AN ABSTRACT OF THE THESIS OF

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Title FEASIBILITY OF INTEGRATION OF SELECTED ASPECTS OF
(CBA) CHEMISTRY, (CHEMS) CHEMISTRY AND (PSSC)
PHYSICS INTO A TWO YEAR PHYSICAL SCIENCE SEQUENCE

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(Major Professor)

The purpose of this study is to compare in selected outcomes the
effectiveness of an integrated chemistry-physics course with chemis-
try and physics courses taught separately.

Six classes, three of which studied an integrated course prepared
from content of the CBA chemistry course and the PSSC physics
course and three of which studied an integrated course developed from
PSSC physics and CHEMS chemistry materials, constituted the treat-
ment groups. Six PSSC physics classes, three CBA chemistry classes
and three CHEMS chemistry classes constituted control groups.

Treatment and control classes were compared in (1) gains in
critical thinking; (2) subject matter achievement gains in chemistry
and physics and (3) changes in attitudes towards science and the scien-
tist.

A pretest battery of tests and questionnaires was administered to
all students in the Fall of 1963. A posttest battery consisting of
identical or equivalent instruments was given in the Spring of 1964. Instruments used were the Otis Mental Ability Test Gamma: Form EM; a student questionnaire; a teacher questionnaire; the Watson Glaser Critical Thinking Appraisals, Form YM and ZM; a chemistry achievement examination and a physics achievement examination. Using classes as units data was analyzed using a paired t-test.

The following conclusions were drawn from this study.

1. There is no significant difference in performance on a critical thinking criterion test between classes that study the integrated chemistry-physics courses and those classes that study separate chemistry courses.

2. There is no significant difference in performance on a critical thinking criterion test between classes that study the integrated chemistry-physics courses and those classes that study the separate physics course.

3. There is no significant difference in performance on an achievement criterion test between classes that study the integrated chemistry-physics courses and those classes that study separate chemistry courses.

4. There is no significant difference in performance on an achievement criterion test between classes that study the integrated chemistry-physics courses and those classes that study the separate physics course.
5. There is no significant difference in changes of attitudes toward science and the scientist between students who study integrated chemistry-physics courses and students who study separate chemistry courses.

The fifth hypothesis was divided into fifteen sub-hypotheses based on selected attitude statements about science and the scientist.

Appendix B.

Of fifteen tests of sub-hypotheses with respect to changes of attitudes towards science among treatment and chemistry control classes, the null hypothesis was accepted for thirteen of them and rejected for two. One of these rejections favored the integrated classes, the other the chemistry control classes.

6. There is no significant difference in changes of attitudes towards science and the scientist between students who study integrated chemistry-physics courses and students who study a separate physics course.

The sixth hypothesis was divided into fifteen sub-hypotheses based on selected attitude statements about science and the scientist.

Appendix B.

Of fifteen tests of sub-hypotheses with respect to changes of attitudes towards science among treatment and physics control classes, fourteen were accepted and one was rejected. The rejection favored the treatment classes.
FEASIBILITY OF INTEGRATION OF SELECTED ASPECTS OF (CBA) CHEMISTRY, (CHEMS) CHEMISTRY AND (PSSC) PHYSICS INTO A TWO YEAR PHYSICAL SCIENCE SEQUENCE

by

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FEASIBILITY OF INTEGRATION OF SELECTED ASPECTS OF (CBA) CHEMISTRY, (CHEMS) CHEMISTRY AND (PSSC) PHYSICS INTO A TWO YEAR PHYSICAL SCIENCE SEQUENCE

CHAPTER I

INTRODUCTION

The need to seek continuity in science offerings has been of interest to the science educator for quite some time. Arbitrary fragmentation into traditional disciplines such as physics, chemistry and biology has been seriously questioned by a persistent core of curriculum specialists over the past half century. Recently, The Panel on Educational Research and Development has again raised this issue with the following statement.

... The division of science, at the secondary school level, into biology, chemistry and physics is both unreasonable and uneconomical.

Ideally, a 3 year course that covered all three disciplines would be far more suitable than a sequence of courses which pretends to treat them as distinct... (59, p. 52)

From our vantage point in history it is evident that previous attempts to integrate the sciences have met with mixed success. Blending of botany and zoology into biology early in the present century has gained wide acceptance until this fused course is taught almost to the exclusion of the separate courses. Yet, integrated physical science courses have never been able to claim a large and enthusiastic following on the secondary school level, at any rate. Integration of the physical sciences has been tried in numerous ways; often technology and functional information have served as the core
of such a course. Several courses of study have been formulated which draw their substance from fundamental concepts in physics, chemistry, astronomy, geology, meteorology and mathematics. A third kind of course limited content to chemistry and physics.

These courses together with others that combined the themes described above were adopted in the era between 1920 and 1955; none of them however, achieved the status of the fused biology course.

The Physical Science Study Committee was initiated in 1956 to consider preparation of an integrated two year sequence in physical science which was to include the major concepts of both physics and chemistry.

The first of the major science curriculum reforms was the Physical Science Study Committee, and, as its name suggests, it began in revolt against the fractionation of chemistry and physics at the high school level into separate disciplines. This revolt was short-lived; it proved impossible in 1956 to bring physicists and chemists under the same roof, and the PSSC proceeded to devote its efforts exclusively to physics. In doing so it set a model for later curriculum programs in science, and the fractionation has persisted. (59, p. 52)

Several months later chemists set about updating the traditional high school chemistry course, utilizing organizational patterns that proved so productive for the Physical Science Study Committee. The two groups that met with the most success were The Chemical Bond Approach Committee (CBAC) and the Chemical Education Materials Study (CHEMS).

The three courses PSSC physics, CBA chemistry and CHEMS
chemistry were vast improvements over the traditional courses in several respects. Emphasis of scientific principles replaces technology and industrial applications, they are intellectually more satisfying in the sense that depth of subject matter coverage in a few selected topics replaces superficial treatment of many, laboratory activities are truly directed at conveying to students the empirical nature of science and finally a variety of superior instructional materials specifically designed to accompany the courses are provided for students.

The problem of fragmentation, however, still remained. This condition is accompanied by unnecessary duplication of subject matter, faulty topic sequence, superficial treatment of some rather profound natural laws and the belief among students that chemistry and physics are unrelated. More specifically, thorough mastery of many concepts in the new chemistry courses depend on understanding, in depth, of energy relationships. These are presented rather superficially with the result that students leave the course with limited insight into these magnificent conservation laws. The PSSC physics course treats this topic in depth--both on macroscopic and submicroscopic levels and energy systems in between. Other topics such as behavior of gases, electrochemical cells, the structure of matter, structure of the atom and electrical phenomena are part of the content of most modern chemistry and physics courses.
This is rather uneconomical in terms of time expenditure and is also costly in dollars. Substantial savings can be realized if the respective contents of both chemistry and physics courses are sifted and content deleted to avoid this duplication.

In the textbook developed by PSSC, Physics (43, p. 95-150), hasty work is made of the evidence for our belief in the atomicity of matter. This is not intended to be a criticism of the text for it is not possible to devote the necessary pages to present a convincing case for this concept in a physics text book. Integration could permit the use of the more elaborate treatment of this concept found in one of the chemistry texts. Another example refers to the rather intuitive manner in which potential and kinetic energy are discussed in Chemical Systems (12, p. 173-199), the CBA textbook, and Chemistry An Experimental Science (33, p. 113-114) the CHEMS textbook. Here the PSSC textbook provides a detailed, quantitative approach that should provide students with a clearer understanding of these concepts.

Close inspection of the courses also reveals that what might be called the tools of the physical scientist and his epistemology are also duplicated in these courses. Graphical analysis, significant figures, measurement, scientific notation and model building are representative examples of this.

Confronted with evidence of this sort PSSC, CBA, and CHEMS
teachers began to ask, why not capitalize on the strengths of the new courses by effecting an integration of them? Two such courses have been constructed by the Portland Project Committee; one combines PSSC with CBA the other PSSC with CHEMS.

School administrators, science educators and parents will be vitally concerned about the educational outcomes of these courses. Questions are sure to be raised regarding their effectiveness in conveying subject matter content as compared with the separate courses.

Other educational values that may be influenced by an integrated course relate to its effect on critical thinking abilities. For example, is there a discernible influence on students' abilities to recognize assumptions, to formulate hypotheses, to interpret data and draw valid conclusions? Yet another question that requires answering which is suggested by such a curriculum change relates to changes in students' attitudes towards science and the scientist as a result of his encounter with the integrated course. Does he more readily perceive himself in the role of a scientist? How does he react to content when presented in the integrated fashion: is it more or less difficult? How is his awareness of the interaction of science and the culture modified? Is there a differential change in how he views the scientific process? All of these and many other questions arise when one contemplates this particular science curriculum change. Such questions give rise to the current study.
The Problem

The purpose of this study is to compare the effectiveness, in selected outcomes, the integrated chemistry-physics courses developed by the Portland Project committees with chemistry and physics courses taught separately. Experimental and control classes are evaluated in terms of differential gains in subject matter achievement, critical thinking abilities and attitudes towards science.

Hypotheses

1. There is no significant difference in performance on a critical thinking criterion test between classes that study the integrated chemistry-physics courses and those classes that study separate chemistry courses.

2. There is no significant difference in performance on a critical thinking criterion test between classes that study the integrated chemistry-physics courses and those classes that study the separate physics course.

3. There is no significant difference in performance on an achievement criterion test between classes that study the integrated chemistry-physics courses and those classes that study separate chemistry courses.

4. There is no significant difference in performance on an
achievement criterion test between classes that study the integrated chemistry-physics courses and those classes that study a separate physics course.

5. There is no significant difference in changes of attitudes towards science and the scientist between students who study integrated chemistry-physics courses and students who study separate chemistry courses.

The fifth hypothesis is divided into fifteen sub-hypotheses derived from selected attitude statements (Appendix A, pages 139-141) about science and the scientist. The sub-hypotheses stated in null form are:

There is no significant difference in changes of attitudes on the following statements between students who study the integrated chemistry-physics courses and students who study separate chemistry courses:

1. Science is a systematic way of thinking.
7. To become a scientist requires superior ability.
9. Scientists are willing to change their ideas and beliefs.
12. Modern science is too complicated for the average citizen to understand and appreciate.
14. It is undemocratic to favor exceptional scientific talents.
15. The monetary compensation of a Nobel Prize winner in physics should be at least equal to that given popular entertainers.
20. Scientists are honored persons who stand very high in popular prestige.

24. Scientific work is boring.

26. Scientific findings always lead to final truths.

34. There is much self-satisfaction to be received from work as a scientist.

36. Science helps us to understand our environment.

42. Scientific work is monotonous.

43. The working scientist believes that nature is orderly rather than disorderly.

47. Curiosity motivates scientists to make their discoveries.

48. The chief reward in scientific work is the thrill of discovery.

6. There is no significant difference in changes of attitudes towards science and the scientist between students who study integrated chemistry-physics courses and students who study a separate physics course.

The sixth hypothesis is divided into fifteen sub-hypotheses derived from selected attitude statements (Appendix A, pages 139-141) about science and the scientist. The sub-hypotheses stated in null form are:

There is no significant difference in changes of attitudes towards science on the following statements between students who study the integrated chemistry-physics courses and students who study a
separate physics course:

1. Science is a systematic way of thinking.

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15. The monetary compensation of a Nobel Prize winner in physics should be at least equal to that given popular entertainers.

20. Scientists are honored persons who stand very high in popular prestige.

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36. Science helps us to understand our environment.

42. Scientific work is monotonous.

43. The working scientist believes that nature is orderly rather than disorderly.

47. Curiosity motivates scientists to make their discoveries.

48. The chief reward in scientific work is the thrill of discovery.
Assumptions

1. The Otis Quick Scoring Mental Ability Test, Gamma: Form EM is a valid and reliable instrument for measuring students' scholastic abilities.

2. The Watson-Glaser Critical Thinking Appraisals, Forms YM and ZM are valid and reliable instruments for measuring critical thinking abilities.

3. Selected items from the Reaction Inventory, Attitudes Towards Science and Scientific Careers measures students' attitudes towards science and the scientist.

4. The chemistry and physics achievement examinations assembled by the investigator possess content validity and reliability.

5. Student and teacher involvement in this experiment did not differentially influence their performance in the courses or on examinations.

Limitations

1. Data accumulated and analyzed over a test period of one year is utilized to generalize about students' subject matter achievement, changes in critical thinking abilities and attitudes towards science.

2. Instructional facilities and equipment available to students and teachers could not be controlled in the experimental and control groups.
3. Teacher preparation was controlled only insofar as there was evidence that he had preparation and/or teaching experience in CBA, CHEMS, or PSSC.

4. Participating schools were limited to the Portland, Oregon, Metropolitan Area, and thus can be expected to yield results characteristic of one kind of school setting.

Meaning of Integration

According to Gwynn (26, p. 243) "integration" is one of the most abused and misused of technical terms. It has been employed in the literature in two senses, one referring to the growth of the whole child and the other referring to the uniting of subject matter. At the present time there is no clear understanding among many teachers as to whether integration refers to one or the other of these meanings.

The term "integration" came into general use as studies revealed that the child did not develop in parts but as a whole. These studies gave rise to the use of the term "integration" to mean the formulation, development and union of the child's activities into a unified growth pattern. "Integration" in this sense refers to the processes which occur within the mind of the individual when he establishes a close relationship between diverse factors in his environment.
In this volume the term "integration" will be used together with "correlation" to mean unification of subject matter content which is extracted from separate disciplines. Hurd as reported in Alcorn (1, p. 155) gives support for this connotation to the term when he says, "There is a trend towards the integration of a wide range of science fields. Within the next few years one may expect high schools to teach Science I, II, III and IV, rather than general science, biology, physics and chemistry." Fuller's remarks (24, p. 5) give further support to this interpretation of the term. He says, "If the beginning student is to understand the fundamental interdependence of modern chemistry and physics, he should be introduced to these two sciences in an integrated course."

Inspection of the outlines and the descriptions of the physics-chemistry courses developed by the Portland Project Committees that appear on pages 32-43 of this volume reveals that these courses are developed in accordance with Fuller's recommendations for "integrated courses"; chemistry and physics content are intermeshed with one another.
CHAPTER II

REVIEW OF THE LITERATURE

Much has been written concerning the educational values to be derived through integration of various subject matter disciplines. This chapter is concerned with a summary of these publications, first in a general way, then with attention fixed on a discussion of integration of chemistry and physics for secondary schools. This chapter is presented in three sections:

1. Historical and Philosophical Considerations That Concern Integrated Curricula
2. Historical and Philosophical Considerations That Concern Integrated Chemistry and Physics Courses
3. Integrated Physical Science Courses and Their Evaluations.

Historical and Philosophical Considerations That Concern Integrated Curricula

Integrated curricula were originated as a reaction against severe compartmentalization which characterized the curriculum of most schools in the early nineteenth century. When it was recognized that the solution of many problems required breadth of knowledge integration of school subjects began to gain favor.

There appear to be at least two fundamental values that can be derived from course integration. The first can be traced to
educational theory formulated by Herbart which emphasizes concentration, i.e., the complete absorption of the learner in the learning task.

The correlated curriculum is a subject curriculum in which two or more subjects are articulated and relationships between them or among them are made a part of the instruction without destroying the subject boundaries. The idea of correlating courses originated in the last century from the psychological and educational conceptions of Herbart. His views laid great stress upon concentration, by which he meant complete absorption in an idea or object of thought, and correlation, by which he meant the reinforcement of the idea by related and supporting conceptions. (51, p. 399-400)

Tyler (54) states in his article dealing with the organization of learning experiences that the primary function of curriculum organization is to relate learning experiences as much as possible to obtain the maximum cumulative effect. This reinforces the Herbart belief about the efficacy of correlation of learning experiences.

In their textbook, Fundamentals of Curriculum Development, Smith, Stanley and Shores (51, p. 495) suggest that bringing the content of two or more courses together and reorganizing the experiences into a coherent whole is an improvement over the piece-meal presentation of the separate courses where the recognition of interrelationships is left to chance. They point out that new relationships can be developed which might have been neglected due to adherence to "specialized interests or fear of teaching beyond the subject boundaries. . ."
The second educational value that is attributed to correlated courses concerns the rapid accretion of knowledge over the past few decades. As the storehouse of fundamental concepts increases, time pressure will become an even more burdensome problem. Integration can assist in providing a partial solution to this problem by limiting duplication of content.

Taba, in her textbook *Curriculum Development - Theory and Practice* (53, p. 189-190), states that integration of knowledge is vital both from the standpoint of explosion and specialization of knowledge and from social implications of technology. She expresses the concern that pursuit of specialized subjects will become increasingly impossible as the number of specialized fields increases. Her statement on the matter is concluded with the assertion that more, rather than less emphasis is needed on integrated knowledge.

One of the more significant discussions that has increasingly occupied many academicians and lay persons alike in the past few decades centers around the inability of specialists to communicate with one another. This problem is an out-growth of zealous and successful efforts of men to add to the storehouse of fundamental knowledge. Taba says:

The fundamental truths are the treasures of many communities of specialists which often become completely cut off from each other in their rapid growth. When decisions are made they are made by a collection of experts who have no way of communicating their knowledge to each other. (53, p. 190)
Certainly integration of school subjects could help alleviate this serious limitation.

Critics of correlated courses have expressed the fear that integration breeds dilution of content and lowering of academic standards. Unfortunately this has occurred in a number of instances. This need not be the end result of integration. Taba says (53, p. 191) that by careful analysis of basic ideas in various fields it should be possible to isolate ideas that have relevance for a number of disciplines. If these concepts are extracted with care from diverse fields and re-assembled, integration of knowledge is possible without a corresponding loss of "depth, precision and intellectual discipline." The facility with which this can be accomplished is affirmed in the following words: "The more basic the ideas the more they tend to point to interrelationships with ideas of other fields at least in subjects within the same large fields."

Is there a perceivable trend towards or away from integration of courses on the secondary school level? Opinions of school principals appear to be divided in this respect. A survey completed in 1962 by a group of secondary and elementary school principals indicated that fifty percent of the respondents expected no change in trends in course organization by 1966. One fifth of them predicted further emphasis on single subjects and one fourth of those polled predicted combination of courses into broad fields. The article
concludes with the assertion that the principals expected a steady movement towards organization of content based on broad fields both in elementary and secondary schools (47, p. 36).

