

6. The number of work units that correspond to a heat unit is called_____

7. The intensity of radiant heat is inversely proportional to _____

8. The specific heat of a substance is the number of_____required to raise the temperature of _____ through _____centigrade.

How many weeks have you studied Heat?

SOUND.

1. Two tuning forks whose frequencies are 435 and 440 respectively when sounded together will produce _____beats per second.
2. The tone produced when a string vibrates as a loop are called_____

   Those produced when it vibrates in two or more loops is called_____
3. The frequency of vibration of a string varies inversely as _____
4. It also varies inversely as_____, when the length is constant.
5. It also varies inversely as_____, when the length and tension are constant.
6. Sound travels_____per second at 20° C.
7. The pitch of a tone depends upon_____
8. The quality of a tone depends upon_____
9. The loudness of a tone depends upon_____

How many weeks have you studied Sound?

LIGHT.

1. Two colors are complementary if they produce_____when they are mixed.
2. If the angle of incidence is 45° the angle of reflection will be_____degrees.
3. The ratio of the speed of light in_____to its speed in any medium is called the index of refraction.
4. A photometer is an instrument for measuring_____
5. A 4-candle-power light must be placed_____feet from a screen in order to give the same illumination as a 16-candle-power light 9 feet away.
6. Light travels_____per second.
7. A continuous spectrum composed of the colors from_____to_____is produced by passing_____light through a prism.
8. The critical angle is that angle of incidence which will produce_____
9. If the image of an object 10 feet away is 3 feet from the lens, the focal length of the lens is_____

_____

How many weeks have you studied Light?

MAGNETISM AND ELECTRICITY.

1. Electromotive force is the difference in_____ between _____.
2. A dynamo is a machine for transforming_____ energy into_____energy.
3. An electric motor is a machine for transforming_____energy into _____energy.
4. The rotating part of a dynamo, consisting of the coil with its core, is called the_____
5. A_____is a device for uniting_____currents in the same direction

6. A_____is a device for changing the voltage of an alternating or interrupted current either up or down.

7. An induction coil is composed of a_____coil containing_____turns of coarse wire and a _____coil containing_____turns of fine wire.

8. The instrument for the comparison of currents by means of_____ is called a galvanometer.

9. If the galvanometer reads in terms of_____it is called an ammeter.

10. The_____is the unit of current which will deposit .001118 gram of_____in one second

11. The_____is the unit of resistance of a column of mercury_____in cross section and 106.3 cm. long.

12. The resistance of a conductor is directly proportional to _____

13. It is also inversely proportional to_____

14. A volt is the E. M. F. which will cause a current of_____to flow through a resistance of _____

15. If the current through an incandescent lamp is 0.55 ampere and the potential difference between its terminals 110 volts, the resistance of the lamp is_____ohms.

16. The watt is the power required to keep a current of_____flowing under a drop of_____

17. Watts = amperes ×_____

18. At 10 cents per kilowatt hour it will cost_____to run a 220 volt motor for 10 hours, if the motor draws 25 amperes.

19. A Leyden jar is a common type of_____consisting of two conductors separated by _____

20. The resistance of 100 ft. of copper wire

(K = 10.19 in thousandths of an inch) No. 24 (Diam. = 0.0201 in.)

is_____ohms.

21. If a storage cell has an E. M. F. of 2 volts and furnishes a current of 5 amperes, its rate of expenditure of energy is_____watts

How many weeks have you studied Magnetism and Electricity?

Name _____ Date _____

School _____ City _____

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BLOOMINGTON, ILLINOIS

Chemistry Test Gamma

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For tester's use:
Correct .....
T-score .....
Omitted .....
Problems .....

School .....

Place .....Name or number of class.....

Your name.....Sex .....Age ....yrs...mo.
Given name family name.

Today's date.....192... How many half-years, terms, or semesters have you studied chemistry, *in all?* Count as half a term the one you are now in unless it is in its first or last month.....

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   Sample question: What is the chief product when coal is burned in a furnace?

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   Carbon dioxide.
   Soot.
   Water.

