THE VALUE OF LABORATORY WORK IN THE NATURAL SCIENCES FOR STUDENTS IN PROGRAMS OF GENERAL EDUCATION

by

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CHAPTER I

INTRODUCTION

General Education

Most of the current programs in higher education are either part of general or special education. While it would be relatively easy to give a definition for special education as essentially vocational training for the various professional and sub-professional occupations, it is quite another task to find an acceptable definition for general education. In its broadest sense general education could be defined as that part of a student's education which will help him to be an intelligent and responsible member of society. In a narrower sense general education has become a more definite and meaningful curriculum pattern in the several disciplines of learning and is receiving ever wider recognition and acceptance. General education, to still another group, has only a vague meaning which they associate with purely descriptive survey courses, hence some of the opposition to general education from both the special and the liberal arts education proponents (31, pp.51-57). Actually it need not be a choice between general and special education at all, but rather a recognition of the fact that present-day living requires both the breadth of a general education and the specialization which is almost necessary to vocational success in a complex technological age.

For those who look to liberal education as the solution, it might be pointed out that liberal education, per se, has lost its historical meaning in our modern society where most of its students will hardly enter a life of intellectual leisure as a separate class of free men. In practice, ironically, we find many of the liberal arts institutions competing in the fields of specialized studies. For the purpose of this discussion at least, though concurrence can readily be found, liberal education or at least its lower division portion will be taken to be coequal with general education or its modern extension to a society where freedom and an opportunity of an education are the prerogatives of all of its members. The general education movement could in a sense be looked upon as the swinging of the pendulum back towards unity from its recent position of extreme diversity under the elective system which accompanied the rise of special education.

General Education in the Natural Sciences

Narrowing the concept of general education down more specifically to the natural sciences it could be considered as the science education of the "non-scientist" or the general students who are interested in the natural sciences only to the extent of obtaining a more intelligent understanding of their natural environment and a cultural appreciation. The great advances of the natural sciences over the last few centuries and their ever-widening impact during the last few decades upon society as a whole would also seem to demand an ever better acquaintance on the part of its members with the natural sciences as part of their general education.

Earlier in this century it became apparent that most of the established single science courses, because of their professional emphases and lack of breadth, did not fulfill the needs of the general student. Many thought the answer was to be found in survey courses in each of the two branches of the natural sciences (31, pp. 56-57). With the great and ever-expanding body of knowledge represented by these two areas, the frequent attempts in survey courses to cover the whole field frequently resulted in a very superficial approach to the subject.

Recent trends indicate that the survey-type course is definitely on its way out and we find a number of other approaches gaining in favor, among them the historical and a more intensive and integrated study of selected topics, while others are working on adapting single science courses to the purposes of general education. With the course organization and topic selection left to individual institutions and instructors this has in effect led to many different programs which, however, may only be a natural concomitant of any new and experimental program. These courses are nearly all terminal in nature, however, and do not in themselves pose a serious problem except that high scholastic standards should remain the watchword for all of them. The numerous reports of symposia, colloquia, surveys, and bibliographies appearing in the literature by those engaged in teaching the physical sciences are proof of the existing interest in the problems of general education courses in the natural sciences. Many of these reports also point to the great need for more evaluation of these courses, which is especially difficult due to their broader aims and lesser emphasis on factual knowledge alone.

Laboratory Work in General Education Science Courses

If one were to single out the one most important factor which contributed to the great advance of the natural sciences over the last few centuries, it would likely be laboratory experimentation. It is, therefore, only reasonable that individual laboratory work is requisite to the training and education of all scientific workers. While it would be readily agreed that the education of the specialist and of the general student of science will differ greatly in some of its aspects, there needs to remain a common ground in their education if they are to be mutually helpful. It would seem that the laboratory, the wellspring of most scientific knowledge, might well provide this ideal common ground. Kruglak (39, p.184) states:

> I do not believe it is possible for a student to understand what science is like, what scientists are like, without some first-hand experience with the objects, tools, and methods of science used in the laboratory.

Most science teachers do agree that individual laboratory work is an essential part of any study of the natural sciences including programs of general education, and a majority of the institutions which offer these courses have laboratory work in conjunction with them (34, p.71).

The position of laboratory work in the training of scientific workers has already been stated and is not the subject of this study except for the observation that a reappraisal of the orthodox procedures is long overdue and steps to make it more meaningful and in keeping with the spirit of science have been taken by numerous workers as can be seen both from the literature and from personal observation. Has not laboratory work in many instances been relegated to just plain "busy work"? Some even refer to it as academic penalty. Certainly in many cases work is carried on with complete "cook book" instructions aimed at confirming already known facts with an often unwarranted stress for precision and under supervision of assistants who at times lack in interest and experience. While the described situation is by no means a fair representation of existing conditions, it is certainly also true that such laboratory work will be even less satisfactory to the needs of general education. All laboratory work should, whenever possible, allow for some spirit of inquiry and creativeness demanding both the powers of objective observation and logical reasoning.

Statement and Importance of Problem

Because the general education approach is a very recent trend as compared, for example, with liberal education, one might well question its present and future influence. Bullington (13, p.272) in answering for the natural sciences says: "General education science is rapidly occupying a position of importance in college curricula. It is growing in prevalence, popularity, and respectability."

Coupled with the fact that a majority of the institutions offering general education science courses have some form of laboratory work, as has already been stated, the place of the laboratory in general education becomes an important issue.

In the summary chapter of his work Science in General Education, McGrath (48, p.392) in discussing the laboratory says that

> One of the unanswered questions about science for students who do not expect to pursue a scientific career concerns the amount and kind of laboratory work they should have. Though there are some stout defenders of the idea that such instruction can be dispensed with in general education, the majority are of the contrary opinion.

Entrekin (27, p.276) in an article with the same title as McGrath's concurs, and in addition suggests some reasons for the omission of laboratory work at some institutions:

> The problem of laboratory work for general education in science is one on which there is a great divergence of opinion. In the majority of cases some type of laboratory work is offered. In many institutions where laboratory work is not included, it is the lack of physical facilities and staff rather than lack of belief in its importance that has been the determining factor.

A physical science work group of 29 representatives on the same problem of the place of the laboratory recommended as one of their proposals (29, p.181)

> That a study be made of the value of individual laboratory experience in attaining the objectives of science courses in general education as contrasted with the cost of setting up such facilities in terms of money, space, manpower, and time.

Kruglak (39, pp.197-202) states that "Evaluation studies on laboratory work in General Education are practically non-existent." In his summary he points also to the urgent need for experimental investigations on laboratory teaching and concludes that

> Until more valid information becomes available the quality of laboratory work will continue to reflect the moods and opinions of administrators and teachers rather than the needs of students.

The purpose of this study is to determine if individual laboratory work in the physical sciences contributes to the over-all aims of general education. For this purpose it is believed that the objectives for general education science courses formulated by the Science Committee of the Evaluation Study of the American Council on Education (33, pp.133-134) which are discussed in the next chapter are as good a summary of the aims as can be found and are, therefore, considered to be valid for this study.

CHAPTER II

DESIGN OF THE STUDY

Location and Subjects

The study was conducted during the 1953-54 school year at the Oregon College of Education in Monmouth and the Southern Oregon College of Education in Ashland. Both institutions can be considered to be representative state teachers colleges with regular school year enrollments of about five hundred or more students and with the majority of the students enrolled in elementary education. The reasons for conducting the study at two institutions were to increase the size of the sample and also to minimize the personal factors by having two different instructors at separate institutions.

The basis for this study was a course in the physical sciences which in the curricula of the institutions is considered to be an integral part of the general education program rather than part of the professional education (53, p.1). The course is described in the general catalog (54, p.58) of the Oregon College of Education as follows:

> Sc. 201,202,203. Foundations of Physical Science. 3 hours each term. A course in the elements of the branches of physical science, i.e., astronomy, chemistry, geology, meteorology, and physics. Study of the development of these fields from their earliest

historical beginnings to their present-day positions and effects on society. Particular emphasis is placed on the development of scientific attitudes. Two lectures; 1 two-hour laboratory period.

While the course is essentially an outgrowth of the earlier survey type approach, both instructors agreed on a more intensive rather than extensive emphasis by limiting the number of topics in each of the five branches and avoiding overlapping with geography and mathematics.

The guiding objectives used for this course may be divided into: (57, p.15)

A. General objectives

1. To acquaint the students with the true aims of scientific endeavor.

2. To show the interrelations of the various branches of physical science which will enable students to obtain a unified picture of their physical environment.

B. Specific objectives

1. To provide the fundamental background necessary to an understanding of the basic principles covered in the different branches of the physical sciences, an understanding which should lead to greater appreciation and enjoyment of their physical surroundings.

2. To provide an opportunity for students to work in an actual laboratory situation which will impress them with the need for objectivity, honesty, accuracy, and thoroughness, thus acquainting students first hand with the methods of the natural sciences.

During the summer of 1953 the respective instructors at the two institutions jointly planned the details for conducting the course. Agreement was reached in the selection of a text (15), a laboratory manual (58), audio-visual aids, and parallel lecture and laboratory assignment schedules for the whole course. Collateral reading in the current periodical literature was a regular part of course assignments. The students were also expected to perform during each term a laboratory project of their own selection. A more complete outline of course organization and laboratory work may be found in the literature (59). Personal visits by the writer, and correspondence between the instructors kept the programs at the two institutions as nearly parallel as possible. It should be pointed out, however, that certain differences did exist such as class sizes which were determined by individual teaching loads, and course examinations. Though agreement was reached in point of view on testing, each instructor constructed his own examinations for actual course performance evaluation, and only the two selected tests for the study were administered under identical conditions for pre-test and post-test differences.

In this study no attempt was made to evaluate the more tangible laboratory outcomes such as acquaintance with manipulative techniques, basic procedures, apparatus and equipment, because these are evident outcomes of any laboratory work as has been shown by several investigators. Nor were lecture demonstrations used in competition with individual laboratory work for it was felt by the instructors of the course that lecture demonstrations, though a very valuable supplement to a natural science course are not a substitute for individual laboratory work. This latter question has also been the subject of numerous other investigations.

A majority of the students also were taking concurrently or had already completed a course in Biological Science Survey. A smaller percentage had also completed a one term course in Foundations of Mathematics. These differences plus those of their high school backgrounds and mental abilities are some of the variables which were not taken as factors into the study. From the data obtained on the backgrounds of these students, however, it can be said that the groups were a fairly representative cross section of students found in general education science courses.

It was also decided to bring a third institution, Oregon State College, at Corvallis, into the study for comparison but not in a parallel participating manner with the other two institutions. The equivalent course, entitled Physical Science Survey, is offered at Oregon State College under a different course number, GS 104-6. It carries four hours credit each term and has a different laboratory program. However, the same text was used, with a similar assignment schedule, and the same pre- and post-testing program as at the other two institutions was carried on.

For a further and more complete description of the student groups see Table I.

Procedures

Section assignment and testing.

At registration time during the fall term all students registering in the course signed up for one of the regularly scheduled lecture sections and were assigned to corresponding laboratory periods. The choice of lecture section was determined in the usual manner of coordinating the students' programs so as to avoid schedule conflicts and with the usual attempts to balance the sections. About 100 students thus were signed up at registration time at each of the two cooperating institutions.

During the first week of classes none of the laboratory sections met and all students took the two selected tests as part of the pre-testing program during the first two regular lecture periods. After the tests were concluded but before processing them the instructor met with

TABLE I

DESCRIPTION OF STUDENT GROUPS

	OCE		SOCE		OSC
	Lab.	Lect.	Lab.	Lect.	
N	22	29	24	37	29
Sex					
M	27.3	41.4	37.5	45.9	34.5
F	72.7	58.6	62.5	54.1	65.5
Class					
Fresh.	22.7	17.2	70.8	70.3	20.7
Soph.	68.2	65.5	12.5	21.6	51.7
Other	9.1	17.3	16.7	8.1	27.6
Ed. Major	90.9	96.6	91.7	86.5	62.1
Course GPA	2.17	2.23	2.28	2.29	2.87
N*	22	26	23	34	27
ACE Dec. Av.	6	6.5	4.4	4.8	5.6**

Figures for sex, class and major are per cent.
*Number for which ACE information was available.
**Figure for OSC not comparable to others as explained in Chapter IV.

the Coordinator of Instruction to determine by the toss of a coin which of the two lecture sections was to have the regular laboratory program while the other would have a lecture period in its place.

The classes in each institution were then conducted throughout the year in as similar a manner as possible as previously outlined. All of the regularly enrolled students took the post-tests during the last week of the spring term. The losses from the original enrollment to the final figures given in the study were due to a number of causes such as students dropping the course, withdrawing from school, needing only one or two terms to complete the sequence, or in a few unavoidable cases changing sections, but by far the largest loss was due to a terminating three-year program in elementary education in the state for which only one term of the sequence was required. Only the results of those students who completed the year's program in their respective sections were used in the study.

Selection of objectives and tests.

Because of the greater diversity in general education science courses between institutions, their evaluation is more difficult than is the case with specialized science courses which are much more uniformly conducted and for which national professional groups have established standardized tests.

Certainly the selection of appropriate aims or objectives must precede the choice of any evaluating instruments. At this point one can either use a list of objectives from personal experience, philosophy, and local circumstances as has already been given, or look about for recognized established lists which are the result of considered composite opinion of experienced workers in the field. It was felt that the latter approach would be the more widely acceptable solution. As one searches the literature for established lists, one finds that some of the basic works on general education such as the Report of the Harvard Committee (31), the Report of the President's Commission on Higher Education (69), the Yearbook on General Education by the National Society for the Study of Education (50), and the more recent and specific work on General Education in Science (16) do not have any concise statement of objectives. Bullington (13, pp.269-270) found from his very comprehensive survey that about 75 different objectives were in use by the 720 institutions investigated, which he grouped into seven categories. McGrath (48, pp.386-391) in his volume on 22 general education science programs at as many different institutions found that most institutions had a list of about eight or ten objectives but that most of them could be classified under a few major headings. From his discussion, also, one can discern about seven.