Historical and Philosophical Considerations That Concern Integrated Chemistry and Physics Courses

Part 1 of the present chapter considered the values that can be derived through course integration in general. The present discussion is more specific to science--with particular emphasis on the integration of chemistry and physics.

A brief recapitulation of historical events in science education that bear on the problem of integration will be followed by a sampling of opinions of prominent scientists and educators relative to the wisdom of integration. This will lead into a discussion of common structural units present in chemistry and physics as viewed by various scientists and educators. This section will conclude with a summary of trends towards integration of chemistry and physics.

The general science movement originated about 1905. This was the first evidence of a growing rebellion against highly specialized science courses for purposes of general education and by 1920 many schools had introduced the course.

Prior to the report of the Committee of Ten in 1893 (58) one semester courses in physics, chemistry, botany and zoology were
common. The report encouraged the extension of these courses to extend over a full one year period. Courses in chemistry and physics were developed that followed the recommendation of the Committee, however, there was never wide acceptance of the full year course in botany and zoology by most secondary schools.

The Committee on College Entrance Requirements in 1899 recommended for the second year of science: biology, botany and zoology, or botany and geology (58). Most schools soon complied with this recommendation and introduced one of the three courses at the freshman or sophomore level.

At first biology textbooks were partitioned in the sense that the first half of the book explored botany content with the second half being devoted to zoology. Gradually authors began to correlate the two divisions around central themes such as life processes. Publication of such texts triggered a corresponding increase in biology courses. The trend was away from botany and zoology courses per se. Today biology is taught in most schools virtually excluding the separate courses which preceded it (58).

The movement towards integration of chemistry and physics, which was to come much later took on a double character. One kind of course stressed consumer application and social values of science; the other was based on exposition of fundamental laws of chemistry, physics and often times geology and astronomy (49).
A more detailed description of a few of these courses together with results of evaluation studies are given later in this chapter.

Charges were made by many academicians that all integrated science courses lacked intellectual challenge. These reactions, in many instances, had some basis in fact because any attempt to survey several subject matter fields runs the risk of superficiality in an effort to treat all or most of the major concepts of those fields. This was pointed out earlier in the chapter as an inherent danger in all curriculum synthesis projects.

Other objections to prevalent practices in designing integrated science courses soon arose. They were conceived to provide for two basic educational needs. First, to serve as a foundation on which to build subsequent specialized subject matter and second, to meet the need of many students for general education in the sciences in the form of terminal courses. Most courses failed in their attempt to provide for each of the two kinds of students. Subject matter coverage was too broad and consequently lacked sufficient depth and intellectual challenge to serve the needs of the former group and were too disjointed to serve the needs of the latter because textbooks consisted of excerpts from college textbooks with little sense of unity (49).

In spite of past failures to achieve a satisfactory blending of physical science concepts, particularly those which deal with chemistry and physics, a strong climate of opinion persists among prominent
science educators urging that new attempts be made in this direction.

It is rather surprising in view of the abundance of support for integrated science courses generally and physics-chemistry courses in particular that progress in this direction has not been more rapid. Possibly, the very people who are advocating efforts in this direction are themselves handicapped by insufficient familiarity with both the sciences. Partition of the subjects in formal education seems to be a barrier that prevents training of persons sufficiently knowledgeable about the several fields to effect their integration. A panel established in 1961, operating under the auspices of the President's Science Advisory Committee, prepared a rather strong statement supporting integration of the sciences (59, p. 21-22). Jarrold Zacharias, one of the leaders in the PSSC movement and a spokesman for the panel, asserted that although there is much reason for satisfaction with the outcome of PSSC, CHEMS, CBA and BSCS (The Biological Curriculum Study), there are major deficiencies as well. He points out that "the division of secondary school science into biology, chemistry and physics is both unreasonable and uneconomical." He says further that ideally a three year sequence which combines content from all three subjects would be far more suitable. He exhorts those interested in science curriculum to recognize that such a coordinated course is possible within the existing framework and might be readily adopted if available. His statement is concluded
with a plea for immediate action on this problem because the time has now arrived that the separate disciplines are presented in a manner acceptable to the professional scientist which should facilitate integration at this time.

Slesnick (49) also says that science must be viewed as a single structure. He says further that the research scientist has divided this field of knowledge to assist in providing research avenues towards understanding the corporate whole. Outside of the artificial arrangements in laboratories or classrooms one does not meet problems "biologically, physically or chemically." He very wisely points out that a tree, a stalled automobile or a mouse in the basement are not phenomena that concern a single subject matter. His statement is concluded with the observation that the solution of problems in science and industry requires knowledge that cuts across subject matter boundaries.

Those few scholars who have devoted many years to intensive study and reflection on common structural units in physics and chemistry are satisfied that there is sufficient commonality in course content to justify their union into a fused course. For example, the Beloit Conference convened in 1961 to bring together college teachers who had experience with integrated chemistry and physics courses. The purposes of the conference were to exchange information and to discuss propagation of this mode of instruction on both college and
secondary levels. Edward Fuller, chairman of the conference, made these comments about the interdependence of chemistry and physics in his summary report.

Chemistry has grown to such an extent that it is futile to introduce a student to this science by presenting him with an array of facts. The essentials of modern chemistry can be grasped by the student only when he comprehends a framework of principles and theories to which facts can be related. Modern theories in chemistry are developing in directions which increasingly demand understanding of certain fundamental concepts of physics. The opposite is also true: The most effective way to present modern chemistry and physics is to teach them together.

Several aspects of modern physics at the introductory level require the student to think in terms of atoms and molecules. Learning some basic chemical concepts along with physics enables the student to grasp more effectively the physical principles involved. The blending of chemistry with physics is most obvious in studies of the structure of matter and its interactions with energy in the form of heat, electricity and electromagnetic radiations. (24, p. 5)

In their textbook, *Fundamentals of Curriculum Development*, (51, p. 406) Smith et al. recognize that some principles of science are more fundamental than others in the sense that the latter are included in the former. The authors point out that Boyle's Law, which concerns the volume changes observed when pressures are applied to gases, commonly considered physics content, must be explained with the molecular theory of matter. The molecular theory of matter is a generalization that cuts across subject matter fields because not only does it explain Boyle's Law, but also the Law of Charles and the Law of Partial Pressures both of which are considered
chemistry content. It is suggested that these major generalizations can constitute the core of an integrated physics-chemistry course.

There appears to be a definite trend towards correlation of subject matter in the sciences on the undergraduate and the graduate levels of education. Harold Schilling, Dean of the Graduate School at Pennsylvania State University, in a speech delivered to a committee of educators interested in combined physics and chemistry courses (48, p. 14), points out that productive scholarship and graduate work are increasingly concerned with problems that transcend traditional disciplinary boundaries and require understanding and competence in more than one field. He says that this trend is quite evident if one would take the time to peruse lists of doctoral dissertations, research projects in progress and dual professional appointments. Dr. Schilling observes, in addition, that in industry the chemist and physicist loses his identification with his subject matter specialty very quickly.

Hurd in Alcorn (1, p. 155-159) believes that there is a trend towards the integration of a wide range of science fields. He feels that within the next few years one may expect schools to teach Science I, II, III and IV rather than general science, biology, physics and chemistry. He predicts that the first two years will be devoted to a two year synthesis of the biological sciences and the remaining two years to study of a two year physical science sequence.
McKibben (36) finds that there is a trend towards a new kind of physical science course which embodies principles of chemistry and physics. The course is academically sound in that broad coverage is replaced by penetration in depth of only a few subject matter areas; applications of science and technology are reduced to a minimum.

An unpublished masters thesis by Martens (35, p. 1-98) surveyed student and teacher attitudes towards integrated chemistry-physics courses. Twenty-seven teachers distributed nationally, who were then engaged in teaching such a course, responded to a questionnaire. A second questionnaire completed by 1034 students indicated their preferred scientific interests and their opinions with respect to the most valuable learning activities of science.

Teachers cited as advantages of the integrated course:

1. Greater emphases on the unity of science.
2. Better coverage of principles.
3. Economy in time utilization.
4. More logical presentation of topics.

In summarizing the content of integrated chemistry-physics courses, Martens says that teachers felt there was little evidence that it departed radically from the content of the separate courses.

Student responses revealed that interests of girls were more in harmony with chemistry and the historical background of the physical sciences; they were also less curious about unknown topics
and their interest seems to increase as they gain added experience with a science subject. Boys were more appreciative of the role of mathematics in the sciences and also showed a higher preference for physics; particularly topics dealing with mechanics, electricity and technological applications.

Martens interprets her findings as crucial in the design of science curriculum. She feels that the integrated physics-chemistry course will give girls experience with physics which should stimulate them to desire more knowledge in this area. She says that by ignoring the boundaries between the sciences the gap between the known and the unknown may be bridged. Finally Martens suggests incorporation of more historical material to enhance the interest of girls in physical science.

Integrated Physical Science Courses and Their Evaluations

The central position of evaluation in all curriculum development is supported by a McNally and Passow publication, *Improving the Quality of Public School Programs* (37, p. 106-107). They observe that evaluation of curriculum development programs can have two foci: the process and the product. Evaluation calls for appraising student attainments both before and after curriculum development activities as well as gathering data to ascertain what changes should be made in these procedures. They affirm that the center of such
evaluations should be the student and the techniques and procedures used are those that will yield data on his growth and achievement.

Anderson (3, p. 234) and Caswell (7, p. 98) concur with the assertions that curriculum innovations must be evaluated and that their effectiveness ultimately depends on changes in the behavior of students. Doll (18, p. 303-325) believes that the behavior and performance of the teacher is also worth noting in such a study. He warns, however, that one should not expect dramatic results of curriculum changes.

One of the earliest attempts at integration of chemistry and physics into a two year course is that reported in 1941 which was undertaken at the Phillips Exeter Academy. Students had the option of electing one year of physics, one year of chemistry, a minor course in chemistry or physics followed by a second year of that course, or a two year course in physical science.

Among the pertinent findings are (1) that the two year course in one science results in higher achievement than one-year courses in chemistry and physics and (2) that the integrated course results in higher achievement than the physical sciences taken separately. (39)

A study to make comparisons of a fused physics-chemistry course which emphasizes consumer application with a conventional physics course is reported by Heidel (28). The study was done at Chuska High School, Chuska, Minnesota. Heidel reports the following results:
1. Both courses produced gains in knowledge of scientific facts and information, however, physics classes demonstrated higher achievement. The author attributes this result to the higher abilities of the students in the conventional physics class.

2. The generalized course did not improve materially, knowledge about physics concepts. The conventional course was far superior to the generalized course in this respect.

3. Neither course demonstrated the capacity to modify attitudes towards science to a significant degree.

4. The generalized course was no more effective in developing consumer applications than was the conventional physics course.

Development and testing of an integrated biology, chemistry, and physics course at the University School which is affiliated with the Ohio State University is described by Slesnick in _The Journal of Research in Science Teaching_ (49). Students who studied a unified sequence, Science I, II and III, at the University School constituted the treatment group, and students who had elected the separate courses; chemistry, biology, earth science, and physical science who attended another Columbus, Ohio, secondary school constituted the control group. Students were matched for mental abilities, age, past academic performance, sex and grade. The main hypothesis
tested concerned the differential change in students' grasp of a "rational image of the universe", when they study the unified course and the separate science courses. The main hypothesis was divided into a number of subordinate hypotheses that related to grade placement, mental ability, science achievement level and sex.

The investigator devised a paper and pencil test to ascertain students' grasp of a "rational image of the universe", from the common subject matter of unified science; questions appear to cut across subject matter boundaries. Five features of a rational image of the universe are defined and questions appropriate to each feature are included in the examination.

These features are quoted:

1. Phenomena reflect the interdependencies and interactions of matter, energy and life.

2. The forms of matter, energy and life reveal a natural orderliness.

3. Things and events are perceived in accurate perspective in relation to time and space.

4. Real problems in controlling, predicting and interpreting events in the universe transcend single disciplines.

5. Man's relationship with his universe as an observer and as a part of the "web" is perceived realistically.

Slesnick concluded that when course content and methods are organized upon a superstructure of major generalizations of science, students were enabled to form a more inclusive "rational image of the universe" than students whose school experience was subject
centered. He finds that this conclusion is not all inclusive because only those students of average and above average mental ability and achievement profited significantly from the unified course. He says furthermore that in one of the features of the "rational image" the experimental group failed to show an advantage over the control group (49).

Description and testing of another integrated physics and chemistry course is reported by Lerner in The Science Teacher (31). Students used the traditional textbooks Modern Physics (20, p. 1-712) and Modern Chemistry (21, p. 1-694) in conjunction with PSSC and CBA materials. Forty-nine students at Barrington High School in Newark, New Jersey, constituted the treatment group; they studied the two year fused physics-chemistry course. A sample of fifty-one students with approximately the same mean I. Q., who were given separate chemistry and physics courses made up the control group. Subject matter achievement was measured with the Dunning Physics Test and the ACS Chemistry Test. Test results lead Lerner to conclude that students' gains in achievement as a result of exposure to both kinds of courses are not significantly different.

He describes two limitations of his investigation; one pertaining to the possible use of invalid instruments, the other questioning the inadequate sample sizes. A number of subjective judgments based upon observation of an discussions with students apparently conveyed
to the investigator that students who experienced the integrated course were better able to do problem solving and demonstrated more enthusiasm than did the typical control student.

Rueck and Korth (45) describe a combined physics and chemistry course they developed and evaluated at Barrington High School in Barrington, Illinois. This endeavor most nearly approximates the course that interested this investigator of all studies reviewed, in that the primary sources of content were materials developed by CBA, CHEMS and PSSC. There are, however, notable differences in course sequence and in instruments used for evaluation. Rueck and Korth utilized the CHEM Study Tests, the Cooperative Chemistry Test and the Cooperative Physics Test.

Comparison of the treatment group with a control group that studied the separate chemistry and physics courses led them to the following conclusions:

1. Subject matter achievement of the physics control group surpassed that of the treatment group.

2. Subject matter achievement of treatment and chemistry control groups were substantially the same.

3. Student interest in treatment classes appeared to exceed that of control classes.

4. Average students appeared to profit from the integrated course.
5. The integrated course seems sound but needs revision and refinement.

Summary

Review of the literature reveals a persistent concern for course correlation and integration. Some opponents of this movement fear dilution and loss of intellectual integrity.

A strong climate of opinion supporting integration of the sciences—particularly chemistry and physics—is evident over the past forty years.

Attempts to integrate chemistry and physics have been accomplished in a variety of ways; some emphasizing technology and applications of science, others utilizing the more traditional content and still others depending on the national curriculum movements for their primary source of content.

Integration of chemistry and physics seems to result in subject matter achievement measured at approximately the same levels as that which is characteristic of non-integrated courses. Other factors, such as students' grasp of a "rational universe image", attitudes of questing, better topic sequence and avoidance of content duplication, are enhanced by the integrated physics-chemistry courses.
CHAPTER III

THE STUDY

This chapter is presented in four major subdivisions:

1. A Description of the Experimental Courses.
2. The Experimental Design.
3. Testing Instruments, Scoring Methods and Statistics Calculated.
4. School, Student and Teacher Characteristics.

A Description of the Experimental Courses

A committee of secondary school and university chemistry and physics teachers undertook investigation of materials produced by PSSC, CHEMS and CBA with the intention of producing a single integrated course that embodied the flavor and content of these new approaches. The investigator acted as coordinator of the project and also assisted with writing of Student Guides and Teacher Guides. Intensive work over a period of two years resulted in the production of student and teacher guides for two integrated courses--one utilizing PSSC and CHEMS materials, the other PSSC and CBA materials.

The initial objective of the writing conference was the production of a single syllabus effecting the synthesis of chemistry and physics
into a two-year sequence. Due to substantial variation in the development of CBA and CHEMS, two separate syntheses appeared to be a more realistic goal. To accomplish this, the committee was divided into two groups, one of which was to consider integration of PSSC with CHEMS, the other, PSSC with CBA.

Two writing sessions were required to achieve the desired integration. A six-weeks conference at Portland State College in Portland, Oregon, during the summer of 1963 resulted in the production of two teacher guides detailing the first year of the two-year sequence. The second conference, in the summer of 1964, saw the completion of the teacher guides and related student guides.

CHEMS - PSSC Course Outline and Description (9, p. 1-117)

Course Outline

1. Overview
   A. What is Science?
      1. Activities
      2. Uncertainty
      3. Functions
   B. Time and Its Measurement
   C. Space and Its Measurement
   D. Kinematics
   E. Vectors
   F. Gravitational Mass
   G. Gases and Particles
H. Chemical Reactions and the Mole
I. Condensed Phases
J. The Periodic Table

II. Dynamics
A. Newton's Laws of Motion
B. Motion at the Earth's Surface
C. Universal Gravitation and the Solar System
D. Momentum and the Conservation of Momentum
E. Work and Kinetic Energy
F. Potential Energy

III. Heat and Energy Effects
A. Heat, Mechanical Energy and Internal Energy
B. Heat Changes and Chemical Reactions
C. Kinetic Molecular Theory and the Energy of a Molecule

IV. Chemical Reactions
A. Rates of Chemical Reactions
B. Equilibrium in Chemical Reactions
C. Solubility Equilibria
D. Acids and Bases
E. Oxidation-Reduction Reactions
F. Chemical Calculations

V. Optics and Waves
A. How Light Behaves
B. Reflection and Images
C. Refraction
D. Lenses and Optical Instruments
E. Particle Model
F. Introduction to Waves
G. Waves and Light
H. Interference
I. Light Waves

VI. Electricity and Magnetism
A. Some Qualitative Facts About Electricity
B. Coulomb's Law and the Elementary Electric Charge
C. Energy and Motion of Charges in Electric Fields
D. The Magnetic Field
E. Electromagnetic Induction and Electromagnetic Waves

VII. Atoms and the Structure of Matter
A. Exploring the Atom
B. Protons and Matter Waves
C. Quantum Systems and the Structure of Atoms
D. The Orbital Model
E. Chemical Bonding and Structure of Matter

VIII. Chemistry of the Elements
A. Chemistry of Carbon Compounds
B. Selections from the Following:
1. The Halogens
2. The Third Row of the Periodic Table
3. Second Column of the Periodic Table
4. The Fourth Row Transition Elements
5. Some Sixth and Seventh Row Elements
6. Some Aspects of Biochemistry
7. Qualitative Analysis

CHEMS - PSSC Course Description

Part I, "Overview", represents an integration of content and experiences from the first portion of the CHEMS and PSSC courses. The objectives of this section are to introduce students to science and the scientist, to develop tools and concepts to be utilized in subsequent portions of the course, and to introduce a number of profound questions and problems that will be intensively studied at a later time.