   The correct answer, carbon dioxide, is underlined.
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PRACTICE QUESTION

If I burn out from 100 cc. of air by means of phosphorus, all the oxygen, forming 21% of the volume of air, how many cc. of nitrogen are left?

79 cc.
50 cc.
23 cc.
21 cc.

Do the calculation in this space.

Chemistry Test Gamma

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QUESTIONS.	ANSWERS.
1. What is the danger if we put fresh coal on a fire, close down the damper, and leave the door of the stove open or a lid off?	Fire goes out. Waste of coal. Poisonous CO gas escapes. Explosion will occur.
2. Opposite the element named underline the symbol that stands for it in chemical notation. Mercury	Mg Hg Na I
3. Complete and balance the equation for the complete combustion of the "gasolene" hexane. $2C_6H_{14} + 19\ 0_2 ==$	$12CO_2 + 14H_2O$ $16CO_2 + 14H_2O$ $12CO + 28H_2O$ $12CO + 12C + 14H_2O$
Do the calculation in this space.	
4. What law is implied in ALL of the following three statements? 23 grams Na + 18 grams H_2O give 40 grams NaOH + 1 gram H_2. 100 grams magnetite give 72.5 grams iron. 50 grams quicklime always give 74 grams slaked lime.	Definite proportions. Charles'. Multiple proportions. Mass action.
5. Oxygen is used with acetylene in welding for the following reason:	Oxygen burns. Oxygen is a colorless gas. Oxygen is cheap. Oxygen supports combustion actively.
6. In preparing iodine in the laboratory, we drive it off in gaseous (or vapor) form from the liquid in which it is formed, but we do not distil it out as we do when we have prepared alcohol. Why not?	Iodine remains a gas. Iodine becomes a solid directly and collects on the cover of the vessel. The gas is too heavy to pass over as is necessary in distillation. The iodine would choke the "worm" of the still.
7. When sulfuric acid, concentrated, is placed on sugar, the solid becomes black, and the mixture becomes very warm. What is the cause of this?	The sugar is burned. The acid is decomposed. The acid takes out water from the sugar molecules. The sugar is hydrolyzed in solution.

Chemistry Test Gamma

8. In the manufacture of aluminum from bauxite and cryolite, as in the Hall process, what treatment is given this mixture to separate out the metal?

Roasting.
Electrolysis.
Reduction with carbon.
Displacement.

9. The valence of the element "Y" is —4 or 4 and that of the element "X" is +3 or 3. Give the correct formula of the binary compound which these two elements could form.

YX_4
X_2Y
X_4Y_3
X_3Y_4

10. In making carbon dioxide for the commercial production of soda-water, why is the action of sulfuric acid on marble used instead of the burning of coal, coke, kerosene, or gas, as a source of this carbon dioxide?

To get pure CO_2
To get cool gas.
It is a cheaper process.
It is more convenient.

11. In developing a photograph, we change silver bromide to metallic silver by the action of an appropriate reagent. What kind of a chemical change is this?

Oxidation.
Replacement.
Double Decomposition.
Reduction.

12. In diluting sulfuric acid, we always pour the acid into the water, but never the water into the acid. Why do we do this?

To stop chemical action.
To prevent spattering.
To prevent an explosion.
To prevent the vessel containing the mixture from cracking.

13. If we make a solution of calcium chloride by dissolving 40 grams of calcium chloride in 100 grams (or CC.) of boiling water, so that it all dissolves, then allowing it to cool to room temperature, and filtering off the precipitate, what kind of a solution have we left?

Concentrated.
Saturated.
Dilute.
Supersaturated.

14. Is this statement true, false, partly true, or doubtful?—Proteins differ from carbohydrates in that their molecules always contain at least one atom of the element nitrogen, as well as in some other respects.

False.
Partly true.
Doubtful.
True.

15. What is the approximate weight of 11.2 liters of carbon dioxide?

10 grams.
11.2 grams.
16 grams.
22 grams.

Do the calculation in this space.

16. Indicate to which kind of substance *two* of those named below belong. Do not indicate which kinds the other two are.