The Science Committee of the Evaluation Study of the American Council on Education, in attempting to arrive at specific objectives for general education science courses, presented the following list to a group of some thirty teachers in the field at a Conference on General Education (33, pp.133-134).

To develop in the students:

1. Knowledge of facts, laws and principles in the body of subject matter studied.

2. Ability to apply the science knowledge he possesses to new problems and situations.

3. Ability to analyze scientific data summarized in maps, tables, curves, charts, graphs.

4. Ability to recognize the need for additional scientific knowledge in a new situation, and the ability to acquire it.

5. Understanding the point of view with which a scientist approaches his problems, and the kinds of things that he does.

6. Ability to read and evaluate popular writing on scientific developments.

7. Willingness to face facts, to revise judgments and to change behavior in the light of appropriate evidence.

8. Understanding the role--development, importance and limitations--of science in the modern world.

This list which is representative of the current trend and was also compatible with the existent programs at the two institutions of the study was therefore considered to be valid for the purposes of this study.

The writer feels that the contributions of individual laboratory work to the above objectives may be found in the following manifestations:

1. A knowledge of facts, etc., more firmly fixed by the opportunity of experiencing concrete illustrations in the laboratory.
2. A real opportunity to apply the science knowledge in the laboratory in the performance of the regular assigned experiments and the special student-planned experiments performed during each term.
3. A real opportunity to analyze scientific data summarized in maps, tables, curves, charts, and graphs not only by the actual interpretative use of existent materials but also by constructing some of these devices on the basis of experimental data.
4. A possibly better recognition of the need for additional scientific knowledge and the

abilities and methods for acquiring it.

5. A real understanding of the point of view with which a scientist approaches his problems in the performance of laboratory experiments which require periodic decisions by the student, and certainly of the kinds of things he does.
6. An enhanced ability to read and evaluate popular writing on scientific developments by an operational acquaintance with some of the basic units, terms, tools, and procedures of the practicing scientist.
7. An opportunity to encounter laboratory situations which will require making decisions on the basis of experimental facts and not just routinely confirming already known facts.
8. A better understanding of the role of science in the modern world on the basis of personal discovery of at least some of the elements involved in scientific development.

The directions for the laboratory experiments used in this study were thought to represent an approach which would aid in the development of student achievements in accordance with the listed objectives.

The next step, obtaining a test or tests for the evaluation of these objectives also resolves itself either in constructing such instruments or selecting from available standardized tests, and again it was felt that the latter course, if possible, would be much more generally acceptable. For this purpose a search of available tests from testing organizations, publishing houses, and professional organizations was made. At this time it came to the writer's attention that some tests had just been released by the Cooperative Study of Evaluation in General Education of the American Council on Education. This series was entitled A Test of Science Reasoning and Understanding, and had been in use for a special study by a group of 22 colleges which were selected partly on the basis of being fairly well representative of American Higher Education (3, p.VI). Speaking of the committees working on the tests in this series, Mayhew (46, p.115) says that "This combination of teacher and evaluator has produced test materials which are respectable from a technical standpoint and acceptable to teachers."

Form A--Physical Sciences was selected from this group of tests as best suited for this study. Efforts to obtain complete information including item analysis were unsuccessful though the latter is of no great importance as no change in the test was contemplated. Some data pertaining to the reliability and validity of the test were found in the Instructor's Manual (4, pp.8,12). The Reliability Estimate with the Kuder-Richardson Test for pre-testing with 439 freshmen had an r value of .71. Under validity the relationship of this test with the ACE Psychological Examination was given among other tests with the following results:

CORRELATION COEFFICIENTS

	No. of Colleges	No. of Students	Correlation Lowest	Correlation Highest	Correlation Average*
Pre-Test (Fall, 1951)	8	1,010	.37	.74	.56
Post-Test (Spring, 1952)	5	864	.37	.62	.42

*Averages were computed by means of the Z transformation

Study No. 7 given in the Final Report of the Cooperative Study of Evaluation in General Education of the American Council on Education (5, pp.132-133) is of interest because it shows the influence of a biological science course background. The summary of this study is here repeated.

> At one college the Test of Science Reasoning and Understanding in Physical and Biological Science was used with both the biological and physical science courses over the same year period. Both groups made significant gains on both tests, but the gain made in each course on the test related to that area was significantly higher than that in the other course. The indication is clearly that achievement of the objectives of science reasoning and understanding

> involve both knowledge of or familiarity with the material and ability to reason in it.

The selected test was a 45 minute multiple choice test consisting of 55 questions which are based on five reading selections from the different areas of the physical sciences. The problems in these selections were as follows:

1. Carolina Bays - 13 questions
2. Cloud Seeding - 13 questions
3. "Freon 21" - 12 questions
4. Heat Theories - 12 questions
5. Space Travel - 5 questions

This test and the others in this series having been devised by the same organization which compiled the list of objectives adopted for this study was, of course, especially designed to evaluate these objectives. The emphasis of these tests is pointed out in their description (4, p.4):

> The Tests of Science Reasoning and Understanding are designed to measure the extent to which students can
>
> 1. apply science knowledge to new problems and situations.
>
> 2. read and evaluate news articles and popular writings on scientific developments.
>
> 3. understand the point of view with which a scientist approaches his problems, and the kind of things he does.

This particular group of criteria was decided upon because it was felt that they would measure the outcomes in terms of the objectives of general education with the exception of the factual content matter of the course which is quite variable and for which other tests are commercially available. With this background of information in mind a second test was selected to measure this latter outcome which covers then, in particular, the first and only remaining of the eight stated objectives. This second test is one of the Cooperative Tests entitled _A Test of General Proficiency in the Field of the Natural Sciences._

Form Y of this latter test was used in the fall and the alternate Form Z in the spring. These tests cover for the greatest part the physical sciences and are divided into two parts as follows:

I	Terms and Concepts	15 minutes
II	Comprehension and Interpretation	25 minutes

For the former _Test of Science Reasoning and Understanding_ Form A was used at both times as no alternate forms were available, but in a personal communication (47) from the Assistant Director of the Cooperative Study of Evaluation in General Education of the American Council on Education he stated: "Our own experience, however, provides us with assurance necessary to use the same form on a pre-test and on a post-test basis. The same form practice effect is minimal."

All forms of the tests used are appended to this study.

Limitations

In summary it should be pointed out that either by design or by existent conditions this study was delimited in the following respects:

1. It attempted to evaluate only the contributions of individual laboratory work to the objectives of general education science courses accepted for this study.
    a. It did not attempt to evaluate the more tangible outcomes of individual laboratory work such as acquaintance with basic scientific equipment and techniques.
    b. It did not attempt to evaluate the contributions of lecture demonstrations.
2. The differences in scholastic background and abilities of the students were not subject to control.
3. The overall number of students included in the study presents a limitation in the size of the sample.

4. The laboratory and lecture groups may not have been entirely commensurable due to inherent scheduling procedures.
5. It was not feasible to keep the size of the lecture sections at the two institutions constant.
6. The selected instruments may not have been a true measure of the desired outcomes.
7. The fact that only two instructors with their particular personalities and teaching methods took part in the study imposes a limitation.
8. The geographical separation of the institutions at which the study was conducted prevented more frequent consultation.

CHAPTER III

RELATED STUDIES

The earliest records of man's inquiry into his natural environment show the association of natural philosophy with the observable and experimental. The Greek word physis meaning nature referred to the observable phenomena of the environment as opposed to the metaphysical. The very growth of this branch of knowledge from its beginnings in Greece and in Alexandria, where evidence has even been found of the existence of student laboratories under the Ptolemies in the third century B. C., to the present is closely associated with experimental inquiry.

During the Scholastic Period when reliance was placed on the authority of established knowledge, almost no progress was made except for some work in human anatomy under secular direction (73, p.494).

The great advance since the Renaissance is clearly associated with the experimental approach, in fact one of the greatest exponents of this period, Leonardo Da Vinci, (45, p.428) stated it clearly when he said:

> In treating any particular subject I would first of all make some experiments, because my design is first to refer to experiments

> and then to demonstrate why bodies are constrained to act in such manner. This is the method we ought to follow in investigating the phenomena of nature.

Practically no laboratory work accompanied early science teaching in this country when the sciences were a part of natural philosophy and the technical aspects of the natural sciences were not even considered dignified enough to be included in the liberal arts curriculum.

In 1768 James Smith was appointed the first professor of chemistry and materia medica at the College of the Province of New York later Columbia College (74, p.76). John Maclean is believed to have established the first chemical laboratory for under-graduate instruction soon after his appointment at Princeton in 1795 (60, p.5120). Though there were several other institutions which attempted student laboratory work earlier, it was not until the latter part of the 19th century that individual laboratory work became firmly established.

This latter success was partly due to the establishment of new technical schools such as the Massachusetts Institute of Technology in 1861, and of special scientific schools at already established institutions. The passage of the Morrill Act in 1862 for the promotion of agriculture and the mechanical arts, the founding of scientific organizations such as the American Chemical Society in 1876, and the inspiration of such great teachers as Louis Agassiz further contributed to this success.

From the time of general acceptance of individual laboratory work to the present, few attempts have been made at the college level to evaluate its effectiveness.

Today dissatisfaction is quite general and Cruickshank (19, p.15) expresses it thus:

> The general practice in the universities at present is to follow orthodox procedure that has come down unchanged in essentials since the institution of teaching laboratories just prior to 1870. With its standardized experiments, laboratory manuals, and general dullness, this method is too familiar to need description.

Studies on laboratory methods in the natural sciences on the secondary level were made earlier and are also more numerous than at the college level but this discussion will limit itself primarily to papers on the college level.

No record was found in the literature of a prior experimental study of the contributions to the objectives of general education made by laboratory work in an integrated physical science course. A number of studies in the separate branches of the natural sciences have been reported and inasmuch as they are an integral part of general education courses, though with different emphases, they are of interest.

A few papers though not in the nature of actual experimental studies are included in the following chronological account because it was felt that their pertinence aids in presenting a more complete picture of the laboratory situation.

Colton (17) in 1921-22 appears to have made one of the earliest recorded studies of natural science laboratory methods. A group of 96 pre-medical students enrolled in a zoology course at the University of Pennsylvania were divided into two groups, one of which received intensive laboratory work for training while the other received extensive laboratory work for information purposes. An especially constructed test showed no significant differences between the two methods and Colton concluded that instructors should have their own choice of laboratory methods.

Bowers (10) in 1924 with much smaller groups of elementary chemistry students at the State Teachers College in Colorado tried to show that laboratory work aids in "fastening" information. With two sets of questions, one on material presented only in the text, and the other also covered by laboratory work, he showed that as time passed the retention was much greater with the latter questions.

Hurd (35) in the period from 1926 to 1928 conducted a number of studies in the Medical School and the

Department of Physics at the University of Minnesota. He found no differences in achievement in a human anatomy class if two or four students worked on a single cadaver. With a class in human physiology he found that an increased amount of laboratory work showed superior achievement which could not be equaled by less laboratory work and an equal number of hours in the library. From his studies with physics students it is of interest to note that he found raised achievement with items associated with laboratory activities; however no evidence was found for other class activities. He (35, p.184) also stated that no valid criteria for pairing students for experimental work were found.

At about the same time Noll (51) conducted some studies at the University of Minnesota in the teaching of chemistry. In regard to the effectiveness of laboratory work he, too, found that general achievement consistently increased with the amount of time spent in the laboratory though the differences were not very significant.

Payne (55) reported in 1932 on a study on the relative values of lecture demonstrations versus individual laboratory work with first year college chemistry students at Transylvania and three other colleges, which indicated better progress with the demonstration method, but he also states that the study did not produce uniformly significant results.

Duel (25) in another physics study at the University of Minnesota from 1930 to 1934 on the measurable outcomes of laboratory work for one term of mechanics, found no statistically significant differences in achievement or scientific aptitude between the groups having two hours of laboratory work per week and those having no laboratory. The manipulative skills of the laboratory groups were of no value in subsequent terms.

Barger (8) reported in 1935 on a variation of the lecture demonstration method called the class participation method which he claimed to have used successfully since 1915 and for which he claimed superiority in regard to information and its retention.

Havighurst (32) in 1935 made one of the early references to survey courses in the natural sciences and reported their increased use and that most of them were only a few years old, with many of them having been given for the first time during 1935.

Schlesinger (65) of the University of Chicago staff, one of the pioneering institutions in the field of general education, in a contribution to a symposium on lecture demonstrations versus individual laboratory work of the American Chemical Society at its eighty-ninth meeting in 1935 recommended the use of individual laboratory work for students in general education who deserve every possible aid in learning to see, to think, and to act. He further stated that with these functions as the chief aims for both future specialists and students of general education "it would never be supposed that lecture demonstrations can be anything but a poor substitute for individual laboratory exercises."

Elder (26) in another report from the same symposium, however, stated that the lecture-demonstration method was well suited for students whose interests were not in the sciences. In his conclusions he stated the need for experimental studies.

Cooke (18) in 1938 suggested another intermediate answer to the controversy of lecture-demonstration versus individual laboratory work by describing a laboratory procedure with pupil demonstration.

Rosenbaum (64, p.568) described in 1939 some specific experiments for a physical science general course and stated that

> Within recent years the development of new general ("survey") courses in the physical sciences has brought with it many problems, among which is the question of laboratory work. Although many institutions have evaded this problem, there is general agreement that some sort of laboratory work is highly desirable, for otherwise students memorize definitions and generalizations without adequate recognition of their observational background.

Adams (1) in 1942 reviewed the work by Sheerar on objectives of general chemistry laboratory work and a two-year investigation by E. O. Smith into the relative advantages of the individual laboratory and the demonstration methods as measured by laboratory performance examinations. Unfortunately the monograph containing the original articles was found to be unavailable but summaries of these two studies from the review by Adams follow.