Force, momentum, energy and the conservation laws are introduced next because thorough understanding of these concepts is crucial to topics that follow: namely, heat and molecular motion, chemical equilibrium, atomic and molecular structure and electricity. Those science educators who have considered the problem of fusing chemistry with physics recognize the topics of "Heat" and "Energy" as two of the major problem areas. The writing committee deliberated on this problem at length and decided that the only feasible solution lies in a complete rewrite of this material. This has been
accomplished and appears in the PSSC-CHEMS Teacher Guide (9).

The first year of the integration concludes with a presentation of chemical equilibrium and equilibrium systems. The background developed earlier in functions and dynamics provides significant help in making these topics more intelligible to students.

The arrangement of topics for the second year experience is calculated to strive toward a depth of understanding of the structure and behavior of atoms and matter insofar as these concepts are understood today. In Part V, "Optics and Waves", students are led to accept credibility in two models for light, i.e., the particulate and wave models. The high level of interest many PSSC teachers noted among students in connection with this material was one of the influences that caused the committee to commence the second year with this topic. Study of electricity, magnetism, and the electromagnetic spectrum follows; light is then shown to be a portion of this spectrum.

Atomic structure is introduced in depth with heavy emphasis on the contributions of Rutherford and Bohr. The particle-wave model is extended to include the entire electromagnetic spectrum. The wave nature of the electron is introduced at this point and the electron associated with the hydrogen atom is represented as a standing wave in single dimension. Here an opportunity presents itself to take full advantage of synthesis of chemistry and physics. A "bridge" was needed that led from the principle quantum number developed in PSSC
to the four required to complete the geometry of the orbital atom model used by many chemists. This additional chapter appears in the teacher guide bearing the title, "Atoms in Three Dimensions". Henceforth, chemical bonds may be described in terms of the orbital atom model.

The remaining CHEMS chapters are somewhat independent of one another. Discretion of the teacher and student interest can dictate which of these will be studied. If time permits, one or more of the PSSC advanced topics can also be presented.

Many CHEMS and PSSC teachers have stated that the content included in the separate courses is well beyond what they can efficiently cover in the time available. Through integration, it was anticipated that sufficient time could be conserved to make the original goals of these course planners more realistic. Experience of pilot teachers who gave instruction in the integrated CHEMS - PSSC course confirms this point of view. Beyond this, it is possible that one or two of the PSSC advanced topics could also be included as time allows.

CBA - PSSC Course Outline and Description (10, p. 1-170)

Course Outline

I. Interpreting the Universe

A. Introduction
B. Fundamental Concepts and Measurements

1. Time and Space
2. Mathematical Functions
3. Kinematics and Vectors
4. Mass

C. Nature of Chemical Change

1. Properties of Elements, Compounds and Mixtures
2. Mixtures and Chemical Change
3. Matter and Its Atomicity

II. Mechanics

A. Newton's Laws of Motion
B. Motion at the Earth's Surface
C. Universal Gravitation
D. Momentum and Conservation of Momentum
E. Work and Kinetic Energy
F. Potential Energy

III. Electrical Nature of Matter

A. Observations of Electrical Systems
B. Energy and Motion of Charges in Electric Fields
C. Interaction of Electricity and Matter

IV. Atomic Models

A. Rutherford Atom
B. Charge Cloud Model

V. Molecules and Energy

A. Kinetic-Molecular Theory
B. Boiling Points and Heats of Vaporization
C. Heat, Molecular Motion and Conservation of Energy

VI. Optics and Waves
A. Behavior of Light
B. Reflection
C. Refraction
D. Lenses
E. Particle Model
F. Introduction to Waves
G. Waves and Light
H. Interference
I. Light Waves

VII. Electromagnetics
A. The Magnetic Field
B. Electromagnetic Induction and Electromagnetic Waves

VIII. Quantum Systems
A. Photons and Matter Waves
B. Quantum Systems and the Structure of Atoms
C. Orbital Model of the Atom

IX. Enthalpy

X. Bonds in Chemical Systems
A. Metals
B. Ionic Solids
C. Ions in Solution
XI. Order, Disorder and Change

A. Free Energy

B. Concentration, Control and Chemical Change

C. Acids and Bases

D. Time and Chemical Change

E. Water

CBA - PSSC Course Description

The first major subdivision, "Interpreting the Universe", serves to introduce students to the concepts of time, space, matter and methods of measurement. Functional relationships constitute the next unit followed by the PSSC treatment of Kinematics. Daltonian chemistry presented largely from CBA materials completes the first portion of the course.

"Mechanics", which is fundamental to electricity, atomic structure, kinetic theory, chemical energetics and chemical bonding, is considered at this time. The principles of mechanics serve as a spring board to electrical energy and charge separation. The dielectric constant is introduced as an extension of Coulomb's Law because it is applied later to the study of ions in solution. Other electrical topics follow: electric fields, conservation of charge and the charge on the electron. Various kinds of electrical circuits then occupy students. The committee spoke out strongly in favor of amplification
of PSSC textual material relative to DC circuits. To accomplish this a chapter appears in the teacher guide title, "More About Electrical Systems".

Part IV develops two fundamental models: The Rutherford Atom and The Charge Cloud Model. The Charge Cloud Model builds on the concept of the nuclear atom and a set of assumptions pertaining to the expected behavior of electron clouds.

Kinetic molecular theory is a topic which profits significantly from integration. Traditionally, students encounter it in both chemistry and physics, each course relating only part of the story. Though integration of this topic is fraught with difficulty, the final outcome for the learner has proved rewarding. Chapter B of the PSSC-CBA Teacher Guide (10, p. 132-159), written for the integrated course and title "Kinetic Molecular Theory", treats the subject fully and more coherently even though it represents far less reading than the CBA and PSSC textbooks devoted to the same subject. The first year of the integrated course is concluded here.

The empirical approach to "Optics and Waves", designed by the Physical Science Study Committee, was judged by the committee to possess a high motivation factor. Moreover, this material, particularly those aspects which deal with the wave-particle controversy, leads naturally into subsequent topics such as the electromagnetic spectrum, the wave nature of matter, atomic spectra,
quantum systems and the orbital model of the atom.

Part VII deals with magnetic fields, electromagnetic induction and electromagnetic waves. Development of this material is in accordance with the PSSC text (43, p. 522-571).

The ultimate quantum behavior of nature on submicroscopic levels is considered next. Here, as in the PSSC-CHEMS integration, a bridge is required to proceed smoothly from the one quantum number developed in PSSC to the four required to describe an atom in three dimensional space. The chapter "Standing Waves in Quantum Systems" was written to accommodate this need. This also appears in the teacher guide.

The last three parts of the course, "Enthalpy", "Bonds in Chemical Systems", and "Order, Disorder, and Change", are studied as they appear in CBA with little modification.

The Experimental Design

This study is designed to compare the effectiveness in selected outcomes the integrated chemistry-physics courses developed by the Portland Project committees, with chemistry and physics courses taught separately. Experimental and control classes were evaluated in terms of gains in subject matter achievement, critical thinking abilities and attitudes towards science.
A non-equivalent control Group Design (25, p. 217) was employed in which treatment and control groups were pretested. Treatment groups studied the integrated chemistry-physics courses for an entire school year and the control groups studied the separate PSSC, CBA, and CHEMS courses. Posttesting occurred at the conclusion of the school year.

Teachers responsible for instruction in treatment classes expressed an interest in teaching the course. Each teacher simply designated classes as treatment or control groups the first day he met them. He had no pre-knowledge of student characteristics that made up these classes prior to selection. When the teachers announced to treatment groups they had been designated to study an integrated course only two students of 149 chose not to participate.

Five Portland, Oregon, Metropolitan schools contributed six experimental classes, six PSSC control classes and six chemistry control classes to this study. Three of the six chemistry control classes studied CBA chemistry and three of them studied CHEMS chemistry. Three of the treatment classes studied the PSSC-CBA integrated course and three the PSSC-CHEMS integration. This information is summarized in Table I. In each case affiliation with a group implies membership at the same school except for the exclusion indicated on the table.

Eight teachers had responsibility for instruction in all eighteen
Table I. Class Organization and Teacher Assignments

<table>
<thead>
<tr>
<th>Group</th>
<th>Class</th>
<th>N</th>
<th>Teacher</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>CBA - PSSC Integration</td>
<td>30</td>
<td>Alpha</td>
</tr>
<tr>
<td></td>
<td>PSSC Control Class</td>
<td>29</td>
<td>Alpha</td>
</tr>
<tr>
<td></td>
<td>*CBA Control Class</td>
<td>24</td>
<td>Beta</td>
</tr>
<tr>
<td>II</td>
<td>CBA - PSSC Integration</td>
<td>24</td>
<td>Beta</td>
</tr>
<tr>
<td></td>
<td>PSSC Control Class</td>
<td>25</td>
<td>Beta</td>
</tr>
<tr>
<td></td>
<td>CBA Control Class</td>
<td>25</td>
<td>Beta</td>
</tr>
<tr>
<td>III</td>
<td>CBA - PSSC Integration</td>
<td>20</td>
<td>Gamma</td>
</tr>
<tr>
<td></td>
<td>PSSC Control Class</td>
<td>29</td>
<td>Gamma</td>
</tr>
<tr>
<td></td>
<td>CBA Control Class</td>
<td>13</td>
<td>Delta</td>
</tr>
<tr>
<td>IV</td>
<td>CHEMS - PSSC Integration</td>
<td>27</td>
<td>Epsilon</td>
</tr>
<tr>
<td></td>
<td>PSSC Control Class</td>
<td>32</td>
<td>Chi</td>
</tr>
<tr>
<td></td>
<td>CHEMS Control Class</td>
<td>25</td>
<td>Epsilon</td>
</tr>
<tr>
<td>V</td>
<td>CHEMS - PSSC Integration</td>
<td>23</td>
<td>Lambda</td>
</tr>
<tr>
<td></td>
<td>PSSC Control Class</td>
<td>16</td>
<td>Mu</td>
</tr>
<tr>
<td></td>
<td>CHEMS Control Class</td>
<td>29</td>
<td>Lambda</td>
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<tr>
<td>VI</td>
<td>CHEMS - PSSC Integration</td>
<td>25</td>
<td>Lambda</td>
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<tr>
<td></td>
<td>PSSC Control Class</td>
<td>18</td>
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</tr>
<tr>
<td></td>
<td>CHEMS Control Class</td>
<td>26</td>
<td>Lambda</td>
</tr>
</tbody>
</table>

* This CBA control class was selected from another school because no such control class could be obtained there.
classes. The last column of Table I summarizes teacher-assignments. Greek letters are substituted for teachers' names.

Table I presents data that shows teacher assignments within each group. In groups I and III the same teacher was responsible for the treatment class and the PSSC control class. Other teachers taught the CBA control classes. The same teacher gave instruction to all three classes within group II. Groups IV, V and VI had an identical pattern in that the same teacher was responsible for the treatment classes and the CHEMS control classes. Other teachers gave instruction in the PSSC control classes.

Testing Instruments, Scoring Methods and Statistics Calculated

Measurement of Intelligence

The Otis Quick Scoring Mental Ability Test, Gamma: Form EM was selected to assess, "the mental abilities-thinking power or the degree of maturity of the mind," (40, p. 1-4) of each participant in this study. Classroom teachers administered the examinations during the first week of the 1963-64 school year. The eighty-item test yields a single score on word meaning, verbal analogies, scrambled sentences, interpretation of proverbs, logical reasoning, number reasoning and design analogies.

Reliability of the test, determined by the split half method, is
reported at 0.92 for grade 10, 0.91 for grade 11 and 0.92 for grade 12.

The standardization of this new form is done by comparison with older forms of the same instrument. Description of the normative population is somewhat vague in the manual of directions which suggests that the norms are characteristic of the entire country (6, p. 361-362).

Measurement of Critical Thinking

The Watson-Glaser Critical Thinking Appraisal: Form YM was administered to all student participants in this study during the first week of the 1963-64 school year. A parallel ZM Form constituted part of the posttesting program and was administered during the last week of the school year.

The examinations consist of a series of items which require the application of some of the relevant abilities involved in critical thinking. The exercises include problems, statements, arguments, and interpretations of data. The test is made up of five sub-tests.

Test 1. **Inference.** (Twenty items) Samples ability to discriminate among degrees of truth or falsity of inferences drawn from given data.

Test 2. **Recognition of Assumptions.** (Sixteen items) Samples ability to recognize unstated assumptions or presuppositions which are taken for granted in given statements or assertions.

Test 3. **Deduction.** (Twenty-five items) Samples ability to reason deductively from given statements or premises, to
recognize the relation of implications between proportions, to determine whether what may seem to be an implication or a necessary inference from given premises is indeed such.

Test 4. Interpretation. (Twenty-four items) Samples ability to weigh evidence and to distinguish between (a) generalizations from given data that are not warranted beyond a reasonable doubt and (b) generalizations which, although not absolutely certain or necessary, do seem to be warranted beyond a reasonable doubt.

Test 5. Evaluation of Arguments. (Fifteen items) Samples ability to distinguish between arguments which are strong and relevant and those which are weak or irrelevant to a particular question or issue (56, p. 2).

Product moment correlations of the YM Form with the Otis Mental Ability Tests: Gamma give a value of .75 for a sample of 20,312 high school students. A somewhat lower correlation coefficient, \( r = .66 \), was obtained between the YM Form and the Iowa Test of Educational Development for 318 Missouri ninth grade students.

Critical thinking abilities, therefore, show a definite positive correlation with both intelligence and achievement. Verbal intelligence and the ability to learn school subjects may not, however, be the only abilities required to do critical thinking.

Reliability of the YM and ZM Forms using the split half method yields an \( r = .86 \) and \( r = .80 \), respectively, for a sample in excess of ten thousand high school students.

The YM and ZM Forms do not have the same difficulty level. The Watson Glaser Critical Thinking Appraisal Manual presents a table of equivalent scores between the forms. A variable difficulty
which sometimes equals a raw score difference of six exists between them (56, p. 2). This must be corrected for in any evaluation procedure.

Measurement of Attitudes

An adapted form of the Allen Reaction Inventory Attitudes Towards Science and Scientific Careers (2, p. 1-53) was assembled by the investigator to assess changes in students' attitudes towards (1) The Nature of Science, (2) Society's Impact on Science, (3) Science's Impact on Society, (4) The Scientist, and (5) Scientific Work. The adapted form of the original inventory appears in Appendix A of this volume. Each student who took part in the study had this instrument administered to him the first week of the 1963-64 school year. The identical instrument was given at the conclusion of the school year to assess changes in attitudes towards science as a result of his classroom experience.

Allen prepared his original attitude scale by reviewing newspapers and magazines noting negative statements about science and the scientist. From this information and discussion with scientists and students a 95-item inventory was developed. These statements were submitted to a panel of practicing scientists to determine their responses. Panel responses were used as a yard stick to evaluate student responses to the same item.
Forty-nine of Allen's statements were selected based on the interest of the investigator to make up the criterion instrument used in this study. As the study progressed preliminary evidence dictated reduction of attitude statements to fifteen for purposes of analysis. Careful perusal of the differences in responses between treatment and control classes gave evidence on which statements might prove fruitful for analysis. Statements which yielded the largest differences between treatment and control class responses were selected for analysis.

Howe's (30, p. 85-87) method was utilized by the investigator to evaluate student responses to the inventory items. Accompanying each statement or attitude are five choices. The student can select the one he feels best expresses his feelings.

AA - Strongly Agree  
A  - Agree  
N  - Neutral  
D  - Disagree  
DD - Strongly Disagree

His selection was converted to a numerical score in the following way: 
AA = 0, A = 1, N = 2, D = 3, and DD = 4.
**Measurement of Achievement in Physics**

To assess students' achievement in physics a 35-item test was assembled from *Tests of the Physical Science Study Committee* (22, V. 1-10). This examination was administered to all students in the six physics control classes and to all students in the six treatment classes. Identical forms were administered in a pre- and post-testing period.

Content validity of the test was assumed for the PSSC control classes because these items were designed by Educational Testing Service and the Physical Science Study Committee to ascertain subject matter achievement of students who study their course. Content validity for the treatment classes was determined by a panel of seven experts who were intimately familiar with the content of the integrated courses. All of the items in *Tests of the Physical Science Study Committee* (22, V. 1-10) served as a pool from which the 35 items were drawn. All seven panelists had to agree that each item selected was valid. If there was one dissenter, the item was deleted.

**Measurement of Achievement in Chemistry**

To assess student achievement in chemistry two 35-item tests were designed. The first of these tests was assembled to measure subject matter achievement in CBA chemistry. *Tests of the Chemical*
Bond Approach Project (11, V. 1-8) were considered a pool from which 35 items were selected. This examination was administered to the three CBA control classes and to the three treatment classes that studied the PSSC - CBA integrated course.

Content validity was assumed for the CBA control classes because all of these items were designed by Educational Testing Service and the Chemical Bond Approach Project to test subject matter achievement in the CBA course. Content validity for the treatment classes was determined by a panel of five experts who were very familiar with the content of the integrated course. In the selection of the 35 items that was to constitute the test, if one panelist dissented on a test item it was deleted.

For purposes of scoring and interpreting data nineteen of the thirty-five items were used. The decision to reduce the number of test items for analysis was caused by an unrealistic time schedule for the integrated classes. Approximately one-third of the CBA content planned for the first year of the integrated course was not considered due to time taken out for testing and the customary slow pace that is usually associated with teachers and students who are engaged in a new course.