Hydrogen sulfide.
Sodium biborate.
Antimony sulfide.
Aluminum.

Acid.
Base.
Salt.
Element.

Chemistry Test Gamma

17. From which of the following sources does the greater part of the ammonia commercially used come?
- Horns and hoofs.
- The air.
- Coal.
- Chile saltpeter.

18. If you were given a sample of "hard water," what reagent would you use with it that would indicate by a reaction that could not be mistaken the presence of a sulfate in the solution if it were there?
- Silver nitrate.
- Sodium phosphate.
- Barium nitrate.
- Calcium chloride.

19. To which group of actions do the following *all* belong?
The cleansing action of soap.
The clarifying or whitening of sugar by means of charcoal.
The formation of a blue color when iodine is put with starch.
- Neutralization.
- Adsorption.
- Precipitation.
- Dissolving.

20. Why does ammonia water always feel cool when it comes in contact with the hands?
- Reaction with skin.
- Rapid escape of gas.
- Evaporation of water.
- Does not feel cool.

21. How many liters of nitrogen are necessary to form 10 liters of ammonia gas by direct union with hydrogen, assuming that no excess of either is used and that the temperature and pressure remain constant?
- 5 liters.
- 10 liters.
- 11 liters.
- 40 liters.

Do the calculation in this space.

22. To which of the following kinds of processes does the hard-boiling of an egg belong?
- Physical.
- Biological.
- Physical and biological combined.
- Chemical.

23. When testing for the presence of iron by the use of potassium or ammonium thiocyanate (sulfocyanide), into what condition must the iron in the solution to be tested be brought?
- Bivalent.
- Ionic.
- Trivalent.
- Precipitated out.

24. How much aluminum can be prepared from 10 tons bauxite which is 74% pure aluminum oxide?
- 3.8 tons.
- 3.9 tons.
- 4 tons.
- 5.2 tons.

Do the calculation in this space.

25. The antidote, or material given to destroy the poison, for corrosive sublimate when it has been swallowed, is:
- Mustard.
- Chalk and water.
- Milk.
- Calomel.

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THEN MAKE SURE THAT YOU HAVE FILLED IN ALL THE BLANKS ON THE COVER CORRECTLY.

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Place .....Name or number of class.....

Your name.....Sex .....Age ....yrs...mo.
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QUESTIONS.	ANSWERS.
1. Explain how it is that we get the same results in increasing the fertility of a piece of land by applying to it Chile saltpeter (sodium nitrate) as by planting it to clover or alfalfa and plowing the green crop into the soil.	In both cases we pulverize the soil. Both treatments make the soil less acid. Both add available nitrogen to the soil. The effects are not the same.
2. The formula of the diamond is:	$CaCO_3$. C. C_2H_2. CaC_2.
3. The valence of the element "Y" is —3 or 3 and that of the element "X" is +4 or 4. Give the correct formula of the binary compound which these two elements could form.	YX_4. X_2Y. X_4Y_3. X_3Y_4.
4. What inference do you draw from the following facts, as to the chemical nature of the bulk of the substance of tapioca, sago, rice and flour?—they are vegetable products; when boiled and cooled they all give a white, jelly-like mass not soluble in water.	They contain carbon. The material is mineral in nature. Mostly starch. Not the same material in all cases.
5. The disinfectant power of hydrogen peroxide is due to what property of the substance?	Poisonousness. Dissolving power. Adhesion to surfaces on which it is put. Active oxidizing power.
6. When we make barium sulfate in the laboratory, what property of the substance do we take advantage of to separate it from the solution in which it is formed?	Specific gravity. Insolubility. White color. Chemical inertness.
7. On the use of what kind of action does the effectiveness of the gas-mask filled with charcoal, as used in the World War and in mining, depend?	Oxidation. Solution. Adsorption. Electrolysis.
8. What element, because of its affinity for oxygen is generally used as a reducing agent in metallurgy?	S P Fe C

Chemistry Test Epsilon

9. How many grams of water are formed by the combustion of 10 grams of hydrogen in air?

70 grams.
80 grams.
90 grams.
100 grams.