Sheerar in replies from 94 institutions in 38 states found better than 66% approval and thus acceptance of the following proposed objectives:

Chemistry laboratory instruction should:

a. develop the ability to make observations, interpret and draw conclusions from observed facts,

b. develop the ability to use simple scientific instruments and manipulative apparatus,

c. develop the ability to keep a record and write a satisfactory report,

d. develop the attitude of drawing conclusions only from observable or accepted data,

e. develop the habits of accuracy, honesty, self-reliance, cleanliness, and orderliness in the laboratory,

f. satisfy the student's curiosity and provide experience to develop latent interests,

g. provide opportunity for instruction.

Substantial agreement with the above objectives is indicated by an even more extensive survey conducted by Adams himself.

E. O. Smith felt that the usual paper-and-pencil tests do not measure laboratory achievement and therefore fail to indicate any marked differences between the different methods of teaching. He found that in laboratory performance tests the students having had individual laboratory work perform consistently better.

Thomas (68, p.379) in 1943 made some suggestions for the improvement of laboratory work in chemistry to keep it more nearly in the spirit of the scientific method by:

a. including an unknown whenever possible.
b. avoiding detailed directions.
c. segregating questions of background and experimental results.
d. not giving results of experiments in advance.
e. utilizing results for further work.

Stewart (67) in 1945 discussed the need for creative experiences in general education and illustrated how it could be met with an experiment in physics.

Roller (63, pp.390-391) in a Colloquium of College Physicists at the State University of Iowa in 1946 gave a list of "Some essential features and uncommon objectives of a physical science course for the general student":

1. General education courses should be especially designed for that purpose.
2. The physical sciences are so important in our culture that they should be included from kindergarten to college.
3. Physics is the most logical choice as a core for such a course.
4. The course should be selective--analytic in approach and not comprehensive--descriptive.
5. Genuine and especially designed individual laboratory work should form an integral part of the course.

In 1946, Cunningham (20) in one of the most recent reviews of studies on the problem of "Lecture Demonstrations versus Individual Laboratory Method in Science Teaching" summarized that for immediate results the demonstration method is superior while for delayed results the individual laboratory method had a slight advantage.

Rogers (61, p. 81) in 1947 again expressed the existing dissatisfaction with laboratory work when he stated that "We need to make of our laboratory, through our attitude and the student's, a place of scientific work--not an intellectual housing slum.

Washton (72, p. 288) reported in 1948 on a survey of liberal arts colleges in which he found that nearly half had science survey type courses with the majority having no laboratory work and concludes "Individualized laboratory work is costly and no one has been able to substantiate all the worthy claims that are supposed to result from laboratory instruction."

Ahman (2) reported in 1949 on an experiment conducted at Iowa State College in 1946 during the immediate post-war period when that institution was forced to conduct some of their chemistry classes off campus at Camp Dodge. Because the physical facilities at these two locations were quite different, an experimental situation was set up for inorganic chemistry where on campus the usual program was carried on of two 1-hour lectures, two 1-hour recitations, and one 3-hour laboratory period while at Camp Dodge a combination recitation-laboratory method of three 2-hour periods per week was tried. The students enrolled in this course were freshman engineering students. Though the students on the main campus under the regular program were slightly ahead in achievement, the difference was not statistically significant and the institution found many desirable features associated with the experimental program.

Rogers (62, p.604) in 1949 in a discussion of general education science courses which included his proposal of a Block-and-Gap Scheme of presentation of subject matter also made this statement:

> Preaching at students a unique scientific method (devised by Francis Bacon) gives a stultified picture of scientific procedure which they may rightly reject as unreal. We should do better to have them find that science uses a variety of apparatus and techniques and then see that a problem can be investigated from several points of view--thus finding, in these senses, many scientific methods.

Sorum (66, p.4168) in 1950 in discussing the implementations of a report by a special Committee on the Teaching of Science and Mathematics composed of seventeen scientific and educational organizations in cooperation with the American Association for the Advancement of Science cites point 8 as follows:

> It is urged that men in the scientific profession--whether it be medicine, agriculture, engineering, or industrial chemistry--insist that in their communities science be taught as a laboratory science.

While this recommendation is obviously aimed at the public schools, it would be difficult to imagine that it applies the less to college general education science courses.

Bullington (12) in 1950 sampled student opinion of nearly 300 college freshmen at two liberal arts institutions, one without laboratory work and the other with laboratory work during alternate weeks. Eighty per cent of the latter group expressed themselves that they would like the same or more laboratory time, while slightly over sixty per cent of the former group felt that laboratory work should be introduced.

Curtis (22), one of the better-known authorities of the country on science education, in a brief review of the subject in 1950 made a plea for the retention of individual laboratory work. He pointed out that the studies were too few with the number of subjects too small and treatment inadequate in most cases to be convincing of the purported values of the demonstration method.

Bullington (14) in 1951 in a comprehensive questionnaire survey on general education science courses already referred to, pointed out the increased use of laboratory work from 25-41% in the thirties to 68% and even higher for teachers colleges. He also reported 22 students as median size for science laboratory sections.

Entrikin (27) reported in 1951 on a visitation trip made possible by a Carnegie Foundation grant which enabled him to confer with teachers at more than fifty institutions of higher learning, and from his observations listed as the three outstanding problems those of securing good teachers, the question of laboratory work, and methods of evaluation.

Kruglak (42) of the University of Minnesota in the first of a series of papers on laboratory teaching in physics presented in 1951 a list of behavior objectives for laboratory instruction. He grouped these into six major categories as follows:

I. Instrumental Skills

II. Skills in the use of controlled experiments

III. Problem-solving skills

IV. Miscellaneous skills

V. Functional understanding of principles.

Wall, Kruglak, and Trainor (71) reported in 1951 on some work with laboratory performance tests in physics for which they found a better spread of grades, motivation, and measurement of instructional outcomes than with the usual paper-and-pencil tests.

Barbour (7, p.566) in 1952 discussed the subject of integration as an objective for general education physical science courses. He listed the following aims for the course at Kalamazoo College which included laboratory work:

1. Understanding of some of the important facts and principles upon which modern science rests.
2. Insight into some of the basic methods used in scientific investigation:
    a. Experience in observation, particularly the "controlled experiment."
    b. Experience in critical thinking and logical analysis.
    c. Appreciation of the way in which science has developed.
3. Insight into the relation between science and other areas of life.

Cohen and Watson (16) in 1952 edited the papers presented at a Workshop in Science in General Education held at Harvard University during the summer of 1950. Included are some reports on the experimental programs in general education at Harvard University which consisted of five lower level courses, four in the physical and one in the biological sciences, on which reports had previously been released. In addition to these lower division courses several general education science courses for upperclassmen at a "Second Level" are briefly described.

Kruglak (38), in another study in 1952 compared the individual laboratory method with the demonstration method with a group of non-technical students in mechanics and found no statistically significant differences between the two methods except with laboratory performance tests. In extending this study to students without laboratory work Kruglak (37) obtained essentially the same results of no statistically significant differences in tests on theory but significant differences on laboratory tests.

Morrell (49, p.80) in a paper presented at the 122nd Meeting of the American Chemical Society in 1952 spoke of the increase in interdepartmental science courses for general education purposes and stated that such courses need not be superficial. He illustrated his statement by describing the course at the University of Illinois.

Perlman (56) reported in 1953 on a study of the advantages of a contemporary problem solving method over an historical approach and concluded that laboratory can be used to advantage in general education physical science courses at the college level without loss of subject matter achievement. He also found no difference between the problem solving and the lecture-demonstration methods.

Kruglak and Carlson (43) reported in 1953 on one of their studies on performance tests in physics in which they found that the groups with laboratory work were superior to the no-laboratory group in tests dealing specifically with laboratory material, but no differences were observed in tests on theory. They also found the conventional laboratory method superior to the demonstration method and recognized some instructor differences under certain conditions. Their conclusions were that probably written tests are not a substitute for actual performance tests and that further refinement of the measuring instruments was needed.

Blick (9) reported in 1953 on a study conducted at the University of Connecticut over a period of three years using three different schedule patterns in teaching general chemistry. He found the commonly used two one-hour lecture periods, one one-hour recitation, and one three-hour laboratory period per week superior to programs having either more lecture or more laboratory periods with the same total number of credit hours for the course.

Henshaw (34, pp. 74-75) reported in 1953 at the Annual Meeting of the American Association of Physics Teachers on his personal observations at 16 institutions and catalog reference to 13 additional liberal arts colleges on the status of laboratory teaching in general education courses. He discussed at length the arguments for and against laboratory work as presented to him and concluded that

> ...he is convinced that there are now good general education science courses taught without laboratory, but few would not be improved with the introduction of a limited number of carefully designed laboratory activities. Ideally, it seems, such activities will contribute most to common objectives of general education:
>
> 1. When they deal, as often as possible with relations or problem situations for which the student does not know the answer in advance.
>
> 2. When they call for as much planning, initiative, and creative thinking as possible on the part of the student, that is, to provide him an opportunity to <u>experiment</u> in the true sense of the word.
>
> 3. When they are integrated as well as possible with the objectives and subject matter of the course.
>
> 4. When they are carried on in an atmosphere in which curiosity is the motivation, rather than academic penalty.
>
> 5. When they are conducted by experienced teachers who are in sympathy with the

> aims of general education and have a sincere interest in developing mature minds.

Van Deventer (70) in 1953 examined the whole meaning of "laboratory" and again pointed out that many existing programs have laboratory work in name only while violating the basic precepts of the meaning of the term. He recognized three approaches to laboratory teaching:

1. Repetition of classical experiments
2. Case Study method
3. Problem approach.

He suggested a combination of these by what he called "The Problem-Area Approach" which he described and illustrated in detail.

In his summary (70, p.171) he stated:

> The use of the usual substitutes for individual laboratory work in general courses, particularly in the form of audio-visual aids and demonstrations, while they are very effective as teaching tools, does not really furnish an answer to the laboratory question.

Frank (28, p.14) in speaking on science education in 1954, and including both majors and non-majors said:

> One of the great dangers of teaching experimental sciences without laboratory experiences is that of unwittingly creating in a student's mind the notion that science is essentially deductive in nature.

Brown (11) observed in 1954 from a personal survey of elementary laboratory instruction in universities of England that English students spend more than twice as much time in the laboratory as American students do.

Kruglak (40,41) in three papers during 1954-55 on the measurement of laboratory achievement in general college physics by performance tests and by paper-pencil laboratory achievement tests found though the latter measured elements other than conventional achievement criteria, they had few elements in common with laboratory performance tests.

CHAPTER IV

TESTS AND TREATMENT OF DATA

Tabulation of Data

The purpose of this study is to compare two methods of teaching an integrated general education course in the physical sciences. One method includes individual laboratory work while the other does not. The contributions of the individual laboratory work to the aims of general education are to be determined by means of statistical analysis of the test data from these two different teaching methods.

The aims or objectives adopted from the Science Committee of the Evaluation Study of the American Council on Education were set forth in the second chapter as well as the selection of the tests for their evaluation and some information about them.

The tests selected were:

1. A Test of Science Reasoning and Understanding
2. A Test of General Proficiency in the Field of the Natural Sciences.

Future references to these two tests will be made simply by identifying them as the Reasoning and Proficiency Tests respectively. Both tests, or alternate forms thereof were administered on a pre- and post-course basis and the results of student performances will be found in Tables II and III.

Some of the observations that can be made from these tables are that with the Proficiency Test a small though not significant difference in the median gains favors the lecture over the laboratory groups. The mean gains, on the other hand, show no consistent difference between these same two groups.

The median gains for the Reasoning Test are the same for all of the groups while the mean gains again show no consistent difference between the laboratory and lecture groups. It is worth noting that the weighted average of 3.85 for the mean gains with the Reasoning Test for the four experimental groups compares favorably with the mean gain of 3.37, the available value (5, p.128), for 790 students of six colleges.

The generally superior performance of the Oregon State College student group is of interest though not unexpected when one considers that this group had a program totalling twelve hours of credit for the three terms as compared with only nine credit hours at the other two institutions. In addition if the decile rank average of 5.6 for the students of Oregon State College, a regular four-year college, were compared in the Norms Bulletin (6, p.17) with that of teachers colleges for

TABLE II

PROFICIENCY TEST PERFORMANCE

	OCE		SOCE		OSC
	Lab.	Lect.	Lab.	Lect.	
N	22	29	24	37	29
Pre-test					
Range	21-66	14-62	8-62	8-54	17-56
Med.	35	35	30	31	38
Mean	36.91	38.69	32.29	30.30	38.21
Post-test					
Range	28-70	7-68	0-76	4-73	33-69
Med.	41	43	38	36	47
Mean	44.14	44.79	39.12	37.62	47.17
Gain					
Med.	6.5	7	5.5	7	9
Mean	7.23	6.10	6.83	7.32	8.97
S.D.	8.82	6.96	12.10	10.00	7.86
S.E.	1.92	1.31	2.52	1.67	1.48

All figures are based on raw scores

TABLE III

REASONING TEST PERFORMANCE

	OCE		SOCE		OSC
	Lab.	Lect.	Lab.	Lect.	
N	22	29	24	37	29
Pre-test					
Range	11-38	14-43	11-33	4-39	12-35
Med.	23	26	20	21	24
Mean	23.41	25.62	20.62	21.11	23.72
Post-test					
Range	12-46	17-46	13-44	11-43	18-39
Med.	28	30	23.5	25	29
Mean	27.95	29.21	23.92	25.11	28.41
Gain					
Med.	4	4	4	4	4
Mean	4.55	3.59	3.30	4.00	4.69
S.D.	4.00	5.91	6.26	4.97	4.47
S.E.	0.87	1.12	1.31	0.83	0.85

All figures are based on number of right answers the other two institutions it would be equivalent to 6.8 or the highest for all groups. There are, of course, other factors which might affect these results either way, such as the differences in the amount and kind of laboratory work, and the course performance evaluation at Oregon State College as compared with the other two institutions.