The second chemistry test was designed to assess subject matter achievement in CHEMS chemistry. A 35-item test was assembled using the Chemical Education Material Study Achievement Tests
as a pool from which to draw items. This examination was administered to the three control classes studying CHEMS chemistry and the three treatment classes studying the CHEMS - PSSC integrated course.

Content validity of the test was assumed for the CHEM control classes because the items were produced by Educational Testing Service and The Chemical Education Materials Study to test subject matter achievement in CHEMS. Content validity for the integrated course was judged by a panel of six experts who were thoroughly acquainted with the course. In the selection of the 35 items that were to constitute the test if one panelist dissented on an item it was not used.

For purposes of scoring and interpreting data 25 of the 35 items were used. The decision to reduce the number of test items for purposes of analysis was caused by an unrealistic time schedule adopted for the integrated classes. They were not able to complete approximately one-fourth of the CHEMS content planned for them. This was due to excessive time required for testing and the customary slow pace usually associated with a pilot program.

Assessment of Student Characteristics

Other student characteristics were assumed to have some effect on their performances. A questionnaire (Appendix A) which was
completed by all students the first week of the 1963-64 school year elicited information from them which summarized their educational background in science and mathematics courses in high school, grade in school and occupation of parents.

Assessment of Teacher Characteristics

Differences among teachers could also have an impact on the results of this study. To obtain a profile of each individual teacher, he was asked to complete a questionnaire (Appendix A) summarizing teaching experience, preparation in science and professional interests and activities. Particularly prominent in the questionnaire were questions directed at training and experience in the new curricula, i.e., in CBA, CHEMS, and PSSC.

All instruments were hand scored by a team of four students who attend Portland State College and checked for discrepancies by a second team of three students.

Arithmetic means of I.Q. scores obtained with the Otis Quick Scoring Mental Ability Test, Gamma: Form EM were calculated for each class together with the standard deviation and confidence interval.

Arithmetic means of performance on the Watson-Glaser Critical Thinking Appraisal: Forms YM and ZM together with standard deviations and confidence intervals were calculated for each class. Using
classes as units, the paired t-test (32, p. 119-140) was applied to the difference of means between the six treatment classes and the six physics control classes to determine if these differences were significant at the five percent level. In this procedure, the pretest raw scores were subtracted from posttest scores, a mean calculated for these differences, and the paired t-test applied to these means to determine significance. The t-test was also applied at the five percent level to determine if the difference of means between the six treatment classes and the six chemistry control classes were significant for changes in critical thinking abilities.

The arithmetic means, standard deviations and confidence intervals for each class were calculated for the chemistry achievement tests. Using classes as units the paired t-test was applied to the difference of means between the six treatment classes and the six chemistry control classes to determine if these differences were significant at the five percent level. In this procedure the pretest raw scores were subtracted from the posttest scores, a mean calculated for these differences and the paired t-test applied to these difference of means to determine significance.

The arithmetic means, standard deviations and confidence intervals for each class were calculated for the physics achievement tests. Using classes as units the paired t-test was applied to the difference of means between the six treatment classes and the six physics control
classes to determine if these differences were significant at the five percent level. In this procedure the pretest raw scores were subtracted from the posttest scores, a mean calculated for these differences and the paired t-test applied to these differences of means to determine significance.

Fifteen of the 49 items that appear on the science attitudes inventory (Appendix A) were chosen for analysis by the investigator. Basis for selection of these statements appear on page 50. These are 1, 7, 9, 12, 14, 15, 20, 24, 26, 34, 36, 42, 43, 47, and 48. Numerical values were applied to each response as described previously in this chapter. The arithmetic mean for each response was calculated using classes as units. The paired t-test was applied to the differences of means for these items to determine significance at the five percent level.

As in the previous calculations, the six treatment classes were compared with the six physics classes and in a separate calculation, the six treatment classes were compared with the six chemistry control classes.

School, Student and Teacher Characteristics

School Characteristics

The Portland, Oregon, Metropolitan Area has historically taken an active role in propagating new curriculum developments in
secondary school science. A variety of pilot programs continue to be introduced into the schools which have been originated by local and national committees. Just prior to the 1963-64 school year when this study was undertaken most of the secondary schools were either fully committed to experimentation in science and mathematics course offerings or moving in that direction.

Of the five schools taking part in this study two were suburban schools and three were within the Portland, Oregon, city limits.

**Student Characteristics**

To make comparisons in students' ability, educational experience and support from home; information in narrative and tabular form is presented on their I.Q., academic experiences, grade level and parents' occupations.

<table>
<thead>
<tr>
<th>Group</th>
<th>Treatment</th>
<th>Class</th>
<th>PSSC</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>10.20</td>
<td>10.16</td>
<td>10.17</td>
</tr>
<tr>
<td>II</td>
<td>10.00</td>
<td>10.20</td>
<td>11.00</td>
</tr>
<tr>
<td>III</td>
<td>9.63</td>
<td>9.69</td>
<td>10.17</td>
</tr>
<tr>
<td>IV</td>
<td>10.14</td>
<td>10.28</td>
<td>10.90</td>
</tr>
<tr>
<td>V</td>
<td>10.13</td>
<td>9.82</td>
<td>10.18</td>
</tr>
<tr>
<td>VI</td>
<td>9.80</td>
<td>9.76</td>
<td>11.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>Means</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10.0</td>
<td>10.0</td>
<td>10.6</td>
</tr>
</tbody>
</table>
Examination of the mean grade placement of the six treatment classes and the six PSSC control classes reveals almost identical means for Groups I and V (Table II). The remaining four groups show an advantage for the PSSC control classes which ranges between 0.54 and 1.20 school grades.

All grade placements are determined assuming a child is placed at grade zero when he enters the first grade. Thus students who are beginning their junior year are at grade placement 10.0 and those beginning their senior year at grade placement 11.0. Table II also reveals that three of the six treatment classes are ahead of their corresponding chemistry control classes in mean grade placement and three are behind. The mean grade placement of all students in the treatment classes, chemistry control classes and physics classes are respectively, 10.0, 10.0 and 10.6 (Table II).

The data gives confidence that the treatment classes are not further advanced in grade placement than control classes.

Table III summarizes I.Q. data measured by the Otis Quick Scoring Mental Ability Test; Gamma: Form EM.

Comparison of the mean I.Q. for individual treatment classes and their corresponding PSSC control classes reveals that there is an advantage in each of the six groups that favors the control classes. The difference in I.Q. mean scores is the least in Group II, 0.53, and is the greatest in Group IV, 10.9. All of the differences,
Table III. I. Q. Scores of Students in Treatment and Control Classes

<table>
<thead>
<tr>
<th>Group</th>
<th>Class</th>
<th>Treatment</th>
<th>CBA</th>
<th>PSSC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$\bar{x}$</td>
<td>$S_\bar{x}$</td>
<td>C. I. 5%</td>
</tr>
<tr>
<td>I</td>
<td></td>
<td>113.25</td>
<td>1.84</td>
<td>109.48</td>
</tr>
<tr>
<td>II</td>
<td></td>
<td>122.79</td>
<td>2.06</td>
<td>118.53</td>
</tr>
<tr>
<td>III</td>
<td></td>
<td>112.63</td>
<td>1.645</td>
<td>109.07</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Treatment</th>
<th>CHEMS</th>
<th>PSSC</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VI</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Group Means: 115.2

$\bar{x}$ = Means
$S_\bar{x}$ = Standard deviations
C. I. = Confidence intervals
however, favor the PSSC control classes. Inspection of the table also shows that four of the chemistry control classes in groups I, III, IV and V have a mean I. Q. above that of the corresponding treatment classes. The mean I. Q. of all students in the treatment classes is 115.2; the chemistry control classes have a mean I. Q. of 117.4, which is above that of the experimental classes. The PSSC students are also numerically above the treatment classes with a mean I. Q. of 119.9. The data gives confidence that the treatment classes are not on a higher ability level than the control classes.

Parental support for a child's academic success may affect his school achievement. A questionnaire completed by each student asked him to give his father's or mother's occupation. These occupations were classified using a modified version of one found in the Dictionary of Occupational Titles (55, p. 9-18). Four categories combined the many titles that appear in the occupations titles dictionary. These are Professional and Managerial; Clerical; Sales and Services; Skilled and Semiskilled Workers; and Unskilled Workers and Laborers.

Table IV was constructed by finding the total number of respondents to questions about parents' occupations in the treatment classes, chemistry control classes and physics control classes.
Table IV. Percent of Total Number of Students Whose Parents Are Engaged in Various Occupation Categories

<table>
<thead>
<tr>
<th>Classes</th>
<th>Professional and Managerial</th>
<th>Clerical Sales and Services</th>
<th>Skilled and Semi-Skilled</th>
<th>Unskilled and Laborers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment Classes</td>
<td>17%</td>
<td>40%</td>
<td>40%</td>
<td>3%</td>
</tr>
<tr>
<td>Chemistry Classes</td>
<td>19%</td>
<td>46%</td>
<td>32%</td>
<td>3%</td>
</tr>
<tr>
<td>Physics Classes</td>
<td>22%</td>
<td>35%</td>
<td>37%</td>
<td>5%</td>
</tr>
<tr>
<td>National Averages 1964</td>
<td>16%</td>
<td>39%</td>
<td>37%</td>
<td>8%</td>
</tr>
</tbody>
</table>

This sum in each case is divided by the total number of children whose parents are in a particular job classification; e.g., the total number of treatment students is divided into the number whose fathers are judged to be in the "Skilled and Semiskilled" category. The treatment classes show the lowest percentage of children whose parents are classified in the "Professional and Managerial" category, an intermediate value between the control classes for parents in the "Clerical, Sales and Services" category, the highest percentage of parents in the "Skilled and Semiskilled" bracket and the lowest percentage of parents in the "Unskilled and Laborers" classification together with the chemistry control classes. This data gives confidence that students who comprise treatment classes are probably not unduly influenced by superior socio-economic status.
Previous subject matter preparation may have an influence upon performance in subsequent courses. The questionnaire submitted to students at the beginning of the 1963-64 school year sought to obtain this background particularly about those courses they had taken in science and mathematics beginning in the ninth grade. Inspection of Figures 1-7 reveals the variations and similarities in their subject matter preparation. The most obvious and yet the most understandable is the superior preparation of most of the physics control classes. This results from the traditional sequence of courses in high school science which places physics in the senior year. Their superior mathematics preparation is in part due to the high correlation between interests and abilities in mathematics and physics. Another striking feature of the figures is the similarity among all classes in preparation in biology I and general science.

Other characteristics that seem apparent in student preparation are the following:

1. In the six groups four treatment classes have superior preparation in science while two chemistry control classes have this advantage. This is the result when all science courses are pooled.

2. Within the six groups all six treatment classes have science preparation which is inferior to all physics control classes.
MEAN PREPARATION IN SCIENCE AND MATHEMATICS—YEARS

**FIG. 1** MEAN PREPARATION OF TREATMENT AND CONTROL CLASSES IN SCIENCE AND MATHEMATICS — GROUP I

**FIG. 2** MEAN PREPARATION OF TREATMENT AND CONTROL CLASSES IN SCIENCE AND MATHEMATICS — GROUP II
Fig. 3  Mean preparation of treatment and control classes in science and mathematics—Group III

Fig. 4  Mean preparation of treatment and control classes in science and mathematics—Group IV
FIG. 5  MEAN PREPARATION OF TREATMENT AND CONTROL CLASSES IN SCIENCE AND MATHEMATICS — GROUP V

FIG. 6  MEAN PREPARATION OF TREATMENT AND CONTROL CLASSES IN SCIENCE AND MATHEMATICS — GROUP VI
**FIG. 7** MEAN PREPARATION OF TREATMENT AND CONTROL CLASSES IN SCIENCE AND MATHEMATICS—ALL GROUPS
3. Comparing mathematics preparation, four treatment classes have superior preparation while two chemistry control classes have this advantage. This is the result when all mathematics courses are pooled.

4. All six physics control classes have more mathematics training than their corresponding treatment classes.

5. Preparation in physical science varies within each school and among schools, the experimental classes being the best prepared in this area.

6. Biology II and electronics are either offered or elected so infrequently that these courses probably do not have an appreciable effect on this study.

7. Chemistry constitutes part of the preparation of an appreciable number of physics control students.

8. The physics control classes have had substantial exposure to chemistry and trigonometry while the treatment and chemistry control classes have not.

Data on subject matter preparation of students who comprise the treatment classes reveals they probably do not have an advantage in this regard.

**Teacher Characteristics**

It is presumed that teacher training may have an effect on the
outcome of this experiment. A questionnaire (Appendix A) was submitted to each teacher participant seeking this kind of background information. Table V presents a summary of the preparation of the eight teachers who gave instruction to students in the experimental and control classes. The table presents information on degrees and dates; semester hours of preparation in science, physics, chemistry, mathematics and attendance at teacher training institutes devoted to preparation of teachers in the new secondary school curricula. In order that data on teacher preparation be presented in a more meaningful way, Table VI was prepared from Table V to facilitate calculation of the mean academic preparations of teachers in treatment and control classes. These tables indicate that there is scarcely any difference in the mean number of semester hours of chemistry accumulated by the treatment and control teachers. Teachers who have responsibility for the physics control classes are substantially better prepared in that subject than those teachers who have charge of treatment classes. The mean mathematics training of teachers in treatment classes shown in Table VI is precisely midway between that of the physics control teachers and chemistry control teachers. This data gives confidence that the subject matter preparation of treatment teachers is not greater than the preparation of teachers responsible for control classes.
Table V. Preparation of Teachers

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Degrees</th>
<th>Dates</th>
<th>Semester Hours</th>
<th>Institute Training</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total</td>
<td>Physics</td>
</tr>
<tr>
<td>Alpha</td>
<td>BS</td>
<td>1952</td>
<td>103</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>BS</td>
<td>1950</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beta</td>
<td>MEd</td>
<td>1955</td>
<td>65</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>MS</td>
<td>1960</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gamma</td>
<td>BS</td>
<td>1949</td>
<td>71</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>MS</td>
<td>1961</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delta</td>
<td>BS</td>
<td>1950</td>
<td>110</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>MEd</td>
<td>1958</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MS</td>
<td>1960</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chi</td>
<td>BS</td>
<td>1962</td>
<td>40</td>
<td>32</td>
</tr>
<tr>
<td>Epsilon</td>
<td>BA</td>
<td>1956</td>
<td>82</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>MS</td>
<td>1961</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lambda</td>
<td>BS</td>
<td>1954</td>
<td>92</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>MS</td>
<td>1960</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mu</td>
<td>BA</td>
<td>1950</td>
<td>102</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>MS</td>
<td>1961</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table VI. Mean Science and Mathematics Preparation of Teachers - Semester Hours

<table>
<thead>
<tr>
<th></th>
<th>Chemistry</th>
<th>Physics</th>
<th>Mathematics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment Classes</td>
<td>43</td>
<td>25</td>
<td>28</td>
</tr>
<tr>
<td>Chemistry Classes</td>
<td>45</td>
<td></td>
<td>26</td>
</tr>
<tr>
<td>Physics Classes</td>
<td></td>
<td>38</td>
<td>30</td>
</tr>
</tbody>
</table>

Spokesmen for the PSSC, CHEMS and CBA committees have expressed the view that institute training in these respective courses is desirable, if not essential, before a teacher can teach any one of them effectively. Table VII depicts summer or inservice experience of teachers in this type of training. Four of the six teachers who gave instruction in the physics control classes had had a PSSC institute of some kind, whereas, among teachers responsible for the experimental classes only two of the six had this training previous to teaching the integrated course. All six teachers involved with instruction in the chemistry control classes had had either a CBA or CHEMS institute; five of the six treatment teachers had such training.

This data gives confidence that institute preparation of treatment teachers is probably not superior to that of control teachers.
Table VII. Institute Preparation of Teachers in PSSC, CHEMS and CBA

<table>
<thead>
<tr>
<th>Treatment Classes</th>
<th>Chemistry Classes</th>
<th>PSSC Classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha CBA PSSC</td>
<td>Beta CBA</td>
<td>Alpha PSSC</td>
</tr>
<tr>
<td>Beta CBA</td>
<td>Beta CBA</td>
<td>Beta</td>
</tr>
<tr>
<td>Gamma PSSC</td>
<td>Delta CBA</td>
<td>Gamma PSSC</td>
</tr>
<tr>
<td>Epsilon CHEMS</td>
<td>Epsilon CHEMS</td>
<td>Chi</td>
</tr>
<tr>
<td>Lambda CHEMS</td>
<td>Lambda CHEMS</td>
<td>Mu PSSC</td>
</tr>
<tr>
<td>Lambda CHEMS</td>
<td>Lambda CHEMS</td>
<td>Mu PSSC</td>
</tr>
</tbody>
</table>

It is presumed that teaching experience may have an effect on the performance of students in this experiment. Table VIII summarizes teacher experience in instructional responsibility in chemistry, physics, and mathematics. Table IX is derived from Table VIII to render any differences that might occur between teachers of treatment and control classes more obvious. Table IX shows their mean experience level in chemistry to be 5.0 years for the chemistry control teachers and 4.2 years for the treatment teachers. Teaching experience specific to CHEMS in the two groups of teachers is 0.84 years. A slight advantage appears in favor of the chemistry control teachers in their mean experience in teaching CBA. In addition, the physics control teachers have taught physics longer, 5.3 years to 4.0 years for the treatment teachers, and have also been engaged in teaching PSSC for a longer period of time; 3 years to 1.5 for treatment teachers. In their mean teaching experience in mathematics,
the treatment teachers fall midway between the chemistry control and physics control teachers. This data gives confidence that treatment teachers probably do not possess more teaching experience than control teachers.