Do the calculation in this space.

10. In putting out a fire, one of the factors of combustion named at the side must be removed. Which one is removed when we use a hand-extinguisher?

Supporter.
Material (fuel).
Temperature.
Flame.

11. When we add lime to a substance, heat the mixture, and get ammonia as a product, the presence of what element in the substance is indicated?

Hydrogen.
Oxygen.
Calcium.
Nitrogen.

12. In an experiment a strip of copper was hung in a solution of mercuric nitrate. After a while the solution became blue and the metal grayish-white. What had happened to the copper?

It had replaced the mercury in the dissolved salt.
It had been covered with mercury but was still all in the strip.
It had been changed in color.
It had been oxidized.

13. Why is it, that although both copper and iron oxidize in the air, copper roofs will last without paint but iron roofs have to be painted to prevent complete rusting away?

Copper oxidizes more slowly.
The rain washes the oxide off copper but not off iron.
The oxide forms a protective coat on the copper.
The iron oxide acts as a catalytic.

14. What material used in the Solvay process for making sodium carbonate primarily determined the location of the factories at Solvay, near Syracuse, N. Y.?

Coal.
Limestone.
Salt.
Water.

15. What weight of iron, if none were lost in the process, could be obtained from 200 tons of ore containing 85% ferric oxide? Atomic weights: Fe=56, O=16.

109 tons.
112 tons.
119 tons.
143 tons.

Do the calculation in this space.

16. A liquid, known to contain soap, potassium nitrate and sugar, was filtered, but remained cloudy, despite repeated filtration. In what condition was the usually insoluble portion of the soap?

In colloidal solution.
In suspension.
Ionized.
Coagulated.

17. The following substance is found in the secretion of the human stomach:

Sodium nitrate.
Methane.
Sugar.
Hydrochloric acid.

18. In an experiment on electrical conductivity of substances the following were tried, and only one of them was a conductor. Mark it among the four given.

- Distilled water.
- Kerosene.
- Solution of $KMnO_4$.
- Solution of glucose.

19. If a plant is cut off just above the ground, and a tube fastened to the stump, a liquid soon rises into it. This osmotic action is due to the presence of what sort of substances in the sap of the plant?

- Insoluble materials.
- Carbon compounds.
- Soluble substances.
- Gases.

20. The characteristic slippery feeling, and bitter taste of the solutions of sodium carbonate, sodium hydroxide, calcium hydroxide, and potassium hydroxide is due to the presence of what substance?

- The alkali or base.
- Hydroxyl (OH ion).
- The metal.
- The water.

21. A man eats a meal containing 162 grams of starch: this is all converted into sugar during digestion. What weight of sugar does he thus get in his meal?
Equation: $2C_6H_{10}O_5 + H_2O = C_{12}H_{22}O_{11}$.

- 324 grams.
- 180 grams.
- 171 grams.
- 162 grams.

Do the calculation in this space.

22. Oxidation includes the combination of an element with any other element chemically in the same class with oxygen. Reduction is similarly extended to the removal of elements other than oxygen. Name the kind of process that takes place when calomel is treated with hydrochloric acid, giving corrosive sublimate.

- Replacement.
- Oxidation.
- Decomposition.
- Reduction.

23. A sample of the muscle of a fish was brought into the laboratory. With HCl it gave no reaction; with H_2SO_4 it turned black; with HNO_3 it turned yellow. What class of compounds did it belong to?

- Hydrocarbons.
- Carbohydrates.
- Esters.
- Proteins.

24. What is the volume at 23 degrees Centigrade of a quantity of a gas that at 73 degrees Centigrade occupies 7.5 liters?

- 6.4 liters.
- 6.0 liters.
- 5.4 liters.
- 5.0 liters.

Do the calculation in this space.

25. Opposite the chemical name given underline the one of the four common names which is that of the same substance.

Mercuric chloride

- Calomel.
- Epsom salts.
- Fool's gold.
- Corrosive sublimate.

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