The relatively large values for the standard deviation of the mean gains for the groups and their differences between the groups point toward a considerable variability in the sample population. In three out of four cases the greater standard deviation of test gains by the laboratory groups confirms the previous findings by Johnson (21, p.101) and others which they explained to mean that individual laboratory work provides a greater opportunity for expression of individual differences.

With the Proficiency Test the laboratory groups indicate a consistent and greater variability as shown by the greater standard deviation. This difference, however, is not consistent for the Reasoning Test, which might be construed to mean that the Proficiency Test was a better instrument for bringing out the differences in performance brought about by the different teaching methods.

No correlations between the American Council on Education Psychological Examination Total Scores and the two tests used were made because the ACE scores were not available for all of the students. It has been found (44), however, that the ACE scores show only a moderate degree of correlation with achievement. The available correlation coefficient values for the Reasoning Test with the ACE Psychological Examination cited on page 21 of Chapter II are comparable with those of other studies.

In correlating the gains of the Proficiency and the Reasoning Tests with each other, i.e. Inter-Test Correlation for all of the groups, no significant correlation in attainment was found which would indicate that the two tests were independent measures of achievement.

The actual values for r, the Inter-Test correlation coefficient, were calculated from the original data according to Pearson's equation (30, p.159) for the product-moment coefficient of correlation.

TABLE IV

CORRELATIONS OF PROFICIENCY AND REASONING TEST GAINS

	r
OCE	
Laboratory Group	.008
Lecture Group	.077
SOCE	
Laboratory Group	.158
Lecture Group	.018
OSC	.018

Statistical Analysis of Data

The main purpose of this study is to determine if significant differences in performance exist between the laboratory and lecture groups. For this particular purpose the tests of hypotheses concerning the variances and means of two populations are well suited and were therefore selected.

The procedures used follow in outline the suggestions set forth by Dixon and Massey (23, pp. 88, 101). The tables of t-values and F distribution in the appendices of this same work were also used for the purposes of this study.

In the test for population variance the calculated F value from the ratio of the actual sample variances was compared with the F distribution in tables for the appropriate number of degrees of freedom and a given level of significance. After the first hypothesis that the two population variances are equal, i.e., the actual value falls within the limits of pre-determined critical regions, had been established the t-test for the hypothesis of equal population means was next used. If in this second test the calculated t-value falls within the limits set by the number of degrees of freedom and chosen significance level the hypothesis is confirmed and the two population means are considered to be equal and no significant differences between the two compared groups exist. For both the F and t-tests the five per cent levels of significance were selected and the necessary interpolation made, which seemed justified as none of the values seemed critical enough to require greater accuracy.

The results for the experimental laboratory and lecture groups for both the Proficiency and Reasoning Tests are shown in Table V.

TABLE V

COMPARISON OF LABORATORY AND LECTURE GROUPS

	Proficiency Test F	Proficiency Test t	Reasoning Test F	Reasoning Test t
OCE				
Experimental	1.61	0.51	2.18	0.66
Critical Region	±2.22	±2.01	±2.33	±2.01
SOCE				
Experimental	1.46	-0.17	1.59	-0.49
Critical Region	±2.08	±2.00	±2.08	±2.00

The distributions of the Population Variance (F) and Population Means (t) are both at the 5% significance level.

For additional information the hypotheses were also tested for the Oregon State College group and the Oregon College of Education laboratory and lecture groups and these results are shown in Table VI.

TABLE VI

COMPARISON OF OCE AND OSC GROUPS

	Proficiency Test F	Proficiency Test t	Reasoning Test F	Reasoning Test t
OSC-OCE Lab.				
Experimental	1.26	-0.74	1.25	-0.12
Critical Region	±2.22	±2.01	±2.33	±2.01
OSC-OCE Lect.				
Experimental	1.28	-1.47	1.74	-0.80
Critical Region	±2.13	±2.00	±2.13	±2.00

The distributions of the Population Variance (F) and Population Means (t) are both at the 5% significance level.

Results

From the statistical results in these last two tables it can be seen that for all of the groups compared the first hypothesis, that the two population variances are equal, can be accepted and, furthermore, that for all of the groups compared the second hypothesis, that the two population means are equal, can also be accepted. This in effect then means that no significant differences in performance of the compared groups existed as measured under the described conditions.

CHAPTER V

CONCLUSIONS AND IMPLICATIONS

The purpose of this study was to determine if individual laboratory work as part of an integrated course in the natural sciences contributes to the objectives of general education. Students enrolled in a course in the Foundations of Physical Science at two institutions of the Oregon State System of Higher Education were divided into equal sections with and without laboratory work and were pre- and post-tested with Proficiency and Reasoning Tests for differences in gains under the two methods. The two methods of teaching were then compared by statistical analysis using the F-test for population variance and the t-test for significance of population means.

The inescapable conclusion from the results of this study is that no significant differences exist between the student groups having individual laboratory work and those without it. The very absence of any definite trends in the results, however, would make one question in retrospect the suitability of the testing instruments employed in spite of the fact that on prior examination the two tests seemed eminently well suited to the purpose for which they were used.

Kruglak (40,41) and others in their studies have found that it is difficult to evaluate the outcome of laboratory work and that too frequently the problem resolves itself to an evaluation of either acquired facts or techniques neither of which do full justice to the contributions of individual laboratory work.

With the Reasoning Test in particular, another approach to the problem was attempted, but it certainly appears questionable if there is any transfer from the laboratory situations requiring thoughtful attention and reasoning to other areas of reasoning and understanding. The results of this study, though inconclusive, are in line with those of other workers (25, p.809; 52, p.300; 55, p.1293). Noll (52, p.300), one of these workers, in reviewing the results of a number of studies on both the secondary and the college level concludes:

> The results of these studies agree very well in that none of them report any very reliable differences between the achievements of groups taught by the respective methods. Most of the investigators do not report evaluation of the obtained differences, but where this has been done no true (from a statistical standpoint) differences have appeared.

This would indicate that no satisfactory method has yet been found for the evaluation of the contributions of individual laboratory work and point to the need for further study.

At this point one might be tempted to draw a number of qualitative inferences from the obtained data which, however, violates the very spirit of the statistical methods of analysis employed. Inasmuch as any experimental study, however, is limited by the sample make-up and methods employed and in particular in an experiment with teaching procedures where it is impossible to delineate and control many of the variables, it might well be justified to describe further some of the conditions which might have contributed to the attained results as well as a few sidelights of the problem as a whole.

The limitations of the sample itself are a factor in this study. Practical considerations made an initial purely random assignment impossible and the rather large drop in course enrollment during the school year would likely have rendered it ineffective. For the same reasons it was also difficult to exercise a closer control of students' backgrounds and abilities. The decrease, however, was not great enough to reduce the sample in either size or make-up to the point where the data were not amenable to statistical analysis.

Some of the differences in performance are certainly attributable to the variations in student ability at the two Colleges of Education as shown by the difference in the average ACE decile ratings and ranges in test performances. There appeared to exist a greater similarity in the student groups at each institution than between them, but even when the comparison of the two teaching methods is confined to only one of the institutions the differences between the two teaching methods are not significant.

It should also be pointed out that a pairing of students from the respective laboratory and lecture groups was finally not attempted because while this method offers some distinct advantages in overcoming sample group differences, it was considered impossible to find sufficient pairs from the groups which would have been alike in all characteristics except the difference of teaching method under study. Furthermore, Hurd's (35, p.115) findings seriously question the value of pairing students for purposes of equating groups unless the comparison of the individuals is continued over a considerable period of time and found to be "identical in a great variety of activities."

No significant differences in student performances could be ascribed to differences between the two instructors.

Several implications of the advantages of individual laboratory work as found by other workers will next be compared with the findings from this study and some additional ones will be alluded to. In addition to the evident outcomes of individual laboratory work such as acquaintance with laboratory equipment and procedure these other advantages have been claimed:

1. higher achievement
2. greater retention
3. additional interest
4. better allowance for individual differences.

Though some of the laboratory groups showed higher achievement the results were neither consistent nor significant.

Several studies (24, p.318; 52, p.300) have indicated that individual laboratory work greatly increases retention of knowledge. A follow-up of the students of this study could possibly be made to ascertain if this claim also applies to general education objectives.

No formal poll of student reaction was made, but from personal reactions it appeared that though all the students were not only very cooperative but showed quite an interest in the study, the students in the lecture sections, nevertheless, gave the impression that they would rather have had some laboratory work, which is quite in keeping with Bullington's (12) findings from an actual student opinion survey. This in itself might well be interpreted to mean that the laboratory creates interest and motivation.

The data of this study are in agreement with previous studies, that individual laboratory work provides a greater opportunity for the expression of individual differences than can possibly be provided in a straight lecture course. This is an advantage which is certainly in accord with the objectives of general education.

Among the other possible advantages of individual laboratory work which may be alluded to, though they are not actual outcomes of this study, the opportunities for personal contacts and development of resourcefulness will be briefly mentioned.

A distinct advantage of the individual laboratory method is in the greater opportunity it provides for personal contacts between instructor and student. This is of immense value in natural science courses where an interchange of ideas, questions, and problems is often so essential to understanding but cannot be afforded in the usually larger lecture groups and in less time.

In addition to certain intrinsic associations between the natural sciences and the laboratory for all students, there are even more convincing reasons for having individual laboratory work for future teachers who are themselves expected to conduct science experiments in the exercise of their profession. Curtis (21, p.9) found that "Students with absolutely no laboratory experience showed no laboratory resourcefulness whatever; they refused to touch the apparatus." This incidental observation is of interest because the large majority of the students of this particular study were future elementary teachers.

In answer to the problem stated in the title, it must be stated that this study did not produce any conclusive evidence that the laboratory contributes directly to the aims of general education, at least as measured by the selected criteria, but neither did the decrease in the amount of lecture time lower the achievement of the laboratory groups.

These experimental findings corroborate Henshaw's conclusions (34) that it is possible to have general education natural science courses without laboratory work but due to the fact that the results of this study cannot be considered as a definitive solution of the problem and also in view of the admitted indirect benefits accruing from individual laboratory work which certainly are in harmony with the objectives of general education, it is not recommended that individual laboratory work be eliminated.

In the Final Report of the Cooperative Study of Evaluation in General Education of the American Council on Education (5, p.138) the statement is made that "there is some indication that the amount of success is due to the attention given to the objectives." This would only seem reasonable if applied in the truest sense that the teaching approach should be in harmony with the objectives and this was certainly attempted in this study. One may wonder at times, however, how much results are influenced by teaching for the immediate objectives of the test situation per se. Stated otherwise, this testing program was carried on as part of a normal course program and not the course program keyed to any possible test outcomes.

Finally, the writer cannot help but feel in summary as Kirk (36, p.238) recently expressed it:

> Most of the arguments for the abandonment of the laboratories in the teaching of science are in essence statements that science teachers have failed to accomplish the things which we claim we can accomplish by laboratory instruction. All of us who teach science will admit that we have fallen short of our stated goals. Blame us, but do not blame the method! Help us to do better, help us to train others to do better still, but do not doom our young people to sterile instruction.

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APPENDIX

Cooperative Study of Evaluation in General Education
of the
American Council on Education

A TEST OF SCIENCE REASONING AND UNDERSTANDING

Physical Sciences

Form A

Note to the Student About This Test

In this test you will find problem situations comprised for the most part of excerpts from articles written for the general public about achievements and activities of scientists. The test is designed to measure your ability to analyze these problems, in terms of your understanding of the broad principles of science, and of the point of view of a scientist and the kinds of things that he does. This understanding is one of the aims of general education.

Directions

Within the test you will find directions for groups of questions. Read these directions carefully so that, before you answer a set of questions, you know what is being asked.

You may, in some cases, encounter words or specific data that are unfamiliar to you. If you do, don't worry about it. It is not likely that this will prevent your answering most of the questions intelligently.

Your answers to the questions are to be recorded on a separate answer sheet. Before answering the questions fill in the blank spaces at the top of your answer sheet. For Name of Test write Physical Sciences, Form A

Mark only the one best answer for any item.

Your score on this test will be the total number of items correctly answered.

The minimum actual testing time is 45 minutes.

Do not mark in the test booklet.

Read the following selection carefully.

Some years ago a systematic aerial survey was made of the coastal region in South Carolina. When some scientists chanced to see these photographs they were struck by the large number of oval markings which showed up. These markings turned out in most cases to be sandy stretches surrounding dark areas of vegetation and were much more easily noticed from the air than from the ground. The most unusual feature of these "bays," as they came to be called, was that they were almost exactly parallel, NW - SE, although they varied in size from several miles to a few tens of feet in length.

Naturally curious as to the origin of these bays, the scientists who first noticed them suggested that they were the craters left by a tremendous shower of meteorites which approached the area from the northwest. When this idea was published there arose a lively controversy as to whether they were due to meteors or to some unusual combination of geological processes involving ground water, wave and wind action.

Directions: The items below (1-13) represent quotations from an article by Douglas Johnson summarizing the various theories on the problem of the Carolina bays. You are asked to classify the quotations according to the KEY. If a portion of the quotation is underlined, classify only that portion. Blacken the proper space on the answer sheet.

KEY:
1. a problem.
2. a fact by observation or experiment.
3. an hypothesis.
4. a deductive test of an hypothesis.
5. an accepted solution to the main problem.

1. "Each bay or crater is oval, as if produced by some object striking the earth obliquely and scooping out an elongated depression."

2. "The long axes of the oval depressions are almost if not completely parallel, and trend uniformly from northwest to southeast, as though a great shower of large objects coming from the same direction had produced the tens of thousands of craters actually observed in the field and on aerial photographs of the Carolina coastal plain."