Table VIII. Teacher Experience

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Number of Years Teaching Experience In</th>
<th>Chemistry</th>
<th>CHEMS</th>
<th>CBA</th>
<th>Physics</th>
<th>PSSC</th>
<th>Mathematics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha</td>
<td>5</td>
<td>2</td>
<td>8</td>
<td>4</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beta</td>
<td>6</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Gamma</td>
<td>4</td>
<td></td>
<td>10</td>
<td>5</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delta</td>
<td>8</td>
<td>1</td>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chi</td>
<td></td>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epsilon</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td></td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lambda</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td></td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mu</td>
<td>3</td>
<td>6</td>
<td>4</td>
<td></td>
<td>4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table IX. Mean Experience of Teachers - Years

<table>
<thead>
<tr>
<th></th>
<th>Chemistry</th>
<th>CHEMS</th>
<th>CBA</th>
<th>Physics</th>
<th>PSSC</th>
<th>Mathematics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment Classes</td>
<td>4.2</td>
<td>0.84</td>
<td>0.84</td>
<td>4.0</td>
<td>1.5</td>
<td>3.0</td>
</tr>
<tr>
<td>Chemistry Classes</td>
<td>5.0</td>
<td>0.84</td>
<td>1.2</td>
<td></td>
<td></td>
<td>3.2</td>
</tr>
<tr>
<td>Physics Classes</td>
<td></td>
<td>5.3</td>
<td>3.0</td>
<td>2.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Summary

A survey of student characteristics such as I.Q., grade placement, educational experience in science and mathematics and parental background make possible the following generalizations about populations taking part in this experiment.
1. The mean I. Q. of treatment students is not greater than the mean I. Q. of the chemistry control students and physics control students.

2. The mean grade placement of students who comprise the treatment classes is equal to that of students in the chemistry control classes but somewhat less than that of students who make up the physics control classes.

3. The mean science preparation of students in treatment classes prior to the onset of this study was approximately 0.6 years per student less than the physics control students but about 0.3 of a year greater than the chemistry control students.

4. The mathematics preparation of students who comprise the treatment classes is approximately 0.8 years per student less than the physics control students but 0.1 years greater than the chemistry control classes.

5. There appears to be very little difference in occupations of parents whose children make up the treatment and control classes.

The following statements appear to be valid generalizations about the teachers who gave instruction to the treatment and control classes.

1. Subject matter preparation of treatment teachers in physics
is substantially lower than their counterparts in the physics control classes, but about equivalent to the chemistry and mathematics preparation of control teachers.

2. The mean experience level of treatment teachers in chemistry is approximately 0.8 years less than control chemistry teachers. Their experience in teaching physics is likewise substantially lower than the physics control teachers. The experience of each group in mathematics teaching is about the same.

3. Institute preparation of teachers to prepare them in the new curricula favors the control teachers in both chemistry and physics.
CHAPTER IV

PRESENTATION AND INTERPRETATION OF DATA

The purpose of this study is to compare in selected outcomes the effectiveness of integrated chemistry-physics courses with chemistry and physics courses taught separately. Experimental and control groups were evaluated in terms of gains in subject matter achievement, critical thinking abilities and attitudes toward science.

Three of six treatment classes studied the CBA - PSSC integrated course, the remainder studied the CHEMS - PSSC integrated course. Three of six chemistry control classes studied CBA chemistry, the remaining three studied the CHEMS chemistry course while six PSSC physics classes served as physics control classes.

To assess the educational value students derived from these courses, the differences between the posttest scores and pretest scores were calculated on criterion instruments; then the paired t-test was applied to the mean of these differences using each class as an observation. Thus six observations constituted each of the three samples that were drawn from the larger populations.

Critical Thinking

To evaluate comparative gains in critical thinking, alternate forms of the Watson-Glaser Critical Thinking Appraisal were administered to all students, the YM Form as a pretest instrument and the ZM Form as a posttest instrument.
Table X summarizes treatment and chemistry control class performance on these instruments; the means, standard deviations and confidence intervals are given. Differences in performance between treatment and chemistry control classes are more evident when Table XI is constructed from data given in Table X. Contrasting the gains in raw scores among treatment and chemistry control classes reveals that four times out of six the treatment classes surpassed the control classes.

The hypothesis was tested that there is no significant difference in gains made by the six treatment classes as compared with the six chemistry control classes. With five degrees of freedom \( t \) must equal 2.571 in order to claim a significant difference in mean gain at the five percent level. Calculation of \( t \) yielded 1.00. The result suggests that the integrated physics-chemistry courses do not significantly enhance critical thinking abilities beyond the level achieved by the separate chemistry courses.

Table XII summarizes student performance on the critical thinking appraisal for treatment classes and physics control classes. Means, standard deviations and confidence intervals are presented. Differences in performance between treatment and physics control classes are more apparent when Table XIII is constructed from data given in Table XII. Five times out of six the mean gain in raw scores favor the treatment classes.
Table X. Means, Standard Deviations and Confidence Intervals of Treatment and Chemistry Control Classes on the Watson-Glaser Critical Thinking Appraisal

<table>
<thead>
<tr>
<th>Group</th>
<th>Class</th>
<th>( \bar{x} )</th>
<th>( S_{\bar{x}} )</th>
<th>C. I. 5%</th>
<th>( \bar{x} )</th>
<th>( S_{\bar{x}} )</th>
<th>C. I. 5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Treatment</td>
<td>66.64</td>
<td>1.62</td>
<td>63.30-69.98</td>
<td>73.44</td>
<td>1.88</td>
<td>69.55-77.33</td>
</tr>
<tr>
<td></td>
<td>CBA</td>
<td>71.29</td>
<td>1.73</td>
<td>67.71-74.87</td>
<td>75.09</td>
<td>1.67</td>
<td>71.60-78.58</td>
</tr>
<tr>
<td>II</td>
<td>Treatment</td>
<td>72.78</td>
<td>1.99</td>
<td>68.65-76.91</td>
<td>76.2</td>
<td>1.90</td>
<td>72.26-80.14</td>
</tr>
<tr>
<td></td>
<td>CBA</td>
<td>72.77</td>
<td>1.86</td>
<td>68.88-76.56</td>
<td>74.35</td>
<td>2.36</td>
<td>69.42-79.28</td>
</tr>
<tr>
<td>III</td>
<td>Treatment</td>
<td>64.10</td>
<td>2.05</td>
<td>59.79-69.41</td>
<td>69.7</td>
<td>1.91</td>
<td>65.66-73.73</td>
</tr>
<tr>
<td></td>
<td>CBA</td>
<td>68.60</td>
<td>2.71</td>
<td>62.48-74.72</td>
<td>68.4</td>
<td>2.71</td>
<td>62.36-74.44</td>
</tr>
<tr>
<td>IV</td>
<td>Treatment</td>
<td>65.28</td>
<td>1.77</td>
<td>61.64-69.92</td>
<td>70.1</td>
<td>1.72</td>
<td>66.62-73.58</td>
</tr>
<tr>
<td></td>
<td>CHEMS</td>
<td>64.08</td>
<td>2.00</td>
<td>55.80-72.36</td>
<td>69.7</td>
<td>2.31</td>
<td>64.89-74.51</td>
</tr>
<tr>
<td>V</td>
<td>Treatment</td>
<td>69.04</td>
<td>1.45</td>
<td>66.04-72.04</td>
<td>73.4</td>
<td>1.46</td>
<td>70.35-76.45</td>
</tr>
<tr>
<td></td>
<td>CHEMS</td>
<td>66.80</td>
<td>1.73</td>
<td>63.23-70.37</td>
<td>69.7</td>
<td>1.48</td>
<td>66.65-72.75</td>
</tr>
<tr>
<td>VI</td>
<td>Treatment</td>
<td>71.00</td>
<td>1.45</td>
<td>68.01-73.99</td>
<td>72.2</td>
<td>1.79</td>
<td>68.49-75.91</td>
</tr>
<tr>
<td></td>
<td>CHEMS</td>
<td>69.09</td>
<td>2.13</td>
<td>64.66-73.52</td>
<td>70.95</td>
<td>2.38</td>
<td>65.99-75.90</td>
</tr>
</tbody>
</table>

\( \bar{x} \) = Mean. \( S_{\bar{x}} \) = Standard deviation. C. I. = Confidence interval.

* Corrected for difference in test difficulty.
Table XI. Class Means and Differences on the Watson-Glaser Critical Thinking Appraisal

<table>
<thead>
<tr>
<th>Group</th>
<th>Treatment Classes</th>
<th>Chemistry Classes</th>
<th>Difference of Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>*Form ZM Form YM</td>
<td>*ZM YM Diff.</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>73.44 - 66.64 = 6.80</td>
<td>75.09 - 71.29 = 3.80</td>
<td>+3.00</td>
</tr>
<tr>
<td>II</td>
<td>76.20 - 72.78 = 3.42</td>
<td>74.35 - 72.77 = 1.58</td>
<td>+1.84</td>
</tr>
<tr>
<td>III</td>
<td>69.70 - 64.10 = 5.60</td>
<td>68.40 - 68.60 = -0.20</td>
<td>+5.80</td>
</tr>
<tr>
<td>IV</td>
<td>70.10 - 65.28 = 4.82</td>
<td>69.70 - 64.08 = 5.62</td>
<td>-0.80</td>
</tr>
<tr>
<td>V</td>
<td>73.40 - 69.04 = 4.36</td>
<td>69.70 - 66.80 = 2.90</td>
<td>+1.46</td>
</tr>
<tr>
<td>VI</td>
<td>72.20 - 71.00 = 1.20</td>
<td>70.95 - 69.09 = 1.86</td>
<td>-0.66</td>
</tr>
</tbody>
</table>

* Corrected for difference in test difficulty.

The second hypothesis tested concerned the performance of the six treatment classes as compared with the six physics control classes with respect to their mean gains in critical thinking abilities. Performance of individual classes are depicted in Tables XII and XIII. The null hypothesis was also accepted for these two groups of students because significance between mean gains at the five percent level with five degrees of freedom requires a t value of 2.571. The calculated value was 0.57. This implies that the integrated chemistry-physics courses do not significantly enhance critical thinking beyond the level achieved by the separate courses in spite of the apparent trend in that direction.
Table XII. Means, Standard Deviations and Confidence Intervals of Treatment and PSSC Classes on the Watson-Glaser Critical Thinking Appraisal

<table>
<thead>
<tr>
<th>Group</th>
<th>Class</th>
<th>Form YM</th>
<th>S_x</th>
<th>C. I. 5%</th>
<th>Form ZM*</th>
<th>S_x</th>
<th>C. I. 5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Treatment</td>
<td>66.64</td>
<td>1.62</td>
<td>63.30-69.98</td>
<td>73.44</td>
<td>1.88</td>
<td>69.55-77.33</td>
</tr>
<tr>
<td></td>
<td>PSSC</td>
<td>69.59</td>
<td>1.46</td>
<td>66.56-72.56</td>
<td>76.23</td>
<td>1.35</td>
<td>73.44-79.02</td>
</tr>
<tr>
<td>II</td>
<td>Treatment</td>
<td>72.78</td>
<td>1.99</td>
<td>68.65-76.91</td>
<td>76.2</td>
<td>1.90</td>
<td>72.26-80.14</td>
</tr>
<tr>
<td></td>
<td>PSSC</td>
<td>74.32</td>
<td>4.28</td>
<td>70.05-78.59</td>
<td>77.2</td>
<td>1.85</td>
<td>68.35-81.05</td>
</tr>
<tr>
<td>III</td>
<td>Treatment</td>
<td>64.10</td>
<td>2.05</td>
<td>59.79-69.41</td>
<td>69.7</td>
<td>1.91</td>
<td>65.66-73.73</td>
</tr>
<tr>
<td></td>
<td>PSSC</td>
<td>68.85</td>
<td>1.87</td>
<td>65.02-72.68</td>
<td>72.1</td>
<td>3.35</td>
<td>64.99-79.21</td>
</tr>
<tr>
<td>IV</td>
<td>Treatment</td>
<td>65.28</td>
<td>1.77</td>
<td>61.64-68.92</td>
<td>70.1</td>
<td>1.72</td>
<td>66.62-73.58</td>
</tr>
<tr>
<td></td>
<td>PSSC</td>
<td>70.90</td>
<td>3.10</td>
<td>64.58-72.22</td>
<td>74.2</td>
<td>1.55</td>
<td>71.01-77.38</td>
</tr>
<tr>
<td>V</td>
<td>Treatment</td>
<td>69.04</td>
<td>1.45</td>
<td>66.04-72.04</td>
<td>73.4</td>
<td>1.46</td>
<td>70.35-76.45</td>
</tr>
<tr>
<td></td>
<td>PSSC</td>
<td>68.93</td>
<td>1.92</td>
<td>64.84-73.02</td>
<td>72.3</td>
<td>2.23</td>
<td>67.51-77.08</td>
</tr>
<tr>
<td>VI</td>
<td>Treatment</td>
<td>71.00</td>
<td>1.45</td>
<td>68.01-73.99</td>
<td>72.2</td>
<td>1.79</td>
<td>68.49-75.91</td>
</tr>
<tr>
<td></td>
<td>PSSC</td>
<td>68.52</td>
<td>1.93</td>
<td>64.43-72.61</td>
<td>72.6</td>
<td>2.25</td>
<td>67.80-77.39</td>
</tr>
</tbody>
</table>

\( \bar{x} = \text{Mean.} \)

\( S_\bar{x} = \text{Standard deviation.} \)

\( C.I. = \text{Confidence interval} \)

\( *= \text{Corrected for difference in test difficulty.} \)
Table XIII. Class Means and Differences on the Watson-Glaser Critical Thinking Appraisal

<table>
<thead>
<tr>
<th>Group</th>
<th>Treatment Classes</th>
<th>Physics Classes</th>
<th>Difference of Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>*Form ZM</td>
<td>Form YM</td>
<td>Diff.</td>
</tr>
<tr>
<td>I</td>
<td>73.44 - 66.64 = 6.80</td>
<td>76.23 - 69.59 = 6.64</td>
<td>+0.16</td>
</tr>
<tr>
<td>II</td>
<td>76.20 - 72.78 = 3.42</td>
<td>77.20 - 74.32 = 2.88</td>
<td>+0.54</td>
</tr>
<tr>
<td>III</td>
<td>69.70 - 64.10 = 5.60</td>
<td>72.10 - 68.85 = 3.25</td>
<td>+2.35</td>
</tr>
<tr>
<td>IV</td>
<td>70.10 - 65.28 = 4.82</td>
<td>74.20 - 70.90 = 3.30</td>
<td>+1.52</td>
</tr>
<tr>
<td>V</td>
<td>73.40 - 69.04 = 4.36</td>
<td>72.30 - 68.93 = 3.37</td>
<td>+0.99</td>
</tr>
<tr>
<td>VI</td>
<td>72.20 - 71.00 = 1.20</td>
<td>72.60 - 68.52 = 4.08</td>
<td>-2.88</td>
</tr>
</tbody>
</table>

* Corrected for difference in test difficulty.

Accepting the null hypothesis with regard to the influence of the combined courses and the separate courses relative to their effect on critical thinking abilities is not an unexpected result. The objectives of the combined courses in this regard are not radically different from those which are incorporated in the independent courses. In addition, the designers of the integrated courses acceded to the pedagogical approach of PSSC, CHEMS, and CBA and affirmed their intentions to support these views concerning the nature of the scientific enterprise. Therefore it is not surprising that their net effects upon students are rather similar, with respect to increasing students' capacity to recognize assumptions, to make inferences, and to interpret evidence.
Achievement in Chemistry Content

Two examinations to assess student growth in their understanding of chemistry were assembled by the investigator to determine relative achievement of treatment and control classes. A thirty-five item test was prepared from a pool of items developed cooperatively by CBA and the Educational Testing Service. This examination was administered to the three CBA control classes and the three treatment classes who studied the PSSC - CBA integration.

A second thirty-five item test was prepared from a pool of items developed by the CHEMS committee and the Educational Testing Service. This examination was administered to the three CHEMS control classes and to the three classes who were given instruction in the combined PSSC - CHEMS course.

Both of these examinations were utilized as pretest and posttest instruments. The nine months which elapsed between testings was considered adequate to eliminate memory of test items as an aid to student performance. In any event both treatment and control classes had similar opportunities to recall test items.

Nineteen of the thirty-five items incorporated in the CBA examination and twenty-five of the thirty-five items in the CHEMS examination were scored to yield the results recorded in Table XIV. Reasons for deletion of certain test items are given in the previous
## Table XIV. Means, Standard Deviations and Confidence Intervals of Treatment and Chemistry Control Classes on Chemistry Achievement Examinations

<table>
<thead>
<tr>
<th>Group</th>
<th>Class</th>
<th>Pre-Test</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$\bar{x}$</td>
<td>$S_{\bar{x}}$</td>
</tr>
<tr>
<td>I</td>
<td>Treatment</td>
<td>3.29</td>
<td>0.40</td>
</tr>
<tr>
<td></td>
<td>CBA</td>
<td>2.62</td>
<td>0.25</td>
</tr>
<tr>
<td>II</td>
<td>Treatment</td>
<td>3.43</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>CBA</td>
<td>3.08</td>
<td>0.37</td>
</tr>
<tr>
<td>III</td>
<td>Treatment</td>
<td>2.52</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td>CBA</td>
<td>3.00</td>
<td>0.40</td>
</tr>
<tr>
<td>IV</td>
<td>Treatment</td>
<td>5.85</td>
<td>0.48</td>
</tr>
<tr>
<td></td>
<td>CHEMS</td>
<td>5.70</td>
<td>0.43</td>
</tr>
<tr>
<td>V</td>
<td>Treatment</td>
<td>6.26</td>
<td>0.66</td>
</tr>
<tr>
<td></td>
<td>CHEMS</td>
<td>5.47</td>
<td>0.57</td>
</tr>
<tr>
<td>VI</td>
<td>Treatment</td>
<td>4.96</td>
<td>0.34</td>
</tr>
<tr>
<td></td>
<td>CHEMS</td>
<td>5.73</td>
<td>0.60</td>
</tr>
</tbody>
</table>

$\bar{x}$ = Mean. $S_{\bar{x}}$ = Standard deviation.
C. I. = Confidence interval.
chapter. The table summarizes means of class performance, standard deviations and confidence intervals. Table XV was prepared from Table XIV for purposes of clarity. Inspection of them reveals that the chemistry control classes achieved a greater mean gain four times to two for the treatment classes.