3. "If meteorites coming from the northwest struck the earth obliquely to form oval craters, they should....be now reposing below the surface at or near the southeastern ends of such craters."

4. "Since many meteors contain significant amounts of iron, a magnetometer survey of these southeastern areas should frequently show the presence of 'magnetic highs' due to the attractive influence of iron within the buried meteorites."

5. "Accordingly I make magnetometer surveys covering the southeastern ends of several bays and adjacent territory. In every instance the surveys show distinct magnetic highs in the areas in question."

6. "The northeastern sides of the bays are prevailingly more strongly curved than the southwestern sides. It is difficult to see why plunging meteorites should produce craters which are systematically asymmetrical."

7. "It is conceivable that an obliquely plunging meteorite might produce a narrow groove where it first touches the earth, and a broader depression where the full body enters; but in that event the narrow ends of the craters should point toward the northwest."

8. "The major accumulation (of sand) is about the eastern quadrant of the craters rather than about the southeastern half.... It is difficult to see why a plunging meteorite should push up more debris on the southeastern side of a crater than on the southwestern side."

9. "Tests made with guns firing large and small projectiles show that a swiftly moving projectile striking the earth obliquely may act in several different ways: (a) it may penetrate the ground in the oblique direction of incidence; (b) if the angle of incidence is too low, it may strike the surface a glancing blow and pass off into space again; (c) it may explode upon impact."

10. "For the inner and usually very regular rims there is (a) the possibility of a wind-blown origin; (b) also the possibility that they are beach ridges built by wave action when lakes occupied the craters, their convergence and disappearance toward the northwest being tentatively ascribed to progressive elongation of the lake in that direction due to the headward migration of artesian springs or some other cause."

11. "If the craters were excavated in loose sand or loam by springs welling up from below under artesian pressure, loose sand or loam should be found at the surface in areas where the craters are abundant."

12. "Calculations of the amount of sand found in the ridges or rims surrounding the craters show that the total is insignificant compared to the vast bulk of material removed to form the basins of the craters."

13. "If the outer rims are really of wind-blown origin, examination of weather records for the Carolina coastal plain, or for that part of the plain occupied by the craters, should show dominant winds from the opposite quarters."

* * * *

(Go on to the next page.)

Read the following article carefully. It is adapted from "Weather or Not," *Time*, August 28, 1950.

Until Irving Langmuir began poking into the subject, meteorology was a passive science. Meteorologists observed and tried to forecast the weather, but when asked why they didn't do something about it, they simply looked reproachful. No meteorologist to begin with, Brooklyn-born Irving Langmuir was educated at Columbia University and Gottingen in Germany. In 1909 he joined General Electric's Research Laboratory, where he found the freedom he wanted to do research. His G. E. bosses told young Langmuir not to bother about practical applications of his experiments, to look around the laboratory and work on anything that interested him.

Like everyone else, Langmuir did nothing about the weather until World War II, when he began studying the water droplets in high, cold clouds which freeze into deadly ice on airplane wings. The schoolbook explanation of rain is that "clouds condense into raindrops and fall to the ground." It is not quite as simple as that. Unless something special happens to it, a cloud remains a cloud; the droplets in it stay about as they are, too small to fall.

After the war, Langmuir went to work on the mystery of rain clouds. He knew that the droplets in clouds do not freeze at 0° C. (32° F.). They are supercooled, i.e., are much colder than zero Centigrade, the normal freezing point. When an ice crystal comes in contact with supercooled droplets, it can steal water from them, so water vapor moves from the droplets to the ice. The ice crystals grow; the droplets shrink. Langmuir reasoned, as others had before him, that this process might be a cause of rain and might show a way to make artificial rain. If small ice crystals could be induced to form in a supercooled cloud, they should grow into big snowflakes at the expense of the cloud's droplets, then fall to the ground as snow, or melt into rain.

Langmuir and his brilliant young protege, Vincent Schaefer, settled down in G. E.'s Schenectady lab and began experimenting. Langmuir and Schaefer tried all kinds of things, with no success. Then, one hot day in July, 1946, Schaefer was alone in the laboratory. The cold chamber was not quite cold enough to suit him, so he put in a hunk of dry ice (temp. -79° C., -110° F.). At once he saw bright motes (specks) swirling through the light beam. As he watched, they grew into glittering snowflakes and settled to the bottom of the chamber.

Langmuir, the man of theory, soon worked out the "mechanism." It was the low temperature of the dry ice, not its carbon dioxide, that did the trick. Any very cold object, e.g., a needle cooled with liquid air, served as well. How cold is cold enough? Langmuir and Schaefer found by careful experiment that the motes form at -39°C (-38°F.). This explained some types of rain. Certain clouds rise high enough to be cooled to that temperature. Ice motes form, find their way into warmer parts of the cloud, where they grow into snowflakes, and fall as snow or rain. "Why not help things along with some dry ice?" asked Langmuir and Schaefer.

One day in November, 1946, Schaefer took off from Schenectady in a small airplane and directed the pilot to a fleecy cloud four miles long that was floating over nearby Massachusetts. When he reached it, he scattered into the cloud six pounds of dry ice. Almost at once the cloud, which had been drifting along peacefully, began to writhe as if in torment. White pustules rose from its surface. In five minutes the whole cloud melted away, leaving a thin wraith of snow. None of the snow reached the ground (it evaporated on the way down), but the dry ice treatment had successfully broken up a cloud.

Directions: For each of the items below (14-26) select the best answer and blacken the corresponding space on the answer sheet.

14. General Electric, in telling Dr. Langmuir not to bother about the practical applications of his experiments, was

    1. violating the best principles of scientific research.
    2. trying something new which is not ordinarily followed by scientists.
    3. running a serious risk of losing the money they were investing in his salary.
    4. pursuing a policy which in many cases has led to something valuable.
    5. doing something which was likely to be successful in Dr. Langmuir's case but might not be so in the case of most scientists.

15. Dr. Langmuir approached the problem of rainfall by

    1. deciding that meteorology must become an experimental rather than an observational science.
    2. studying carefully the behavior of water droplets and ice particles in the laboratory.
    3. deciding how rain must form and then examining the behavior of droplets in a cloud to see if it formed that way.
    4. deciding how rain must form and setting up a laboratory experiment to prove it.
    5. using a trial-and-error procedure.

16. In approaching the question of rainfall, the primary problem was

    1. whether or not artificial rain could be made.
    2. whether or not it would be ultimately desirable to make artificial rain.
    3. how cloud droplets become raindrops.
    4. how clouds get cold enough to form rain.
    5. whether or not artificial cloud drops could be made in the laboratory.

17. Dr. Langmuir recognized that the key phenomenon in the rain-forming process was the

    1. growth of ice crystals.
    2. supercooling of the water droplets.
    3. shrinkage of the water droplets.
    4. melting of the snowflakes.
    5. movement of the cloud.

18. Which one of the following statements indicates how the hypothesis for the problem of rain formation was tested?

    1. "Langmuir and his brilliant young protege, Vincent Schaefer, settled down in G. E.'s Schenectady lab and began experimenting."
    2. "Then, one hot day in July, 1946, Schaefer was alone in the laboratory. The cold chamber was not cold enough to suit him, so he put in a hunk of dry ice."
    3. "Langmuir reasoned...that this process might be the cause of rain, and might show a way to make artificial rain."
    4. "One day in November, 1946, Schaefer took off from Schenectady in a small airplane, and directed the pilot to a fleecy cloud. ..When he reached it, he scattered into the cloud six pounds of dry ice."
    5. "None of the snow reached the ground... but the dry ice treatment had successfully broken up a cloud."

19. Which one of the following statements constitutes a conclusion drawn by Langmuir and Schaefer as a result of their observation or experimentation?

    1. "When an ice crystal comes in contact with supercooled droplets, it can steal water from them, so water vapor moves from the droplets to the ice."
    2. "Almost at once the cloud, which had been drifting along peacefully, began to writhe as if in torment."
    3. "At once he saw bright motes swirling through the light beam. As he watched, they grew into glittering snowflakes and settled to the bottom of the chamber."
    4. "It was the low temperature of the dry ice, not its carbon dioxide that did the trick."
    5. "Why not help things along with dry ice?" asked Langmuir and Schaefer.

20. A scientist attacking a problem like Dr. Langmuir's will tend to

    1. develop a strong conviction of the correctness of his point of view, and look for data to prove it, discarding those which do not agree with it.
    2. reach a conclusion after a thorough examination of the data and, after he has tested his conclusion, discard any later data which do not agree with it.
    3. modify his conclusion when necessary to make it agree with new data as these become available.
    4. refrain from drawing any conclusion since he obviously cannot examine all of the data related to his problem.
    5. withhold efforts to make practical applications of his experimental results until these results have provided a final solution to the problem.

21. Dr. Langmuir's rain-making activities as reported involved

    1. disregarding accepted natural laws.
    2. making use of already-existing natural laws.
    3. breaking natural laws.
    4. changing natural laws.
    5. performing an operation outside the realm of natural law.

22. Which one of the following sentences best describes Dr. Langmuir's attitude in connection with the problem?

    1. He was certain from the beginning of his investigation what the final result would be.
    2. He believed that the formation of rain is the result of the interaction of an intricate set of natural phenomena.
    3. He began the experiments with little or no idea that they might eventually result in an understanding of the formation of rain.
    4. He was interested mostly in the practical aspects of the problem.
    5. He believed the problem was soluble by purely theoretical means.

23. Research in artificial rain making

    1. is of little concern to the average citizen because it is so technical.
    2. was an initial mistake and never should have been started, because of the political bickering and legal tangles which were bound to develop.
    3. was innocently begun but should be made illegal together with the practice of artificial rain-making.
    4. should be pursued by the federal government as project number one of all current research and development projects.
    5. should be continued actively by interested groups with resources available.

24. Langmuir and Schaefer's work shows that for rain to result from scattering dry ice into a cloud, it is necessary that the

    1. base of the cloud is below 32°F.
    2. cloud droplets are too small to fall.
    3. cloud droplets have frozen.
    4. cloud is about to produce snow.
    5. cloud droplets are liquid and below 32°F.

25. Thunderheads in summertime can have their tops considerably colder than freezing because

    1. the intensity of the earth's radiant heat varies inversely as the square of the distance.
    2. solar radiation is better absorbed by water drops.
    3. lower levels of the air are heated by greater turbulence and friction.
    4. air at a high level is always colder than air at a lower level.
    5. air which expands does work at the expense of its internal energy.

26. The growth of snow crystals at the expense of adjacent water drops

    1. occurs only when they come into actual contact.
    2. requires the presence of some object colder than -38°F.
    3. involves water changing from liquid to vapor to solid.
    4. ceases when the crystals become larger than the drops.
    5. occurs in clouds containing only supercooled water droplets.

* * * *

Items 27-38 are related to the following selection which is adapted from an address by Thomas Midgley, Jr., on how the gas called "freon 21" ($CHCl_2F$) was developed for electric refrigerators in the early 1930's. Read this selection carefully before attempting to answer any of the items.

One morning Kettering (General Motors' director of research) remarked to me that the refrigeration industry needed a new refrigerant if it ever expected to get anywhere. I was skeptical that anything other than a mixture of substances would reduce existing hazards, but after discussing it with Keilholtz (chief engineer for Frigidaire), two of my associates and I went to the library and started work.

The desired combination of properties was a boiling point between 0°C. and -40°C., stability, nontoxicity, and nonflammability. International Critical Tables gave us a partial summary of the volatile organic compounds. The now proved mistake that carbon tetrafluoride boiled at -15°C. struck us in the face and started us thinking about fluorine. No one could doubt at that time that it was terribly toxic. Perhaps we could add some chlorine compound with beneficial results. Someone suggested chloro-fluorides as a class to be investigated further. And so the discussion ran.

Recognizing that the Critical Table list was very incomplete, I decided to bring into play the periodic table. Perhaps volatility could be related to it in some way, and it took but a moment to see that this was true. Volatile compounds of boron, silicon, phosphorus, arsenic, antimony, bismuth, selenium, tellurium, and iodine (underlined in the accompanying table) are all too unstable and toxic to consider. The inert gases (starred in the accompanying table) are too low in boiling point.

							He*
--	--	B	C	N	O	F	Ne*
--	--	--	Si	P	S	Cl	A *
--	--	--	--	As	Se	Pr	Kr*
--	--	--	--	Sb	Te	I	Xe*
				Bi			--

Now look over the remaining elements. Every refrigerant used has been made from combinations of these elements. Flammability decreases from left to right. Toxicity (in general) decreases from the heavy elements at the bottom to the lighter elements at the top. These two desiderata focus on fluorine. It was an exciting deduction. Seemingly no one previously had considered it possible that fluorine might be non-toxic in some of its compounds. This possibility had certainly been disregarded by the refrigeration engineers.

If the problem before us were solvable by the use of a single compound, then that compound would certainly contain fluorine. The heats of formation between the halogens (fluorine, chlorine, bromine, iodine) and carbon were checked. They increase from iodine to fluorine, thus indicating a high degree of stability for fluorine-carbon compounds. Next came methods of preparation. Carbon tetrafluoride (CF_4) seemed rather hard to make. And then how could dichloro-difluoro-methane (CCl_2F_2) boil at -20°C. and carbon tetrafluoride at -15°C.? It just didn't make sense. Plottings of boiling points, hunting for data, slide rules, eraser dirt, pencil shavings, and all the rest of the paraphernalia that takes the place of tea leaves and crystal spheres in the life of the scientific clairvoyant were brought into play. We decided that carbon tetrafluoride boiled at about -136°C (Not long after this a publication on the subject appeared. Carbon tetrafluoride boils at -128°C., not -15°C.).

Feeling pretty certain at the time that -15°C. was wrong, we selected dichloro-monofluoro-methane ($CHCl_2F$ usually called "freon 21")as the starting point for experimentation. I called one of the chemical supply houses by telephone and ordered five 1-ounce bottles of antimony trifluoride (SbF_3). I believe this was all there was in the country at the time.

The bottles arrived. One was taken at random, and a few grams of dichloro-monofluoro-methane were prepared. A guinea pig was placed under a bell jar with it and, much to the surprise of the physician in charge, didn't suddenly gasp and die. In fact, it wasn't even irritated. Our predictions were fulfilled. We took another bottle, made a few more grams and tried it again. This time the animal did what the physician expected. We repeated again but this time we smelled the material first. The answer was phosgene; a simple caustic wash was all that was needed to make it perfectly safe. Then we examined the two remaining bottles of antimony trifluoride. They were not pure. In fact, they were both badly contaminated with a double salt containing water of crystallization. This makes phosgene in ample quantities as an impurity.

Of five bottles marked "antimony trifluoride," one had really contained good material. We had chosen that one by accident for our first trial. Had we chosen any one of the other four, the animal would have died as expected by everyone else in the world except ourselves. I believe we would have given up what would then have seemed a "bum hunch."

Directions: For each of the items 27-38 select the best answer, then mark the corresponding space on the answer sheet.

27. The statement, "The desired combination of properties was a boiling point between 0° and -40°C., stability, nontoxicity, and nonflammability," represents
    1. an hypothesis.
    2. the specification of a problem.
    3. a test of an hypothesis.
    4. systematized data.
    5. a fact by controlled experiments.

28. The statement, "Flammability decreases from left to right. Toxicity decreases from... bottom to..top. These two desiderata focus on fluorine," represents
    1. an hypothesis.
    2. a test of an hypothesis.
    3. a problem.
    4. a conclusion from systematized observations.
    5. a fact by observation.

29. The statement, "The heats of formation between the halogens and carbon were checked. They increase from iodine to fluorine," represents

1. an hypothesis.
2. a test of an hypothesis.
3. a problem.
4. the specification of a problem.
5. systematized data.

30. The statement, "And then how could dichloro-difluoro-methane boil at -20°C. and carbon tetrafluoride at -15°C?" represents

1. a problem.
2. a test of an hypothesis.
3. an hypothesis.
4. a fact by observation
5. a conclusion from systematic observations.

31. The statement, "We decided that carbon tetrafluoride boiled at about -136°C," represents

1. an hypothesis.
2. a test of an hypothesis.
3. a fact by controlled experiment.
4. a problem.
5. a fact by observation.

32. The statement,"A guinea pig was placed under the bell jar with it and...didn't suddenly gasp and die," represents

1. an hypothesis.
2. a test of an hypothesis.
3. the specification of a problem.
4. a conclusion from systematic observations.
5. generalized data.

33. The statement, "This time the animal did what the physician expected," represents

1. an hypothesis.
2. a conclusion from systematic observations.
3. generalized data.
4. the specification of a problem.
5. a fact by controlled experiment.

34. The statement,"Both were badly contaminated with a double salt containing water of crystallization" represents

1. an hypothesis.
2. a problem.
3. generalized data.
4. a fact by observation.
5. the specification of a problem.

35. The primary objective of this investigation was to

1. determine the boiling points of fluorine compounds.
2. correct errors in the International Critical Tables.
3. find a nonpoisonous nonflammable refrigerant.
4. determine the toxicity of dichloro-monofluoro-methane.
5. test for impurities in antimony trifluoride.

36. In deciding to concentrate upon compounds of fluorine, which one of the following was a basic assumption?

1. Trends discovered in part of the Periodic Table are likely to continue.
2. Compounds of a toxic element will be non-toxic.
3. Compounds with lower boiling points are less flammable.
4. Mixtures of compounds are less toxic than single compounds.
5. Compounds of carbon are flammable.

37. Which one of the following statements represents Midgley's attitude in connection with the problem?

1. Pioneer work of this kind is primarily a trial-and-error process.
2. He was certain that a single compound would be found which would satisfy the need.
3. He did the job reluctantly and only because his superior demanded it.
4. He believed that the solution would be gained most quickly by following his hunches.
5. He believed that systematic study of available data would suggest more fruitful hypotheses to investigate.

38. Which one of the following statements do you believe represents the probable final outcome of the problem, if they had used impure antimony trifluoride (SbF_3) in the first trial with the guinea pig?

1. Midgley would have immediately made a new sample of gas and tried another animal.
2. They would have turned to the study of other compounds and never returned to compounds of fluorine again.
3. Either at General Motors laboratory or somewhere else, the true properties of freon 21 would have been determined within a few months or years.
4. After hearing of the results, Kettering would have forbade further research on the subject.
5. Midgley would have recommended the use of freon 21 as a refrigerant in spite of its apparent lethal effect upon the guinea pig.

* * * *

(Go on to the next page.)

Before attempting to answer items 39-50, read carefully the following condensed statements of two theories which have been used to explain heat phenomena.

Theory A: It is supposed that there exists a very subtile, and self-repulsive fluid, called "caloric," dispersed throughout all the bodies of the universe, and capable of passing, with more or less facility, through them all; but this fluid cannot be exhibited by itself in an uncombined state; for nothing will confine it; nor has it any known weight. The distance between the constituent atoms of a body is governed by a balance between the attraction of the atoms for each other and the repulsion of the intervening caloric. The temperature of a body depends upon the density of the caloric within it.

The sensation which animals perceive by the communication of caloric to their bodies, is called heat, or heating; and the sensation which they perceive by the escape of the caloric from their bodies is called cold, or cooling. Therefore it appears that cold is not a positive thing, but only the absence or privation of caloric. When we touch a hot body, the caloric passes from that body into our hands, or face, etc., expands that part, and excites in us a sensation of heat. When we touch a cold body, the caloric passes from us into that body, and we feel the sensation of cold.

Theory B: Heat is considered to be not only a form of energy, but more particularly the kinetic energy of vibration (for a solid) or of translation (for a fluid) of the constituent atoms or molecules of the substance. Hence an increase in the average kinetic energy of these atoms or molecules gives rise to an increase in the absolute temperature of the substance.

Directions: The items below (39-50) consist of a series of experimental or observational data (facts) which are related to the two theories described above. In addition to the information in the above paragraphs you may draw upon any other background knowledge which you have. For each item mark space

1- if the fact lends more direct support to theory A than to theory B.
2- if the fact lends more direct support to theory B than to theory A.
3- if the fact supports both theories.
4- if the fact cannot be used to support either theory.

39. When a sterling silver spoon is placed in hot coffee, the handle gets warm quickly.

40. Water expands when it freezes and ice contracts on melting.

41. The tension in power and telephone lines is greater in winter than in summer.

42. When a wire is bent back and forth it becomes warmer at the point where the bending occurs than at other points.

43. When a volume of gas is suddenly compressed, its temperature rises.

44. When compressed carbon dioxide gas is suddenly released from a cylinder its temperature is much lower than its initial temperature.

45. When warmed from 2^oC. to 6^oC., water first contracts and then expands.

46. If two blocks of metal, one black and the other highly polished, are both heated to the same temperature, the polished block will cool more slowly than the black one.

47. Smoke particles in air, strongly illuminated and observed under a microscope, are seen to move in an erratic and random fashion.

48. When a narrow beam of X-rays is reflected from a single crystal, such as common salt, there is less broadening of the reflected beam as the temperature of the crystal is reduced.

49. More heat can be absorbed by a gas when it is warmed up while its volume is allowed to increase at constant pressure, than when it is warmed up the same number of degrees, keeping the volume constant.

50. For every calorie of heat generated by friction between two bodies 4.18 joules of work are necessary, without regard to the nature of the bodies.

* * * *

Items 51-55 are concerned with the following:

You have probably heard of the idea that sometime men will try to travel by rocketship to the moon and back. Many of the problems involved -- what the human body will endure, how to get away from the earth, how to "navigate" in interplanetary space, and the like -- are under scientific study. Therefore the writers of magazine articles, comic strips and motion pictures on travel to the moon generally make their stories conform to basic principles of science. On this assumption, answer items 51-55 below by selecting the best choice and blacken the corresponding space on the answer sheet.

51. As the space ship leaves the earth each traveler reclines because

1. it is necessary to lower the center of gravity of the space ship.
2. he desires to avoid nausea caused by the take-off.
3. his instruments are most conveniently operated in that position.
4. when the ship is in space it is impossible for a man to stay erect.
5. he is subjected to forces much greater than his weight.

52. While the ship is moving through interplanetary space, the travelers inside find they are unable to

1. rise from their couches.
2. move from one place to another.
3. pour water into a glass.
4. bounce a ball against the ceiling.
5. talk to each other directly.

53. While the ship is traveling through space the rocket motors are not continually in operation because

1. they are satisfied to continue at essentially a constant speed until they approach their destination.
2. the escaping gases from a rocket must push against air to be effective.
3. no oxygen is available in space to burn the rocket fuel.
4. they are satisfied to slow down after the rapid acceleration of the take-off.
5. they have escaped completely from the earth's gravitational pull.

54. Gravitational attraction at the surface of the moon is calculated to be only about one-sixth as great as at the surface of the earth. This may account for the fact that the moon has no atmosphere. Which one of the following statements will <u>not</u> be true in the light of one or both of the above facts?

1. Travelers on the moon would see both the sun and the stars shining in a black sky.
2. Travelers on the moon would find shadows much sharper and darker than on the earth.
3. Aside from the difficulties introduced by a "space suit," a traveler on the moon would be able to carry very heavy loads with ease.
4. Aside from the difficulties introduced by a "space suit," a traveler could throw a baseball much farther on the moon than on the earth.
5. Aside from the difficulties introduced by a "space suit," a traveler could throw a baseball horizontally on the moon with much greater speed than on the earth.

55. Which one of the following requirements for a successful rocket-trip to the moon and back is most readily available?

1. The necessary funds.
2. Theoretical knowledge of "navigation" between planets.
3. A practical means of landing on the moon.
4. A practical means of landing on the earth.
5. Sufficiently powerful engines to escape from the earth.

END OF TEST

EDUCATIONAL TESTING SERVICE

COOPERATIVE GENERAL ACHIEVEMENT TESTS

REVISED SERIES

II. A Test of General Proficiency in the Field of Natural Sciences

FORM Y

by

CARL A. PEARSON, Southwest High School (Minneapolis)

with the editorial assistance of

THEO. A. ASHFORD, University of Chicago; PAUL J. BURKE, Graduate Record Office; BERTHA OWENS, Hastings-on-Hudson High School; GEORGE M. LASH, Bayside High School (New York); and RICHARD G. SAGEBEER, Kingswood School

Please print:

Name...Date..............................
Last First Middle

Grade or Class..Age..............................Date of Birth..............................
Yrs. Mos.

School..City..............................Sex..............................
M. or F.

Instructor..

Number of **years** you will have studied the following by the end of the present semester or quarter: (Count a semester as ½ year, a quarter as ⅓ year.)

	General Science	Biology	Botany	Chemistry	Physics	Other Natural Sciences (list)
In high school						
In college						

General Directions: Do not turn this page until the examiner tells you to do so. This examination consists of two parts, and requires 40 minutes of working time. The directions for each part are printed at the beginning of the part. Read them carefully, and proceed at once to answer the questions. DO NOT SPEND TOO MUCH TIME ON ANY ONE ITEM. ANSWER THE EASIER QUESTIONS FIRST; then return to the harder ones if you have time. There is a time limit for each part. You are not expected to answer all the questions in either part in the time limit; but if you should, go on to the next part. If you have not finished Part I when the time is up, stop work on that part and proceed at once to Part II. If you finish Part II before the time is up, you may go back and work on either part. No questions may be asked after the examination has begun.

You may answer questions even when you are not perfectly sure that your answers are correct, but you should avoid **wild** guessing, since wrong answers will result in a subtraction from the number of your correct answers.

Part	Minutes	Raw Score	Scaled Score	Percentile
I Terms and Concepts	15			
II Comprehension and Interpretation	25			
Total	40			

15 Amsterdam Avenue, New York 23, N. Y.

PART I

TERMS AND CONCEPTS

(15 minutes)

Directions: Each of the following incomplete statements or questions is followed by five choices. Select the one that **best** completes the statement or answers the question and put its **number** in the parentheses at the right.

1. Starch and sugar belong to the class of nutrients called
1–1 carbohydrates.
1–2 amino acids.
1–3 proteins.
1–4 fats.
1–5 minerals. . . . . 1( )

2. Protecting the body from a particular disease by a method such as inoculation is known as
2–1 hygiene.
2–2 disinfection.
2–3 quarantine.
2–4 immunization.
2–5 sterilization. . . . . 2( )

3. Dehydration is a process that removes
3–1 water.
3–2 hydrogen.
3–3 bacteria.
3–4 oxygen.
3–5 air. . . . . 3( )

4. The rusting of iron is an example of
4–1 neutralization.
4–2 precipitation.
4–3 oxidation.
4–4 reduction.
4–5 double decomposition. . . . . 4( )

5. Hibernation and migration enable animals to continue their existence in spite of extreme variations in
5–1 air pressure.
5–2 altitude.
5–3 humidity.
5–4 temperature.
5–5 topography. . . . . 5( )

6. Accurate forecasting of weather conditions for several days in advance is most dependent upon a detailed knowledge of
6–1 the probable appearance of sunspots.
6–2 the composition and movements of air masses.
6–3 fluctuations in magnetic intensity.
6–4 the phases of the moon.
6–5 the chemical composition of the atmosphere. . . . . 6( )

7. It is because of gravity that
7–1 a sled slides downhill.
7–2 two sticks become hot when they are rubbed together.
7–3 a car is likely to run off the road when it goes rapidly around a curve.
7–4 a balloon breaks when it is blown very large.
7–5 water evaporates into the air. . . . . 7( )

8. A geologist would be most interested in the discovery of a new
8–1 disease germ.
8–2 tribe of Indians.
8–3 kind of rock.
8–4 kind of animal.
8–5 comet. . . . . 8( )

9. A controlled procedure whose purpose is to test a scientific principle is called
9–1 a theory.
9–2 an experiment.
9–3 a thesis.
9–4 a conclusion.
9–5 a hypothesis. . . . . 9( )

10. The bronchial tubes are associated with the
10–1 kidneys.
10–2 esophagus.
10–3 bladder.
10–4 liver.
10–5 lungs. . . . . 10( )

11. Materials through which an electric current *cannot* pass are called
11–1 insulators.
11–2 stators.
11–3 magnets.
11–4 conductors.
11–5 electrolytes. . . . . 11( )

12. Frequency modulation (FM) is a means of
12–1 increasing the speed of jet-propelled aircraft.
12–2 transmitting radio programs.
12–3 reducing the glare in electric lighting.
12–4 transmitting sounds on a beam of light.
12–5 eliminating echoes in large rooms. 12( )

13. An increase in the absolute humidity of the air is an increase in the
13–1 temperature of the air.
13–2 density of the air.
13–3 pressure of the air.
13–4 moisture content of the air.
13–5 amount of organic material in the air. . . . . 13( )

14. The economical production and long-distance transmission of electrical power would have been impossible except for the invention of
14–1 the vacuum tube.
14–2 radar.
14–3 the AC generator.
14–4 the cyclotron.
14–5 the magnetic compass. . . . . . . 14( )

Go on to the next page.