Table XV. Class Means and Differences on the Chemistry Achievement Tests

<table>
<thead>
<tr>
<th>Group</th>
<th>Treatment Class Posttest - Pretest = Difference</th>
<th>Chemistry Class Posttest - Pretest = Difference</th>
<th>Difference of Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>5.04 - 3.29 = 1.75</td>
<td>4.85 - 2.62 = 2.23</td>
<td>-0.48</td>
</tr>
<tr>
<td>II</td>
<td>6.00 - 3.43 = 2.57</td>
<td>6.09 - 3.08 = 3.01</td>
<td>-0.44</td>
</tr>
<tr>
<td>III</td>
<td>6.00 - 2.52 = 3.48</td>
<td>7.66 - 3.00 = 4.66</td>
<td>-1.18</td>
</tr>
<tr>
<td>IV</td>
<td>8.61 - 5.85 = 2.76</td>
<td>8.66 - 5.70 = 2.96</td>
<td>-0.20</td>
</tr>
<tr>
<td>V</td>
<td>11.09 - 6.26 = 4.83</td>
<td>7.37 - 5.47 = 1.90</td>
<td>+2.93</td>
</tr>
<tr>
<td>VI</td>
<td>10.00 - 4.96 = 5.04</td>
<td>9.17 - 5.73 = 3.44</td>
<td>+1.60</td>
</tr>
</tbody>
</table>

The third hypothesis tested concerned the performance of six treatment classes and six chemistry control classes with respect to mean gains on the chemistry criterion tests. Applications of the paired t test leads to acceptance of the null hypothesis that there is not a significant difference in mean performance between treatment and chemistry control classes. A t value of 2.571 is required to demonstrate significance at the five percent level with five degrees of freedom. The calculated value was 0.57.
Acceptance of the null hypothesis in this case is rather unexpected because the designers of the combined courses deliberately shifted course content to favor concept formation in chemistry. Physics concepts deemed fundamental to mastery of chemistry concepts preceded them; e.g., dynamics, which is considered normally to fall within the realm of physics precedes the gas laws, part of chemistry content. Also conservation of energy is developed in detail before students study chemical energetics.

This result suggests integration of chemistry and physics does not significantly enhance chemistry concept formation in spite of the calculated effort to promote logical content development.

Achievement in Physics Content

An examination to measure achievement in physics content was assembled by the investigator from test items created by the Physical Science Study Committee in cooperation with Educational Testing Service. This 35-item examination was administered at the beginning of the 1963-64 school year to all students in treatment and physics control classes. The identical examination was employed as a posttest device approximately nine months later. Memory of test items from pretesting to posttesting was considered negligible. If there was some retention, both treatment and control classes had the same advantage.
Mean raw scores together with confidence intervals and standard deviations appear in Table XVI. To represent the data in a more meaningful way Table XVII is derived from Table XVI. Inspection of this data reveals that in five groups the treatment classes surpassed the control class.

The fourth hypothesis tested concerned the performance of six treatment classes and six physics control classes on the physics criterion test.

Applying the paired t-test leads to the acceptance of the null hypothesis that there is not a significant difference in mean performance of treatment and physics control classes on the physics achievement test. A t value of 2.571 is required to demonstrate significance at the five percent level with five degrees of freedom. The calculated t value is 0.806.

Apparently neither the integrated chemistry-physics courses nor the PSSC course can demonstrate any superiority in their effect on student achievement. The differences that do appear, though not statistically significant, favor the integrated courses. This leads to the speculation that within the limits of this study integration of chemistry and physics does not significantly enhance students' grasp of physics concepts.
Table XVI. Means, Standard Deviations and Confidence Intervals of Treatment and Physics Control Classes on a Physics Achievement Examination

<table>
<thead>
<tr>
<th>Group</th>
<th>Class</th>
<th>Pre-test</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$\bar{x}$</td>
<td>$S_{\bar{x}}$</td>
</tr>
<tr>
<td>I</td>
<td>Treatment</td>
<td>13.53</td>
<td>0.76</td>
</tr>
<tr>
<td></td>
<td>Physics</td>
<td>13.59</td>
<td>0.39</td>
</tr>
<tr>
<td>II</td>
<td>Treatment</td>
<td>11.84</td>
<td>0.85</td>
</tr>
<tr>
<td></td>
<td>Physics</td>
<td>13.84</td>
<td>0.82</td>
</tr>
<tr>
<td>III</td>
<td>Treatment</td>
<td>12.57</td>
<td>0.64</td>
</tr>
<tr>
<td></td>
<td>Physics</td>
<td>14.03</td>
<td>0.76</td>
</tr>
<tr>
<td>IV</td>
<td>Treatment</td>
<td>11.00</td>
<td>0.87</td>
</tr>
<tr>
<td></td>
<td>Physics</td>
<td>14.00</td>
<td>0.72</td>
</tr>
<tr>
<td>V</td>
<td>Treatment</td>
<td>11.50</td>
<td>0.60</td>
</tr>
<tr>
<td></td>
<td>Physics</td>
<td>13.00</td>
<td>0.81</td>
</tr>
<tr>
<td>VI</td>
<td>Treatment</td>
<td>13.24</td>
<td>0.40</td>
</tr>
<tr>
<td></td>
<td>Physics</td>
<td>14.82</td>
<td>0.88</td>
</tr>
</tbody>
</table>

$\bar{x} =$ Mean. $S_{\bar{x}} =$ Standard deviation.
C.I. = Confidence Interval.
Table XVII. Class Means and Differences on the Physics Achievement Tests

<table>
<thead>
<tr>
<th>Group</th>
<th>Treatment Class Posttest - Pretest = Difference</th>
<th>Physics Control Class Posttest - Pretest = Difference</th>
<th>Difference of Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>18.80 - 13.53 = 5.27</td>
<td>22.19 - 13.59 = 8.60</td>
<td>-3.33</td>
</tr>
<tr>
<td>II</td>
<td>20.54 - 11.84 = 8.70</td>
<td>22.13 - 13.84 = 8.29</td>
<td>+0.41</td>
</tr>
<tr>
<td>III</td>
<td>20.05 - 12.57 = 7.48</td>
<td>21.16 - 14.03 = 7.13</td>
<td>+0.35</td>
</tr>
<tr>
<td>IV</td>
<td>17.50 - 11.00 = 6.50</td>
<td>16.84 - 14.00 = 2.84</td>
<td>+3.66</td>
</tr>
<tr>
<td>V</td>
<td>21.81 - 11.50 = 10.31</td>
<td>21.50 - 13.00 = 8.50</td>
<td>+1.81</td>
</tr>
<tr>
<td>VI</td>
<td>22.70 - 13.24 = 9.46</td>
<td>22.55 - 14.82 = 7.73</td>
<td>+1.73</td>
</tr>
</tbody>
</table>

Attitudes Toward Science

To evaluate comparative changes in students' attitudes toward the nature of science, science's impact on society, the scientist and careers in science, an attitude inventory was administered to all students who took part in this study. The same instrument was used as a pretest and posttest device with nine months intervening between testings. Forty-nine items were selected from the list compiled by Allen in his Reaction Inventory Attitudes Toward Science and Scientific Careers. Selection of these statements was based on the interest of the investigator. As the study progressed, preliminary evidence dictated that the number of statements should be reduced to fifteen for purposes of analysis. Careful perusal of the differences in responses between treatment and control classes gave evidence on which
Statements might prove fruitful for analysis. Statements which yielded the largest differences between treatment and control class responses were selected for analysis. These statements are:

1. Science is a systematic way of thinking.
7. To become a scientist requires superior ability.
9. Scientists are willing to change their ideas and beliefs.
12. Modern science is too complicated for the average citizen to understand and appreciate.
14. It is undemocratic to favor exceptional scientific talent.
15. The monetary compensation of a Nobel Prize winner in physics should be at least equal to that given popular entertainers.
20. Scientists are honored persons who stand very high in popular prestige.
24. Scientific work is boring.
26. Scientific findings always lead to final truths.
34. There is much self-satisfaction to be received from work as a scientist.
36. Science helps us to understand our environment.
42. Scientific work is monotonous.
43. The working scientist believes that nature is orderly rather than disorderly.
47. Curiosity motivates scientists to make their discoveries.

48. The chief reward in scientific work is the thrill of discovery.

Numerical values were assigned to each response in the manner of Table XVIII. Pretest scores for each student were subtracted from posttest scores; then a class mean of these differences was calculated for each treatment class, chemistry control class and physics class. These means appear in Appendix B.

Table XVIII. Method of Ascribing Quantitative Values to Responses on the Attitudes Inventory

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Meaning</th>
<th>Point Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA</td>
<td>Strongly Agree</td>
<td>4</td>
</tr>
<tr>
<td>A</td>
<td>Agree</td>
<td>3</td>
</tr>
<tr>
<td>N</td>
<td>Neutral</td>
<td>2</td>
</tr>
<tr>
<td>D</td>
<td>Disagree</td>
<td>1</td>
</tr>
<tr>
<td>DD</td>
<td>Strongly Disagree</td>
<td>0</td>
</tr>
</tbody>
</table>

The fifth hypothesis tested dealt with students' attitudes towards science and the scientist. The hypothesis stated in the null form follows: There is no significant difference in changes of attitudes towards science and the scientist between students who study integrated chemistry-physics courses and students who study separate chemistry courses. The fifth hypothesis is divided into fifteen sub-hypothesis (page 88) based upon attitude statements about science and the scientist.
Table XIX summarizes results of the fifteen tests of sub-hypotheses together with an indication of significance. Thirteen tests of sub-hypotheses leads to acceptance of the null hypothesis: two are rejected. The calculated t value for attitude number nine which relates to the willingness of scientists to change their ideas and beliefs, however, is significant for treatment and chemistry control classes. This could suggest that students who studied the integrated courses were more convinced of the tentative nature of scientific facts and principles than their counterparts in the chemistry control classes. Analysis of results on attitude number 47 indicates that treatment classes appear to be less convinced than chemistry control classes, that curiosity motivates the scientist's actions as a result of experiences in their respective courses.

The sixth hypothesis tested dealt with students' attitudes towards science and the scientist. The hypothesis stated in the null form follows: There is no significant difference in changes of attitudes towards science and the scientist between students who study integrated chemistry-physics courses and students who study a separate physics course.

The sixth hypothesis was divided into fifteen sub-hypotheses (page 88) based on selected attitude statements about science and the scientist.

The paired t test applied to the difference of means of class
<table>
<thead>
<tr>
<th>Attitude Number</th>
<th>Calculated t Value Treatment and Chemistry Control Classes</th>
<th>Significance</th>
<th>Calculated t Value Treatment and Physics Control Classes</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>+0.320</td>
<td>NS</td>
<td>-0.124</td>
<td>NS</td>
</tr>
<tr>
<td>7</td>
<td>-0.023</td>
<td>NS</td>
<td>-0.939</td>
<td>NS</td>
</tr>
<tr>
<td>9</td>
<td>+2.813</td>
<td>S</td>
<td>+1.019</td>
<td>NS</td>
</tr>
<tr>
<td>12</td>
<td>-0.982</td>
<td>NS</td>
<td>+0.469</td>
<td>NS</td>
</tr>
<tr>
<td>14</td>
<td>+0.104</td>
<td>NS</td>
<td>-2.078</td>
<td>NS</td>
</tr>
<tr>
<td>15</td>
<td>+0.692</td>
<td>NS</td>
<td>+1.98</td>
<td>NS</td>
</tr>
<tr>
<td>20</td>
<td>+2.56</td>
<td>NS</td>
<td>+5.14</td>
<td>S</td>
</tr>
<tr>
<td>24</td>
<td>-2.36</td>
<td>NS</td>
<td>-0.916</td>
<td>NS</td>
</tr>
<tr>
<td>26</td>
<td>+1.22</td>
<td>NS</td>
<td>-0.700</td>
<td>NS</td>
</tr>
<tr>
<td>34</td>
<td>+0.502</td>
<td>NS</td>
<td>+0.250</td>
<td>NS</td>
</tr>
<tr>
<td>36</td>
<td>+1.28</td>
<td>NS</td>
<td>+2.07</td>
<td>NS</td>
</tr>
<tr>
<td>42</td>
<td>-0.537</td>
<td>NS</td>
<td>-0.822</td>
<td>NS</td>
</tr>
<tr>
<td>43</td>
<td>+2.05</td>
<td>NS</td>
<td>+1.29</td>
<td>NS</td>
</tr>
<tr>
<td>47</td>
<td>-3.59</td>
<td>S</td>
<td>+0.792</td>
<td>NS</td>
</tr>
<tr>
<td>48</td>
<td>+1.82</td>
<td>NS</td>
<td>+1.09</td>
<td>NS</td>
</tr>
</tbody>
</table>

NS = Not Significant
S = Significant
performance must yield a value of 2.517 to be significant at the five percent level with five degrees of freedom.

Table XIX summarizes results of the fifteen tests of sub-hypotheses together with an indication of significance. Fourteen tests of the sub-hypotheses lead to acceptance of the null hypothesis: one leads to rejection. The calculated t value for attitude number twenty which related to the status of scientists demonstrates significance for treatment classes and physics control classes. Treatment students are more willing to grant him elevated honor and prestige.
CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

This study was designed to compare the effectiveness in selected outcomes, integrated chemistry-physics courses with chemistry and physics courses taught separately. Treatment and control classes were evaluated in terms of gains in subject matter achievement, gains in critical thinking abilities and changes in attitudes toward science.

The Otis Mental Ability Test: Gamma Form EM was utilized to assess the I. Q.'s of all students who took part in this study in the Fall of 1963. The Watson-Glaser Critical Thinking Appraisal, Form YM was used in a pretest battery to determine critical thinking abilities of all students at the onset of this study. Achievement tests were assembled by the investigator and administered at the beginning of the 1963-64 school year to measure previous knowledge about chemistry and physics. A science attitudes inventory adapted from the Reaction Inventory, Attitudes Toward Science and Scientific Careers was also included in the pretest battery. Posttests were administered in the Spring of 1964 consisting of the Watson-Glaser Critical Thinking Appraisal, Form ZM, and the identical achievement tests and attitudes inventory utilized in the pretest battery.
Conclusions

Six major hypotheses were set forth in Chapter I. These hypotheses were tested as reported in Chapters III and IV. Within the assumptions and limitations set out in Chapter I the following conclusions are warranted:

1. There is no significant difference in performance on a critical thinking criterion test between classes that study the integrated chemistry-physics courses and those classes that study the separate chemistry courses.

2. There is no significant difference in performance on a critical thinking criterion test between classes that study the integrated chemistry-physics courses and those classes that study the separate physics course.

3. There is no significant difference in performance on an achievement criterion test between classes that study the integrated chemistry-physics courses and those classes that study separate chemistry courses.

4. There is no significant difference in performance on an achievement criterion test between classes that study the integrated chemistry-physics courses and those classes that study the separate physics course.

5. The fifth hypothesis stated in the null form follows:
There is no significant difference in changes of attitudes towards science and the scientist between students who study integrated chemistry-physics courses and those students who study separate chemistry courses. The fifth hypothesis was divided into fifteen sub-hypotheses based on selected attitude statements about science and the scientist. (Appendix B.)

Of fifteen tests of sub-hypotheses with respect to changes of attitudes toward science among treatment and chemistry control classes, the null hypothesis was accepted for thirteen of them and rejected for two. One of these rejections favored the integrated courses, the other the chemistry courses.

6. The sixth hypothesis stated in the null form follows: There is no significant difference in changes of attitudes towards science and the scientist between students who study integrated chemistry-physics courses and students who study a separate physics course. The sixth hypothesis was divided into fifteen sub-hypotheses based on selected attitude statements about science and the scientist. (Appendix B.)

Of fifteen tests of sub-hypotheses with respect to changes of attitudes toward science among treatment and physics control classes
fourteen were accepted and one was rejected. The rejection favored the treatment classes.

Discussion

Critical Thinking

Acceptance of the null hypothesis with respect to critical thinking for treatment and control classes was to be expected because the essential difference between the combined courses and the non-integrated courses lies in the sequence of content. Methods of instruction and emphasis on the process of science are not vastly different. Yet, comparison of treatment classes with chemistry control classes shows that four out of six times treatment classes surpassed control classes in their mean gains. Comparison of treatment classes with physics control classes shows that five out of six times treatment classes excel in their mean gains. The data does demonstrate then, that there is a tendency for treatment classes to make greater gains in critical thinking, though this difference is not significant.

Achievement in Chemistry

Student characteristics such as grade placement, I.Q., previous courses in science and mathematics and parents' occupations are essentially the same for treatment and chemistry control classes.
In addition, factors related to teachers, such as experience and preparation are similar for the treatment and chemistry control classes. Data analysis of achievement test results leads to acceptance of the null hypothesis with respect to achievement in chemistry for the two groups of students. The conclusion seems warranted then, that the integrated courses are no more effective in developing understanding of chemistry concepts than the separate chemistry courses. This was the first time integrated courses of this kind were taught by treatment teachers. Added teaching experience could lead to vastly different results.

Achievement in Physics

Student characteristics in the physics control classes such as grade placement, I. Q., and previous courses in science and mathematics, are substantially greater than corresponding treatment classes. Data analysis of test results leads to acceptance of the null hypothesis with respect to achievement in physics for the two groups of students even though obvious advantage is evident among treatment classes in these examinations. Though it is not possible to demonstrate that this difference is significant, when it is considered along with students' lower mental ability and maturity, the capacity of the integrated courses to convey physics content is striking. Further, when analysis of data is done using students rather than
classes as observations which make up the sample, the integrated courses are significantly superior to the non-integrated physics course in their ability to convey physics content.

Attitudes Towards Science

In thirty tests of sub-hypotheses, the null hypothesis was accepted twenty-seven times and rejected three times. Two of the three rejections favored the integrated courses; one did not. The implication is that the courses do not differentially effect students' attitudes toward science, the scientist, scientific careers, and the impact of science on society. Again, this result is anticipated in the sense that the major difference between the courses tested lies in the cognitive domain rather than in the area of attitudes and appreciations. Differential attitude changes should probably not be expected unless they arise from the interaction of content sequence with attitudes.

Recommendations

1. A study similar to this should be repeated in several years after teachers have had experience with the integrated courses.

2. An evaluation which encompasses results obtained from a two-year exposure to the integrated courses should be undertaken.
3. The integrated courses should be tested in a variety of schools; those having wider geographical distribution, private schools, and rural schools.

4. The effect of the team teaching method of instruction utilizing chemistry and physics teachers should be compared with those results achieved in the separate courses.

5. This study could be repeated using an alternate method of data analysis; i.e., using students rather than classes as observations. There is ample evidence in this study that such a procedure may give substantially different results. An alternate method of data analysis did show the integrated courses to be significantly superior to the separate physics course. Rather than carrying out data analysis using classes as units individual student performances were considered observations that comprised the sample. This method of analysis provides a much larger sample and therefore many more degrees of freedom. The t value to achieve significance approaches 1.96, which is associated with an infinite sample size. This alternate method of analysis yields a t value of 1.98 which is significant at the five percent level.

6. Distinct facets of critical thinking such as the ability to recognize assumptions, frame hypotheses, interpret data,
and draw conclusions based on evidence should be separated from one another and analysis of data relative to these specific abilities should be studied.

7. Achievement test items should be constructed that intersect both chemistry and physics. These should be used together with items that test achievement in the separate disciplines to assess cognitive gains that result from exposure to the combined and non-integrated courses.
BIBLIOGRAPHY


APPENDICES
APPENDIX A
TEACHER QUESTIONNAIRE

A. Name ____________________________ School ____________________________

Age ________ Subject(s) taught in Pilot Study ____________________________

B. Training

1. Total semester hours of preparation in science ________
2. Total semester hours of preparation in chemistry ________
3. Total semester hours of preparation in physics ________
4. Total semester hours of preparation in mathematics ________
5. Have you had preparation in a teacher training institute in one or more of the following? Please check the appropriate box or boxes.

☐ PSSC  ☐ CBA  ☐ CHEMS

6. Degrees - please circle and give the date the degree was granted.

BS, BA, BEd, ________ other; ________ date.
MS, MA, MEd, ________ other; ________ date.

C. Experience

1. Total number of years you taught chemistry ________
2. Total number of years you taught CBA or CHEMS ________
3. Total number of years you taught physics ________
4. Total number of years you taught PSSC ________
5. Total number of years you taught mathematics ________

D. Professional Activities and Interests

1. Please list the professional organizations to which you belong.

________________________________________________________________________

________________________________________________________________________

2. Please list the publications you read regularly.

________________________________________________________________________

________________________________________________________________________

3. Please list other professional activities.

________________________________________________________________________

________________________________________________________________________
STUDENT QUESTIONNAIRE

Name ___________________________ Date ___________________

Last    First    Middle

Age _____ Sex M F

Grade  9  10  11  12

Circle one

School __________________________ Teacher __________________________

Course CBA CHEM PSSC PC

Circle one

Father's Occupation __________________________ Mother's Occupation __________________________

School subject most liked __________________________

School subject least liked __________________________

Courses you have had in Science

☐ General Science
☐ Physical Science
☐ Biology I  ☐ Biology II
☐ Chemistry
☐ Physics
☐ Electronics

________________________ other

Courses you have had in Mathematics

☐ General Mathematics
☐ Algebra I
☐ Algebra II
☐ Geometry
☐ Trigonometry
☐ Number Theory
☐ Calculus

________________________ other
CHEM STUDY ACHIEVEMENT TEST

You will be given 45 minutes to work on this test. There are several different types of questions. You will find special directions for each type inside the test book. Be sure you understand the directions before attempting to answer any questions.

It is not expected that everyone will finish all the questions in the time allowed. Work steadily and as quickly as you can without sacrificing accuracy. If a question seems too difficult, make the most careful guess you can, rather than waste time puzzling over it.

YOU ARE TO INDICATE ALL YOUR ANSWERS ON THE SEPARATE ANSWER SHEET ENCLOSED IN THE TEST BOOK. You may use any blank spaces in the book for scratchwork, but no credit will be given for anything written in the test book. After you have decided which of the suggested answers you want to give for a question, blacken the space between the dotted lines under its letter on the answer sheet, using only the special electrographic pencil.

Example:

I. Chicago is a

   (A) state
   (B) city
   (C) country
   (D) continent
   (E) village

   Sample Answer

   A   B   C   D   E
   I   |||||

Mark only one space on the answer sheet for each question; no credit will be given for a question if more than one space is marked. If you wish to change an answer, erase your first line completely and mark your new choice. Be careful not to make stray marks on your answer sheet.

DO NOT OPEN THIS BOOK UNTIL YOU ARE TOLD TO DO SO
Questions 1 and 2 refer to the following situations:

An electrical force of 1 unit exists between two spheres which have a charge of 1 electrical unit each, when the centers of the spheres are 1 cm. apart.

An electrometer contains two spheres having charges of +2 and +3 electrical units, respectively. They are suspended as shown in the figure below.

1. If the centers of the spheres are 2 cm. apart, the electrical force between the spheres will be

   (A) \( \frac{2 \times 3}{2} \) units of force, attraction
   (B) \( \frac{2 \times 3}{2} \) units of force, repulsion
   (C) \( \frac{2 \times 3}{2 \times 2} \) units of force, attraction
   (D) \( \frac{2 \times 3}{2 \times 2} \) units of force, repulsion
   (E) \( \frac{2 + 3}{2} \) units of force, repulsion

2. What is the ratio of the electrical force between the spheres in Figure 1 to the electrical force between the spheres in Figure 2?

   (A) 1:4
   (B) 1:2
   (C) 1:1
   (D) 2:1
   (E) 4:1
Questions 3 - 6 pertain to the following information regarding the element sulfur.

Atomic number = 16
Atomic weight = 32.1
Mass number of the most abundant isotope of sulfur = 32

3. A neutral atom of an isotope of sulfur other than the most abundant isotope may contain

(A) 16 protons, 17 neutrons, 16 electrons
(B) 16 protons, 17 neutrons, 17 electrons
(C) 17 protons, 16 neutrons, 17 electrons
(D) 17 protons, 15 neutrons, 17 electrons
(E) 16 protons, 16 neutrons, 16 electrons

4. The assignment of the value 32.1 rather than 32 for the atomic weight of sulfur is based on which of the following assumptions?

(A) All sulfur atoms contain the same number of protons and electrons.
(B) All sulfur atoms contain the same number of neutrons.
(C) Some sulfur atoms contain whole numbers of protons but fractional numbers of neutrons.
(D) The electrons in the sulfur atom have negligible mass.
(E) The proportion of various isotopes is constant in a stable sample of sulfur.

5. In a molecular weight determination, a given volume of sulfur vapor was found to weigh 2.0 grams and the same volume of oxygen, O₂, under the same conditions of temperature and pressure weighed 0.250 grams. On the basis of these data the molecular weight of sulfur is most likely

(A) 32 grams/mole
(B) 64 grams/mole
(C) 128 grams/mole
(D) 256 grams/mole
(E) 512 grams/mole

6. Two moles of silver atoms (atomic weight 107.9) combine with one mole of sulfur atoms to form a mole of the compound, silver sulfide. What is the weight of a mole of silver sulfide?

(A) 123.9 grams
(B) 140.0 grams
(C) 247.9 grams
(D) 280.0 grams
(E) None of the above
Questions 7 – 9 deal with the following experiment relating the pressures and temperatures of some samples of gases. Some helium gas was placed in a flask to which was attached a mercury manometer. The following pressures were observed by placing the flask in four different temperature baths.

<table>
<thead>
<tr>
<th>Pressure in mm. of mercury</th>
<th>750 mm.</th>
<th>820 mm.</th>
<th>1020 mm.</th>
<th>1300 mm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature in °C</td>
<td>0°</td>
<td>25°</td>
<td>100°</td>
<td>200°</td>
</tr>
</tbody>
</table>

The data are plotted on the graph below.

7. Since the above graph indicates that the pressure changes linearly with the temperature, it is possible to use the apparatus as a gas thermometer and predict the temperature at various pressures. When the pressure is 375 mm. Hg, the temperature is approximately

(A) -60°C
(B) -105°C
(C) -135°C
(D) -165°C
(E) -273°C

8. Which of the following statements is FALSE?

(A) The point on the graph representing the temperature at zero pressure (extrapolated) is defined as zero on the absolute temperature scale.
(B) The behavior of helium gas is found to be very close to that of a perfect gas in the range tested.
(C) The translational motion of the gas molecules at -273°C becomes zero.
(D) If the temperature of the sample is increased from 125°C to 250°C the pressure will be doubled.
(E) The pressure is directly proportional to the temperature when the temperature is expressed in degrees Kelvin or degrees absolute.

9. The experiment is repeated, using nitrogen gas at a pressure of 750 mm. Hg at 0°C. Which of the following is FALSE?

(A) If additional gas is added to the container and the experiment repeated, the entire curve would be expected to be higher but parallel to the one shown.
(B) At any given temperature the nitrogen molecules would be moving with a lower average velocity than the helium molecules.
(C) At 0°C the average kinetic energy of the nitrogen molecules is the same as the average kinetic energy of the helium molecules.
(D) The temperature at zero pressure (extrapolated) would be essentially the same for nitrogen as for helium.
(E) The graph would be essentially the same as for helium.
Questions 10-11 relate to the table below which shows the results of mixing a few milliliters of 0.1 M solution of each of five substances with a few milliliters of 0.1 M solution of each of the other substances, one at a time. "Ppt." indicates that a precipitate formed, and "none" indicates that no visible reaction occurred.

<table>
<thead>
<tr>
<th></th>
<th>NaNO₃</th>
<th>K₂SO₄</th>
<th>Pb(CH₃COO)₂</th>
<th>Pb(NO₃)₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaCl</td>
<td>none</td>
<td>none</td>
<td>ppt.</td>
<td>ppt.</td>
</tr>
<tr>
<td>Pb(NO₃)₂</td>
<td>none</td>
<td>ppt.</td>
<td>none</td>
<td></td>
</tr>
<tr>
<td>Pb(CH₃COO)₂</td>
<td>none</td>
<td>ppt.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>K₂SO₄</td>
<td>none</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

10. A correct interpretation of the above data indicates the slight solubility of

   (A) PbCl₂ only
   (B) PbCl₂ and PbSO₄ only
   (C) PbCl₂, PbSO₄, and NaCH₃COO only
   (D) PbCl₂, KCH₃COO, and KNO₃ only
   (E) KCH₃COO, KNO₃, PbSO₄, and NaCH₃COO only

11. Which of the following pairs of substances would you predict would NOT produce a precipitate when equal volumes of their 0.1 M solutions are mixed?

   (A) Pb(NO₃)₂ (aq) and Na₂SO₄ (aq)
   (B) Pb(NO₃)₂ (aq) and KCH₃COO (aq)
   (C) Pb(NO₃)₂ (aq) and KCl (aq)
   (D) Pb(CH₃COO)₂ (aq) and HCl (aq)
   (E) Pb(CH₃COO)₂ (aq) and K₂SO₄ (aq)

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Questions 12-14 refer to the following situation.

A sealed ampule full of ether is placed in a flask containing air at a pressure of 740.0 mm. of mercury. The flask is connected to a mercury manometer (pressure gauge) as shown below. After the ampule is broken and the system is allowed to come to equilibrium at room temperature, the total pressure indicated by the manometer is 803.0 mm. Hg.

12. What is the partial pressure exerted by the gaseous ether molecules?
   (A) 63 mm. Hg
   (B) 677 mm. Hg
   (C) 740 mm. Hg
   (D) 760 mm. Hg
   (E) 803 mm. Hg

13. If the temperature of both flasks is raised 10°C, what will happen to levels 1 b and 2?
   (A) Neither level will change.
   (B) Both levels will rise the same amount.
   (C) Level 1 b will remain unchanged but level 2 will rise.
   (D) Both levels will rise but level 1 b will rise more than level 2.
   (E) Both levels will rise but level 2 will rise more than level 1 b.

14. After the manometer is disconnected from flask 1 b, the flask is heated until ether vapor has driven all the air out of the flask. Then the flask is sealed and the vapor is allowed to come to equilibrium with the remaining liquid at room temperature. Which of the following statements is FALSE?
   (A) The pressure in the flask would be the same as the partial pressure of ether in question 28.
   (B) Ether molecules are entering the gas phase at the same rate that ether molecules are condensing to the liquid phase.
   (C) The potential energy of the gas phase molecules is higher than the potential energy of the liquid phase molecules.
   (D) If the temperature of the system were increased, the pressure in the flask would be increased.
   (E) All the ether molecules have the same kinetic energy.
Questions 15 - 17 relate to the following graph which represents the potential energy diagram for the reaction:

\[ \text{Heat} + 2\text{NH}_3(g) = \text{N}_2(g) + 3\text{H}_2(g) \]

The curves represent two possible paths for the reaction. One is for a non-catalyzed reaction and the other is for a catalyzed reaction.

15. One can correctly conclude from the above graph that the heat of the reaction corresponds to the interval labeled

(A) A  
(B) B  
(C) C  
(D) D  
(E) E

16. The activation energy for the non-catalyzed reaction corresponds to the interval labeled

(A) A  
(B) B  
(C) C  
(D) D  
(E) E

17. The activation energy for the catalyzed reaction corresponds to the interval labeled

(A) A  
(B) B  
(C) C  
(D) D  
(E) E

GO ON TO THE NEXT PAGE
Questions 18 - 21 are concerned with the following reaction:

$$2 \text{SO}_2(\text{g}) + \text{O}_2(\text{g}) = 2 \text{SO}_3(\text{g}) + 45 \text{ kcal}$$

18. Which one of the following sets of conditions would produce the greatest number of moles of $\text{SO}_3(\text{g})$ at equilibrium?

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Temp.</th>
<th>$\text{SO}_2$</th>
<th>$\text{O}_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) 1 atm.</td>
<td>400°C</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>(B) 10 atm.</td>
<td>400°C</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>(C) 10 atm.</td>
<td>500°C</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>(D) 100 atm.</td>
<td>400°C</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>(E) 100 atm.</td>
<td>500°C</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

19. If 64 grams of $\text{SO}_2(\text{g})$ reacts completely, how many moles of $\text{SO}_3(\text{g})$ would be formed? (Atomic weights: Sulfur = 32, Oxygen = 16.)

(A) 0.4 mole  
(B) 0.5 mole  
(C) 0.8 mole  
(D) 1.0 mole  
(E) 1.8 moles

20. When 0.2 mole of $\text{SO}_3(\text{g})$ is produced, the number of kilocalories of heat evolved is

(A) 2.2 kcal  
(B) 4.5 kcal  
(C) 9.0 kcal  
(D) 45 kcal  
(E) 90 kcal

21. If 40 liters of $\text{SO}_2(\text{g})$ reacts completely to form $\text{SO}_3(\text{g})$, how many liters of oxygen gas, measured at the same conditions of temperature and pressure, would be used?

(A) 10 liters  
(B) 16 liters  
(C) 20 liters  
(D) 32 liters  
(E) 40 liters

Questions 22 and 23 relate to the electrical conductivity of aqueous solutions:

22. Which one of the following substances, when dissolved in water will form a solution which is a poor conductor of electricity?

(A) HCl, hydrochloric acid  
(B) NaOH, sodium hydroxide  
(C) CsCl, cesium chloride  
(D) KBr, potassium bromide  
(E) C₂H₅OH, ethyl alcohol

23. In the process of the conduction of electricity by an aqueous solution, using a direct current, which one of the following is FALSE?

(A) Cations and anions move in opposite directions.  
(B) Electrons are liberated by one electrode and taken up by the other electrode.  
(C) The total number of positive charges must always be equal to the total number of negative charges.  
(D) The number of cations is always found to be equal to the number of anions.  
(E) Chemical changes take place at the electrodes.

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Questions 24 - 27 relate to the apparatus illustrated below.

Each of the beakers contains a 1 M nitrate solution of the metal used as an electrode in the beaker. The half-cell reactions, with $E^\circ$ values and the relevant atomic weights are:

- $\text{Ni(s)} = \text{Ni}^{2+} + 2e^- \quad E^\circ = +0.25 \text{ volt}$
- $\text{Pb(s)} = \text{Pb}^{2+} + 2e^- \quad E^\circ = +0.13 \text{ volt}$
- $\text{Ag(s)} = \text{Ag}^+ + e^- \quad E^\circ = -0.80 \text{ volt}$

<table>
<thead>
<tr>
<th>Metal</th>
<th>Atomic Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ni</td>
<td>58.7</td>
</tr>
<tr>
<td>Pb</td>
<td>207.2</td>
</tr>
<tr>
<td>Ag</td>
<td>107.9</td>
</tr>
</tbody>
</table>

24. When the voltmeter is connected between the Ni and Pb electrodes it reads 0.12 volt. After 0.01 mole of electrons have passed through the voltmeter the mass of the nickel electrode in the left-hand beaker will be

(A) 0.6 gram greater  
(B) 0.3 gram greater  
(C) 0.6 gram less  
(D) 0.3 gram less  
(E) unchanged

25. If the voltmeter is connected between the Ni and the Ag electrodes, it will read

(A) 0.12 volt  
(B) 0.25 volt  
(C) 0.55 volt  
(D) 0.80 volt  
(E) 1.05 volts

26. With the voltmeter still connected between the Ni and the Ag electrodes, current is allowed to flow through the cell until the mass of the nickel electrode has changed by 0.59 gram. During this time, the mass of the silver electrode will

(A) increase by 0.59 gram (g.)  
(B) increase by 1.08 g.  
(C) increase by 2.16 g.  
(D) decrease by 0.59 g.  
(E) decrease by 2.16 g.

27. Based on the information given above, in which of the following cases would a spontaneous reaction be expected to take place between the metal and the solution paired with it?

I. $\text{Ag(s), Ni}^{2+} (aq)$  
II. $\text{Pb(s), Ag}^+ (aq)$  
III. $\text{Pb(s), Ni}^{2+} (aq)$  
IV. $\text{Ag(s), Pb}^{2+} (aq)$  
V. $\text{Ni(s), Pb}^{2+} (aq)$

(A) V only  
(B) I and II only  
(C) I and V only  
(D) II and V only  
(E) I, III, IV only

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Questions 28 - 29 deal with the nuclei of hydrogen atoms. The following spectrum was obtained from a mass spectrograph experiment using a sample of hydrogen gas. Due to the presence of a second isotope (deuterium D), five gaseous ions were produced: $H_2^+$, HD$^+$, D$_2^+$, H$^+$, and D$^+$. The atomic weight of deuterium is 2.