15. The rate at which an automobile increases in speed after starting is called its
15–1 velocity.
15–2 acceleration.
15–3 momentum.
15–4 kinetic energy.
15–5 inertia. . . . . . . 15( )

16. A seismograph is used to record
16–1 ocean depths.
16–2 sunspots.
16–3 earthquakes.
16–4 cosmic rays.
16–5 weather conditions at high altitudes. 16( )

17. The flower is the part of a plant especially adapted to carry on the process of
17–1 food making.
17–2 seed dispersal.
17–3 osmosis.
17–4 reproduction.
17–5 food storage. . . . . 17( )

18. The pancreas is primarily an organ of
18–1 respiration.
18–2 secretion.
18–3 circulation.
18–4 excretion.
18–5 reproduction. . . . . . 18( )

19. The spontaneous process whereby two gases intermingle so as to form a homogeneous mixture is known as
19–1 cohesion.
19–2 sublimation.
19–3 condensation.
19–4 diffusion.
19–5 osmosis. . . . . . . 19( )

20. A substance which is formed in the tissues of an animal and which has the ability to neutralize the poisons given off by disease germs is known as
20–1 an antitoxin.
20–2 an antiseptic.
20–3 a serum.
20–4 a toxin.
20–5 a vaccine. . . . . 20( )

21. Which one of the following is usually an internal combustion engine?
21–1 A hydraulic ram
21–2 The motor of an electric washing machine
21–3 The motor of an automobile
21–4 A locomotive
21–5 A living animal . . . . . 21( )

22. An important factor in causing seasons is the
22–1 rotation of the earth on its axis.
22–2 tilt of the earth's axis.
22–3 varying distance between the earth and the moon.
22–4 irregularity of the earth's surface.
22–5 change in direction of ocean currents. . . . . . . 22( )

23. Animals classified as rodents have
23–1 hoofs.
23–2 long and pointed canine teeth.
23–3 egg-laying mechanisms.
23–4 strong chisel-shaped incisors.
23–5 hands with fingers for grasping. . 23( )

24. Which one of the following organisms is the most capable of providing for its own needs, independent of other organisms?
24–1 A lion
24–2 A snake
24–3 An elm tree
24–4 A termite
24–5 A mushroom . . . . 24( )

25. A compound microscope is an instrument consisting of
25–1 one and only one high-power convex lens.
25–2 at least two convex lenses.
25–3 one and only one high-power concave lens.
25–4 only two concave lenses.
25–5 two concave mirrors. . . . . 25( )

26. A commutator would be found in an electric
26–1 heater.
26–2 doorbell.
26–3 fuse.
26–4 motor.
26–5 storage battery. . . . . 26( )

27. A deciduous tree is one that
27–1 needs very little water for life and growth.
27–2 sheds its leaves in the fall.
27–3 grows best at high altitudes.
27–4 is adapted for growth in swampy regions.
27–5 is green throughout the year. . . 27( )

28. The process of removing all the hydrogen ions from a solution by adding an equal number of hydroxyl ions is called
28–1 ionization.
28–2 hydrolysis.
28–3 electrolysis.
28–4 precipitation.
28–5 neutralization. . . . . . 28( )

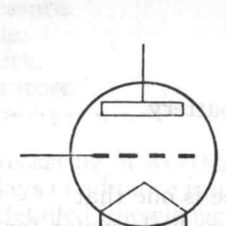
Go on to the next page.

29. The valence of an element is the
29–1 number of electrons gained or lost in chemical combination.
29–2 weight gained or lost in chemical combination.
29–3 number of electrons in an inner shell.
29–4 atomic weight.
29–5 atomic weight divided by the number of electrons in the outer shell. . 29(   )

30. Which one of the following best explains why raindrops are nearly spherical in shape?
30–1 Evaporation
30–2 Gravity
30–3 Capillary action
30–4 Brownian movement
30–5 Surface tension . . . . . 30(   )

31. Which one of the following is an instrument used to measure the specific gravity of a liquid?
31–1 Beam balance
31–2 Manometer
31–3 Hydrometer
31–4 Barometer
31–5 Hygrometer . . . . . 31(   )

32. A chemical element is found to consist of several substances of different atomic weights and identical chemical properties. These substances are called
32–1 allotropic forms.
32–2 isotopes.
32–3 electrons.
32–4 deuterons.
32–5 isobars. . . . . . . 32(   )



33. The symbol above represents a
33–1 dynamo.
33–2 galvanometer.
33–3 transformer.
33–4 storage cell.
33–5 radio tube. . . . . 33(   )

34. Amino acids are the units that make up the chemical structure of
34–1 proteins.
34–2 urine.
34–3 gastric juice.
34–4 vitamin C.
34–5 fats. . . . . 34(   )

35. A Geiger counter is a device used to
35–1 detect deposits of iron ore.
35–2 count numbers of electrons passing through a wire.
35–3 measure light intensity.
35–4 detect radioactivity.
35–5 count articles automatically by using an electric eye. . . . . 35(   )

36. Carborundum is a compound made up of carbon and
36–1 oxygen.
36–2 silicon.
36–3 hydrogen.
36–4 iron.
36–5 calcium. . . . . 36(   )

37. A rectifier is a device for changing
37–1 chemical energy into electrical energy.
37–2 potential energy into kinetic energy.
37–3 alternating current to direct current.
37–4 low voltage to high voltage.
37–5 mechanical energy into electrical energy. . . . . 37(   )

38. A temperature of absolute zero is the
38–1 lowest temperature theoretically possible.
38–2 lowest temperature that has ever been attained.
38–3 point at which mercury freezes.
38–4 point at which water freezes and ice melts.
38–5 point used as the reference level on all temperature scales. . . . . . 38(   )

39. A burette is a laboratory device used to
39–1 weigh accurately small quantities of solids.
39–2 filter precipitated solids from liquids.
39–3 decompose liquids by electrolysis.
39–4 measure accurately small volumes of liquids.
39–5 evaporate liquid solvents without decomposing the solute. . . . . 39(   )

40. The force that prevents a rapidly rotating propeller blade from flying apart because of its speed is
40–1 friction.
40–2 centrifugal force.
40–3 inertia.
40–4 elasticity.
40–5 cohesion. . . . . 40(   )

41. The Eustachian tube is a connection between the
41–1 eye and the brain.
41–2 ear and the throat.
41–3 trachea and the gullet.
41–4 nose and the throat.
41–5 ear and the brain. . . . . 41(   )

Go on to the next page.

42. The deviation of a compass needle from the north–south position due to the fact that the magnetic pole is not located at the geographic pole is known as
42–1 true direction.
42–2 induction.
42–3 experimental error.
42–4 detraction.
42–5 declination. . . . . 42( )

43. A diatom is
43–1 an atom composed of two protons.
43–2 a small animal.
43–3 a part of the nucleus of an atom.
43–4 a one-celled plant.
43–5 an electrically charged group of atoms. . . . . 43( )

44. A photometer may be used to measure the
44–1 candle power of a lamp.
44–2 wave length of light.
44–3 index of refraction of a substance.
44–4 focal length of a lens.
44–5 speed of light. . . . . 44( )

45. Sound pulsations are made to cause electrical pulsations in a
45–1 photoelectric cell.
45–2 telephone receiver.
45–3 transformer.
45–4 radio tube.
45–5 microphone. . . . . 45( )

46. Deuterium is a kind of
46–1 oxygen.
46–2 hydrogen.
46–3 carbon.
46–4 gaseous fuel.
46–5 iron ore. . . . . 46( )

47. White blood corpuscles which engulf bacteria are known as
47–1 platelets.
47–2 antibodies.
47–3 amebae.
47–4 ptomaines.
47–5 phagocytes. . . . . 47( )

48. A Wheatstone bridge is used to
48–1 measure electrical resistance.
48–2 measure coefficients of linear expansion.
48–3 change high voltage to low voltage.
48–4 produce a rigid structure with a high safety factor.
48–5 determine the resultant of two or more forces acting at an angle. . 48( )

49. The loudness of a sound is usually expressed in terms of
49–1 kilowatt-hours.
49–2 wave length.
49–3 kilocycles.
49–4 decibels.
49–5 number of vibrations per second. . 49( )

50. The capacity of a metal container used for measuring quantities of different kinds of grain is most suitably expressed in
50–1 grams.
50–2 grams per cubic centimeter.
50–3 cubic inches.
50–4 specific gravity units.
50–5 pounds. . . . . 50( )

Go on to the next part.

Number wrong	0–2	3–6	7–10	11–14	15–18	19–22	23–26	27–30	31–34	35–38	39+
Amount to be subtracted	0	1	2	3	4	5	6	7	8	9	10

Number right________

Subtract________
(See table above)

Raw Score on Part I = Difference________

PART II

COMPREHENSION AND INTERPRETATION

(25 minutes)

Directions: This part consists of selections from newspapers, magazines, textbooks, etc. Following each selection are several multiple-choice items concerning it. Read the selection carefully first, and then decide on the basis of the selection which one of the choices given after each question or incomplete statement **best** answers the question or completes the meaning of the statement. Make use of your knowledge of science and logical thinking, but assume that all statements of fact in the selection are true. If you cannot decide, you may reread the selection. Then put the **number** of your choice in the parentheses at the right.

For years scientists have dreamed of cheap oxygen. With it, revolutionary changes would take place in the smelting of ores, the making of steel, and the manufacture of synthetic fuels. Coal—even Dakota's lignite, Minnesota's peat, or the sub-bituminous coal found in more than half the states—could be caused to react with cheap oxygen and water to make an inexpensive gas equivalent to natural gas in heating value.

In 1902 Carl von Linde developed a commercial means of liquefying air and distilling oxygen out of it. About 30 years later, two chemists, Franz Fischer and Hans Tropsch, discovered that the gases resulting from the action of oxygen on coal and steam could be made to react under heat and pressure to produce cheap inflammable fuel gas, gasoline, Diesel oil, and many other chemicals.

Commercial production of oxygen by Germany during World War II for use in the Fischer-Tropsch reaction brought the price of the gas down from $72 to $4 a ton. By improvement of engineering methods and construction of larger plants, it was found that the cost of oxygen could be cut to $2 a ton.

In such a plant air is whirled at tremendous speeds in centrifugal compressors. Part of this air is allowed to expand, the expansion lowering the temperature to −275°F, and causing the compressed air to liquefy. The liquid air is then piped into a fractionating column of the type used in oil refineries. Because of their different boiling points, the oxygen and the nitrogen in the liquid air separate. Energy- and cost-saving steps are necessary all along the line. The extremely cold liquid oxygen is circulated through heat exchangers to cool the incoming air before it is compressed. Also, at the point where the compressed air expands to produce the refrigerating effect, it is passed through a turbine which produces the power to run electric generators.

Cheap oxygen's greatest impact will fall on the coal industry. Powdered coal, even though of low quality, can be burned at the mine in a chamber under pressure in the presence of oxygen and steam. This reaction produces inflammable hydrogen and carbon monoxide, plus some methane, the chief constituent of natural gas. This gas has high heating value and may be transported by pipe line at a fraction of the cost of rail transportation.

Steel makers plan to substitute oxygen for air in open-hearth furnaces. Heated by gas or petroleum flames, most open-hearth furnaces attain a temperature of 3300°F. When a stream of oxygen is added, the temperature reaches 5000°F, which hastens the melting time and quickens the chemical reactions that take place. This will increase the capacity of open-hearths and blast furnaces—at least 25 per cent. Cheap oxygen offers a means of recovering low-grade iron ores from the fabulous Minnesota Mesabi range deposits and extending the industrial life of this iron mountain scores of years.

Oxygen will also find jobs in smelting the ores of tin, lead, zinc, and other metals, as well as in powering rocket engines. The process described for making oxygen will also produce the nitrogen necessary to supply almost endless amounts of ammonia at unheard-of low prices, and ammonia is the basis for nitrogen fertilizers and explosives.

1. Which of the following would be the most appropriate title for this selection?
   - 1–1 How to Manufacture Cheap Oxygen Commercially
   - 1–2 The Occurrence and Use of Oxygen
   - 1–3 The Coming Age of Oxygen
   - 1–4 The Chemistry of Oxygen
   - 1–5 The Use of Oxygen in Making Synthetic Fuels . . . . 1(   )

2. The best source of cheap oxygen is
   - 2–1 water.
   - 2–2 rocks.
   - 2–3 natural gas.
   - 2–4 nitrogen.
   - 2–5 air. . . . . 2(   )

3. The high cost of oxygen has been due principally to
   - 3–1 its scarcity.
   - 3–2 its chemical activity.
   - 3–3 lack of efficient means of producing low temperatures.
   - 3–4 its limited uses.
   - 3–5 the abundance of cheap substitutes. . 3(   )

Go on to the next page.

4. In the production of oxygen, which of the following occurs when the incoming air is compressed?
4–1 The temperature of the air increases.
4–2 Power is produced to run generators.
4–3 The air is immediately liquefied.
4–4 The temperature of the air decreases.
4–5 Oxygen is separated from nitrogen. . 4( )

5. One of the by-products in the Linde oxygen process is
5–1 ammonia.
5–2 methane.
5–3 carbon monoxide.
5–4 hydrogen.
5–5 nitrogen. . . . . 5( )

6. The liquefying temperature of oxygen is nearest to
6–1 −275°F.
6–2 0°F.
6–3 330°F.
6–4 3300°F.
6–5 5000°F. . . . . 6( )

7. The Fischer-Tropsch reaction produces
7–1 carbon monoxide and hydrogen.
7–2 synthetic gasoline.
7–3 cheap oxygen.
7–4 liquid air.
7–5 ammonia. . . . . 7( )

8. In addition to the uses mentioned in the selection, it is possible that cheap oxygen might also be used
8–1 for filling dirigibles and balloons.
8–2 as a household fuel.
8–3 for filling automobile tires.
8–4 in welding.
8–5 for filling fire extinguishers. . . 8( )

9. Oxygen and steam may be made to react with coal under pressure to form
9–1 natural gas.
9–2 rayon.
9–3 carbon monoxide.
9–4 low-grade ores.
9–5 gasoline. . . . . 9( )

10. If the cheap oxygen produced by the improved process described in the selection were used, what would be the cost of the oxygen necessary to burn four tons of alcohol in a rocket, if two tons of oxygen were used up in burning one ton of alcohol?
10–1 $8
10–2 $16
10–3 $72
10–4 $144
10–5 $576 . . . . 10( )

11. The greatest decrease in the cost of oxygen was brought about by its large-scale use in in the manufacture of
11–1 ammonia.
11–2 steel.
11–3 synthetic fuels.
11–4 inflammable hydrogen.
11–5 liquid air. . . . . 11( )

12. The cooling effect of the expansion of the air which occurs in the production of oxygen is a phenomenon which
12–1 occurs only because the temperature is already at a low point.
12–2 is a peculiarity of air.
12–3 occurs because the gas was originally under a low pressure.
12–4 is caused by the liquefaction of part of the air.
12–5 occurs when any gas expands. . . . 12( )

* * * * * * * *

Go on to the next page.

It is a common observation that the evaporation of any liquid causes a reduction in the temperature of the remaining body of liquid. This phenomenon can be simply interpreted in terms of the following assumptions of the kinetic theory:

a) All substances are composed of small, separate particles (molecules) which are in constant motion.

b) At any given temperature, the molecules of a substance move with different speeds. Some are almost stationary, some move with very high speeds, but most molecules move at about the average speed. Molecules do not move at constant speed, but alter their speed upon collision.

c) The temperature of a substance is a measure of the average speed of its molecules. The greater the average speed, the higher the temperature.

When a liquid evaporates, molecules of the liquid escape into the space above the liquid. The molecules which escape are those which are moving rapidly enough to overcome the attractive forces of their neighbors. It follows, therefore, that the faster molecules will escape from the liquid, leaving the slower molecules behind. As a result, the average speed of the molecules left in the liquid is lower than the average speed of the original molecules. The temperature of the remaining liquid is, therefore, lower than that of the original liquid.

13. The evaporation of part of a liquid results in
13–1 a decrease in the average speed of the molecules of the liquid.
13–2 an increase in the temperature of the liquid.
13–3 an increase in the rate of collision between molecules of the liquid.
13–4 an increase in the average speed of the molecules of the liquid.
13–5 a decrease in the amount of vapor above the liquid. . . . . 13( )

14. Which one of the following statements describes a property of the molecules of a liquid?
14–1 The molecules all move with the same speed.
14–2 The molecules exert attractive forces upon each other.
14–3 The molecules decrease in speed when the liquid is heated.
14–4 The molecules move at a constant speed if the temperature of the liquid changes continuously.
14–5 The molecules go into the vapor state more rapidly if the liquid is cooled. . . . . 14( )

15. Evaporation lowers the temperature of
15–1 only heavy liquids at high temperatures.
15–2 only light liquids at low temperatures.
15–3 only liquids whose molecules move rapidly.
15–4 only liquids whose molecules move slowly.
15–5 any liquid at any temperature. 15( )

16. At which one of the following temperatures do the molecules of a given substance have the highest average speed?
16–1 10°C
16–2 20°C
16–3 30°C
16–4 40°C
16–5 50°C . . . . . 16( )

17. The lowering of the temperature of a liquid by evaporation was probably first discovered by
17–1 deducing the consequences of the kinetic theory.
17–2 controlled experimentation.
17–3 speculation.
17–4 observation.
17–5 inspiration. . . . . 17( )

18. Which one of the following is most likely to occur when a very rapidly moving molecule collides with one which is practically stationary?
18–1 The rapidly moving molecule will gain, and the stationary molecule will lose, kinetic energy.
18–2 The rapidly moving molecule will lose, and the stationary molecule will gain, kinetic energy.
18–3 Both molecules will gain kinetic energy.
18–4 Both molecules will lose kinetic energy.
18–5 The kinetic energy of each molecule will be unaffected. . . . . 18( )

19. One can infer from the passage that the cooling of any substance results in a decrease in the
19–1 weight of the molecules.
19–2 decomposition of the molecules.
19–3 volume of the molecules.
19–4 number of collisions between the molecules.
19–5 attractive forces between the molecules. . . . . 19( )

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The great botanist Sachs was interested in the factors which affect the process of sugar manufacture (photosynthesis) in the green leaves of plants. These factors he thought to be the illumination, the temperature, and the carbon dioxide content of the atmosphere, assuming otherwise normal growing conditions. In order to determine whether or not light was essential to photosynthesis, Sachs carried out the following experiment:

Early in the morning of a warm, sunny day he cut a given area from one half of each of a number of leaves. This tissue he deprived of all its water by heating it to 100°C until it lost no more weight. In the late afternoon he cut from the intact halves of the same leaves an area of leaf tissue equal to that which had been taken in the morning. This leaf tissue he also deprived of its water. Upon comparing the dry weights, he found that the tissue taken in the evening weighed more than that taken in the morning. The difference represented only part of the material manufactured by the leaf surface during the day, for some of the sugar made was conducted away from the leaf and some was lost by respiration. When the experiment was repeated with plants which were kept in the dark during the day, he found no increase in dry weight.

20. In the experiment, Sachs wished to discover whether
20–1 the raw materials of photosynthesis are carbon dioxide and water.
20–2 sugar is a product of photosynthesis.
20–3 a warm day is needed for photosynthesis.
20–4 carbon dioxide is needed for plant respiration.
20–5 light is needed for the production of sugar by plant leaves. . . . . . . 20(   )

21. "Otherwise normal growing conditions" (line 6) probably means
21–1 average soil and water conditions.
21–2 conditions necessary for rapid growth of the plant.
21–3 good atmospheric conditions.
21–4 the best possible atmospheric and soil conditions.
21–5 bright sunlight. . . . . 21(   )

22. One of the materials consumed in the process of photosynthesis by a plant is
22–1 light.
22–2 starch.
22–3 sugar.
22–4 carbon dioxide.
22–5 chlorophyll. . . . . 22(   )

23. Sachs would have found a greater increase in the dry weight of the leaves if
23–1 it had not been such a warm day.
23–2 conduction of sugar away from the leaf had not occurred.
23–3 the first weighing of the leaf areas had been done the evening before.
23–4 transpiration had occurred.
23–5 respiration had occurred. . . . . . 23(   )

24. Sachs had to repeat the experiment using plants kept in the dark in order to
24–1 prevent the evaporation of water.
24–2 prove that sugar was formed.
24–3 demonstrate that darkness is not healthful for plants.
24–4 show that all plant activities go on in darkness.
24–5 demonstrate the necessity of light for an increase in weight. . . . . . 24(   )

25. The most justifiable conclusion which Sachs could draw from the experiment was that
25–1 plant leaves absorb water during the day.
25–2 the increase in weight of the leaves is caused by the absorption of carbon dioxide.
25–3 light is essential to the increase in dry weight of the plant.
25–4 light falling on the plant causes the leaves to consume oxygen.
25–5 carbon dioxide is absorbed from the air. . . . . 25(   )

26. To round out the evidence secured from this experiment, Sachs should have carried out another to determine
26–1 the amount of carbon dioxide lost when the leaves were heated.
26–2 the necessity of high temperatures for photosynthesis.
26–3 whether carbon dioxide is formed in photosynthesis.
26–4 the amount of water needed by the leaves.
26–5 whether the increase in weight was caused by formation of sugar. . . 26(   )

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Solubility in Water of Certain Compounds

The following table shows the number of grams of the solute that can be dissolved in 100 grams of water (the solvent) at the temperature indicated.

Solute	0°C	10°C	20°C	30°C	40°C	50°C	60°C	70°C	80°C	90°C	100°C
Boric acid	2.59	3.45	4.8	6.3	8.0	10.3	12.9	15.7	19.1	23.3	28.7
Calcium hydroxide	0.185	0.176	0.165	0.153	0.141	0.128	0.116	0.106	0.094	0.085	0.077
Lithium sulfate	26.1	25.9	25.5	25.1	24.7	24.5	24.2	23.8	23.5	23.2	23.0
Potassium chlorate	3.3	5.0	7.4	10.5	14.0	19.3	24.5	31.2	38.5	46.9	57.0
Potassium chloroplatinate	0.74	0.90	1.12	1.41	1.76	2.17	2.64	3.19	3.79	4.45	5.18
Potassium nitrate	13.3	20.9	31.6	45.8	63.9	85.5	110.0	138.0	169.0	202.0	246.0
Silver nitrate	122.0	170.0	222.0	300.0	376.0	455.0	525.0	595.0	669.0	780.0	952.0
Sodium chloride	35.7	35.8	36.0	36.3	36.6	37.0	37.3	37.8	38.4	39.0	39.8
Sodium iodide	158.7	168.6	178.7	190.3	205.0	227.8	256.8	294.0	296.0	299.0	302.0
Sodium tetraborate	1.3	1.6	2.7	3.9	6.3	10.5	20.3	24.4	31.4	40.8	52.3

27. A 100-degree change in temperature causes the smallest change in the solubility of which one of the following substances?
27–1 Boric acid
27–2 Lithium sulfate
27–3 Sodium tetraborate
27–4 Potassium chlorate
27–5 Potassium chloroplatinate . . . . 27( )

28. A solution consisting of 3.19 grams of potassium chloroplatinate in 100 grams of water at 70°C is
28–1 a normal solution.
28–2 a colloidal solution.
28–3 a saturated solution.
28–4 an unsaturated solution.
28–5 a supersaturated solution . . . . 28( )

29. Which one of the following conclusions can be drawn from the data given in the table?
29–1 The solubility in water of most of the compounds listed in the table usually increases with a rise in temperature, the amount of the increase varying greatly with the substance.
29–2 The solubilities of compounds in other solvents, such as alcohol or benzene, are proportional to their solubilities in water.
29–3 The composition of the solute and that of the solvent are the only factors that determine solubility.
29–4 The solubility of any compound in water is directly proportional to the temperature of the solution.
29–5 Water solutions of the compounds in the table boil at 100°C. . . . . . . 29( )

30. Which compound shows the greatest percentage increase in solubility from 0°C to 100°C?
30–1 Potassium nitrate
30–2 Sodium tetraborate
30–3 Boric acid
30–4 Potassium chloroplatinate
30–5 Silver nitrate . . . . 30( )

31. Potassium nitrate is more soluble in water than is sodium chloride at
31–1 all temperatures.
31–2 no temperature.
31–3 only one temperature.
31–4 only temperatures below approximately 23°C.
31–5 only temperatures above approximately 23°C. . . . 31( )

32. The effect of a rise in temperature on the solubility of lithium sulfate is similar to the effect of a rise in temperature on the solubility of
32–1 calcium hydroxide.
32–2 potassium chlorate.
32–3 potassium chloroplatinate.
32–4 potassium nitrate.
32–5 sodium iodide. . . . . 32( )

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33. What will be the result if 50 grams of silver nitrate are thoroughly mixed with 10 grams of water at 30°C until as much silver nitrate as possible is dissolved?

33–1 All of the silver nitrate will be dissolved.
33–2 40 grams of the silver nitrate will be undissolved.
33–3 30 grams of the silver nitrate will be undissolved.
33–4 20 grams of the silver nitrate will be undissolved.
33–5 The mixture will be a very dilute solution. . . . . 33( )

34. At approximately what temperature are the solubilities in water of lithium sulfate and sodium tetraborate the same?

34–1 58°C
34–2 60°C
34–3 68°C
34–4 73°C
34–5 78°C. . . . . 34( )

35. What is the lowest approximate temperature at which 20 grams of potassium nitrate will dissolve in 10 grams of water?

35–1 0°C
35–2 10°C
35–3 20°C
35–4 90°C
35–5 Some temperature above 100°C . . 35( )

36. If a cubic centimeter of pure water weighs one gram, the weight of 10 cubic centimeters of a saturated water solution of silver nitrate at 40°C

36–1 is 10 grams.
36–2 is 37.6 grams.
36–3 is 47.6 grams.
36–4 is 386 grams.
36–5 cannot be determined from the table. . . . . 36( )

If you finish before the time is up, you may go back and work on either part.

Number wrong	0–2	3–6	7–10	11–14	15–18	19–22	23–26	27+
Amount to be subtracted	0	1	2	3	4	5	6	7

Number right________

Subtract________
(See table above)

Raw Score on Part II = Difference________