28. Which two of the five positively charged ions would form a spectral line at position II?

(A) $H_2^+$ and D$^+$
(B) HD$^+$ and H$^+$
(C) $H_2^+$ and HD$^+$
(D) H$^+$ and D$^+$
(E) HD$^+$ and D$_2^+$

29. The HD$^+$ ion contains

(A) 1 proton, 1 neutron, 1 electron
(B) 2 protons, 1 neutron, 2 electrons
(C) 2 protons, 2 neutrons, 1 electron
(D) 1 proton, 2 neutrons, 0 electrons
(E) 2 protons, 1 neutron, 1 electron

Questions 30 - 32 deal with calculations involving the solubility product constant, $K_{sp}$.

30. The solubility of BaCO$_3$ is $4.0 \times 10^{-5}$ moles/liter. The calculated $K_{sp}$ for BaCO$_3$ is

(A) $2.0 \times 10^{-5}$
(B) $4.0 \times 10^{-5}$
(C) $1.6 \times 10^{-9}$
(D) $8.0 \times 10^{-10}$
(E) $1.6 \times 10^{-11}$

31. The solubility product constants for some silver salts at 25$^\circ$C are given below.

<table>
<thead>
<tr>
<th>Salts</th>
<th>$K_{sp}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>AgCl</td>
<td>$1 \times 10^{-10}$</td>
</tr>
<tr>
<td>AgBr</td>
<td>$1 \times 10^{-14}$</td>
</tr>
<tr>
<td>AgI</td>
<td>$1 \times 10^{-16}$</td>
</tr>
</tbody>
</table>

The solubility of silver iodide at 25$^\circ$C, expressed in moles per liter, is

(A) $1 \times 10^{-32}$
(B) $1 \times 10^{-16}$
(C) $2 \times 10^{-16}$
(D) $0.5 \times 10^{-8}$
(E) $1 \times 10^{-8}$

32. Ten ml each of 0.1 M solutions of KCl, KBr, and Kl are mixed in a small beaker. When a small drop of 0.01 M silver nitrate, AgNO$_3$(aq), is added to the mixture, which of the following will take place?

(A) AgCl(s) will be the precipitate present at equilibrium.
(B) AgBr(s) will be the precipitate present at equilibrium.
(C) AgI(s) will be the precipitate present at equilibrium.
(D) Equal quantities of AgCl(s), AgBr(s), and AgI(s) will be formed.
(E) No precipitate will form.

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Questions 33 - 35 deal with acids and bases.

33. An acid reacts with the carbonate ion, \( \text{CO}_3^{2-} \), as a base according to the equation,

\[
2\text{H}_3\text{O}^+(aq) + \text{CO}_3^{2-}(aq) = 3\text{H}_2\text{O} + \text{CO}_2(g).
\]

If 0.2 mole of \( \text{H}_3\text{O}^+ \) is consumed, the amount of \( \text{CO}_2(g) \) liberated will be

(A) 0.05 mole
(B) 0.1 mole
(C) 0.2 mole
(D) 0.4 mole
(E) 2.0 moles

34. The hydrogen carbonate ion, \( \text{HCO}_3^- \), may, in water solution, act as either an acid or a base. An equation for a reaction in which it is acting as an acid is

(A) \( \text{HCO}_3^-(aq) + \text{H}_2\text{O} = \text{H}_2\text{CO}_3(aq) + \text{OH}^-(aq) \)
(B) \( \text{HCO}_3^-(aq) + \text{H}_2\text{O} = \text{CO}_3^{2-}(aq) + \text{H}_3\text{O}^+(aq) \)
(C) \( \text{HCO}_3^-(aq) + \text{H}_3\text{O}^+(aq) = \text{CO}_2(g) + 2\text{H}_2\text{O} \)
(D) \( \text{HCO}_3^-(aq) + \text{OH}^-(aq) = \text{H}_2\text{CO}_3(aq) + \text{O}^{2-}(aq) \)
(E) \( \text{HCO}_3^-(aq) + \text{CH}_3\text{COOH}(aq) = \text{CO}_2(g) + \text{H}_2\text{O} + \text{CH}_3\text{COO}^-(aq) \)

35. 0.100 mole of solid sodium carbonate, \( \text{Na}_2\text{CO}_3(s) \) is added to 1.00 liter of a solution of 0.400 \( \text{M} \) hydrochloric acid, \( \text{HCl} \). After the solution is warmed to expel the carbon dioxide gas, \( \text{CO}_2(g) \), the resulting hydronium ion, \( \text{H}_3\text{O}^+ \), concentration will be

(A) 0.050 \( \text{M} \)
(B) 0.100 \( \text{M} \)
(C) 0.200 \( \text{M} \)
(D) 0.300 \( \text{M} \)
(E) 0.400 \( \text{M} \)
CBA ACHIEVEMENT TEST

You will be given 45 minutes to work on this test. There are several different types of questions. You will find special directions for each type inside the test book. Be sure you understand the directions before attempting to answer any questions.

It is not expected that everyone will finish all the questions in the time allowed. Work steadily and as quickly as you can without sacrificing accuracy. If a question seems too difficult, make the most careful guess you can, rather than waste time puzzling over it.

YOU ARE TO INDICATE ALL YOUR ANSWERS ON THE SEPARATE ANSWER SHEET ENCLOSED IN THE TEST BOOK. You may use any blank spaces in the book for scratchwork, but no credit will be given for anything written in the test book. After you have decided which of the suggested answers you want to give for a question, blacken the space between the dotted lines under its letter on the answer sheet, using only the special electrographic pencil.

Example:

I. Chicago is a

(A) state
(B) city
(C) country
(D) continent
(E) village

Sample Answer

A B C D E

I || || || ||

Mark only one space on the answer sheet for each question; no credit will be given for a question if more than one space is marked. If you wish to change an answer, erase your first line completely and mark your new choice. Be careful not to make stray marks on your answer sheet.

DO NOT OPEN THIS BOOK UNTIL YOU ARE TOLD TO DO SO
Questions 1 - 3 relate to the following information.

By convention, the charge acquired by a glass rod which has been rubbed with a cloth is called positive (+). A student possessing five charged objects (I, II, III, IV, V) performs some experiments and records the following data.

I repels glass charged with a cloth but attracts IV.

II attracts V but repels III.

IV repels II.

The force between I and II is 1 unit when they are 4 cm. apart.

The force between II and III is 8 units when they are 1 cm. apart.

1. Which of the following can the student correctly conclude regarding the signs of the charges on the objects?
   (A) I, V positive; II, III, IV negative
   (B) I, II positive; III, IV, V negative
   (C) II, III positive; I, IV, V negative
   (D) I, III, V positive; II, IV negative
   (E) None of the above

2. What will be the force between objects I and II when they are 1 cm. apart?
   (A) \( \frac{1}{4} \) unit
   (B) 4 units
   (C) 8 units
   (D) 16 units
   (E) None of the above

3. What is the ratio of the charge on I to the charge on III?
   (A) 4:1
   (B) 2:1
   (C) 1:1
   (D) 1:2
   (E) None of the above

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Questions 4-9 relate to a reaction of NO with O₂ which goes to completion rapidly.

6. The amount of oxygen required to form 0.69 gram of NO₂ in a reaction with NO is most nearly
   (A) 0.45 gram
   (B) 0.36 gram
   (C) 0.32 gram
   (D) 0.24 gram
   (E) 0.12 gram

7. The reaction referred to in Question 4 takes place in a calorimeter which requires 1050 calories to raise its temperature 1.0°C. If the temperature of the calorimeter is raised 0.20°C by the reaction, then the amount of heat produced per gram of NO₂ formed is most nearly
   (A) 210 calories
   (B) 310 calories
   (C) 620 calories
   (D) 740 calories
   (E) 840 calories

8. If the reaction had been carried out using 0.30 gram of NO and 0.36 gram of O₂, the amount of O₂ remaining unreacted would have been most nearly
   (A) 0.20 gram
   (B) 0.16 gram
   (C) 0.10 gram
   (D) 0.02 gram
   (E) 0.00 gram

9. Which of the following statements is supported by the graph?
   (A) The maximum quantity of O₂ that would react with any quantity of NO under any conditions is 0.32 g.
   (B) The maximum quantity of NO that would react with any quantity of O₂ under any conditions is 0.60 g.
   (C) The ratio of the amount of NO₂ formed to the amount of oxygen reacted is not constant within experimental error.
   (D) The amount of NO₂ formed per unit of time is doubled when the temperature is doubled.
   (E) The amount of NO reacting is always about twice as great as the amount of O₂ reacting.
Questions 10 - 13 relate to several samples of dry air, each of which is composed of 79% nitrogen, 20% oxygen, and 1% argon by volume. (Molecular weights: \( N_2 = 28 \), \( O_2 = 32 \), \( Ar = 40 \))

10. At constant temperature, the pressure on the first sample of dry air is doubled. This results in a doubling of the

(A) percent by volume of oxygen in the sample
(B) average kinetic energy of the molecules
(C) average velocity of the molecules
(D) density of the sample
(E) volume occupied by the dry air

11. At constant pressure, the absolute temperature of the second sample of dry air is doubled. This results in a doubling of the

(A) percent by volume of oxygen in the sample
(B) average kinetic energy of the molecules
(C) average velocity of the molecules
(D) density of the sample
(E) number of molecules per milliliter

12. At constant volume, the absolute temperature of the third sample is doubled. As a result the

(A) pressure of the sample will be doubled
(B) density of the sample will be doubled
(C) sample will liquefy
(D) oxygen and nitrogen molecules will tend to split into two equal parts, \( O \) and \( N \), respectively
(E) argon will tend to form diatomic molecules, \( Ar_2 \)

13. Suppose that the argon molecules are removed from the fourth sample of dry air and are replaced by an equal number of nitrogen molecules. If no other change is made, then the value of which of the following will be greater for the new gas mixture than it was for the original dry air?

(A) The percent by volume of oxygen
(B) The average kinetic energy of the molecules
(C) The average velocity of the molecules
(D) The density
(E) The time required for a given number of molecules to effuse through a pinhole
Questions 14-17 relate to the following bond energies.

<table>
<thead>
<tr>
<th>Bond</th>
<th>Energy (kcal/mole)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-H</td>
<td>104.2</td>
</tr>
<tr>
<td>Cl-Cl</td>
<td>58.0</td>
</tr>
<tr>
<td>H-Cl</td>
<td>103.2</td>
</tr>
</tbody>
</table>

14. On the basis of these data what is the activation energy in kcal/mole for the reaction represented by the equation, \( \text{H}_2 + \text{Cl}_2 \rightarrow 2\text{HCl} \)?

(A) 58.0  
(B) 104.2  
(C) 132.7  
(D) 162.2  
(E) It is impossible to determine the activation energy without further information about the reaction.

15. Activation energy is

(A) equal to one half the sum of the bond energies of the reactants and the products  
(B) always equal to the lowest bond energy of any of the reactants and products  
(C) related to reaction pathway  
(D) equal to the sum of the bond energies of the reactants  
(E) never related to bond energies of the reactants

Questions 16-17: Using hot and cold water, a student finds that the "calorimeter constant" of a certain calorimeter is 20 calories per degree.

16. If 80 grams of water at 28°C is poured into the empty calorimeter which is at 18°C, the final temperature will be

(A) 20°C  
(B) 23°C  
(C) 24°C  
(D) 25°C  
(E) 26°C

17. If 50 grams of methyl alcohol (specific heat = 0.60 cal/gram/degree) at 28°C is poured into the empty calorimeter which is at 18°C, the final temperature will be

(A) 20°C  
(B) 22°C  
(C) 23°C  
(D) 24°C  
(E) 26°C

GO ON TO THE NEXT PAGE
Questions 18 - 21 relate to a new temperature scale, graduated in degrees N. The reading 0°N corresponds to 0°K, and the reading 100°N corresponds to 273°K (the freezing point of water).

18. The boiling point of water would be most nearly
   (A) 30°N
   (B) 120°N
   (C) 140°N
   (D) 212°N
   (E) 373°N

20. One calorie is defined as the amount of heat required to raise the temperature of 1 gram of water by 1 degree centigrade. The number of calories required to raise the temperature of 5 grams of water by 20°N would be most nearly
   (A) 100
   (B) 200
   (C) 300
   (D) 400
   (E) 500

21. If the temperature of a sample of gas were changed from 50°N to 49°N, at constant pressure, the volume would
   (A) increase by 1%
   (B) decrease by 1%
   (C) increase by 2%
   (D) decrease by 2%
   (E) increase by 5%

19. Which of the lettered curves in the above graph correctly represents the relationship which would exist between the volume of a gas and its temperature in degrees N?
   (A) A
   (B) B
   (C) C
   (D) D
   (E) E

22. According to the data given, which reaction liberates the most energy?
   (A) 1
   (B) 2
   (C) 3
   (D) 4
   (E) It cannot be determined from the data given.

Question 22 relates to the following reactions which are all exothermic.

1. \( \text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} \)
2. \( \frac{1}{2}\text{C} + \frac{1}{2}\text{O}_2 \rightarrow \frac{1}{2}\text{CO}_2 \)
3. \( \text{CH}_4 + \text{O}_2 \rightarrow \text{C} + 2\text{H}_2\text{O} \)
4. \( \text{C} + \text{O}_2 \rightarrow \text{CO}_2 \)
Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one which is best in each case and then blacken the corresponding space on the answer sheet. Within each group of questions, information derived from some may be needed to answer others.

Questions 23 - 25 relate to the following energy diagrams.

23. It can be correctly concluded from the energy diagrams that
   (A) only reaction I is exothermic
   (B) only reaction II is exothermic
   (C) both reactions I and II are exothermic
   (D) both reactions I and II are endothermic
   (E) neither reaction I nor reaction II is exothermic

24. For reaction I, the over-all reaction energy (∆H) in kcal/mole is
   (A) -50
   (B) -30
   (C) -10
   (D) +10
   (E) +30

25. For reaction II, the activation energy in kcal/mole is
   (A) -30
   (B) +30
   (C) +40
   (D) +70
   (E) +80

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Questions 26 - 29 involve the determination of the energy of the bond holding the carbon atoms together in acetylene, \( \text{C}_2\text{H}_2 \). (The Lewis structure of acetylene is \( \text{H} : \text{C} : : \text{C} : \text{H} \))

The necessary values for \( \Delta H \) (at 25°C and 1 atmosphere) are:

- Reaction energy of formation of \( \text{C}_2\text{H}_2 \) (g) + 54 kcal/mole
- Energy of sublimation of C (s) + 172 kcal/mole
- Dissociation energy of hydrogen + 104 kcal/mole
- Bond energy of C-H 99 kcal/mole

26. The correct form of the equation for which \( \Delta H \) is 54 kcal/mole is

(A) \( 2\text{C} (g) + 2\text{H} (g) \rightarrow \text{C}_2\text{H}_2 (g) \)

(B) \( 2\text{C} (s) + 2\text{H} (g) \rightarrow \text{C}_2\text{H}_2 (g) \)

(C) \( 2\text{C} (s) + \text{H}_2 (g) \rightarrow \text{C}_2\text{H}_2 (g) \)

(D) \( \text{C} (s) + \text{H}_2 (g) \rightarrow \text{C}_2\text{H}_2 (g) \)

(E) \( \text{C}_2\text{H}_6 (g) \rightarrow \text{C}_2\text{H}_2 (g) + 2\text{H}_2 (g) \)

27. The most desirable form of the equation for determining the bond energies in \( \text{C}_2\text{H}_2 \) is

(A) \( \text{C}_2\text{H}_2 (g) \rightarrow 2\text{C} (g) + 2\text{H} (g) \)

(B) \( \text{C}_2\text{H}_2 (g) \rightarrow 2\text{C} (s) + 2\text{H} (g) \)

(C) \( \text{C}_2\text{H}_2 (g) \rightarrow 2\text{C} (s) + \text{H}_2 (g) \)

(D) \( \text{C}_2\text{H}_2 (g) \rightarrow 2\text{C} (g) + \text{H}_2 (g) \)

(E) \( \frac{1}{2}\text{C}_2\text{H}_2 (g) \rightarrow \text{C} (s) + \frac{1}{2}\text{H}_2 (g) \)

28. The energy necessary to convert carbon and hydrogen from the forms in which they are found at 25°C and 1 atmosphere pressure to the forms in the correct equation for question 27 is

(A) zero

(B) + 104 kcal

(C) + 276 kcal

(D) + 344 kcal

(E) + 448 kcal

29. To calculate the correct value for the energy of the bond between the carbon atoms one should now take the value for \( \Delta H \) calculated for the correct equation in question 27 and

(A) add 99 kcal

(B) add 2(99) kcal

(C) subtract 99 kcal

(D) subtract 2(99) kcal

(E) divide by 4
Questions 30–33 relate to the following table of electronegativities.

### Electronegativity Table

<table>
<thead>
<tr>
<th></th>
<th>H</th>
<th>Li</th>
<th>Be</th>
<th>B</th>
<th>C</th>
<th>N</th>
<th>O</th>
<th>F</th>
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<tbody>
<tr>
<td>2.1</td>
<td>1.0</td>
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<td>2.0</td>
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<td>3.0</td>
<td>3.5</td>
<td>4.0</td>
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<tr>
<td>Si</td>
<td>P</td>
<td>S</td>
<td>Cl</td>
<td>Ge</td>
<td>As</td>
<td>Se</td>
<td>Br</td>
<td></td>
</tr>
<tr>
<td>1.8</td>
<td>2.1</td>
<td>2.5</td>
<td>3.0</td>
<td>1.8</td>
<td>2.4</td>
<td>2.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sn</td>
<td>Sb</td>
<td>Te</td>
<td>I</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

30. **On the basis of the given data, which of the following statements can be correctly made concerning the hydrides of the second period?**

(A) The most polar bond would be formed between hydrogen and boron.
(B) The most polar bond would be formed between hydrogen and fluorine.
(C) The most polar bond would be formed between hydrogen and oxygen.
(D) The hydride of carbon would be very soluble in water.
(E) Lithium hydride would be very soluble in benzene.

31. **On the basis of the given data, the highest dipole moment should be predicted for which of the following molecules?**

(A) F₂
(B) ClF
(C) BrCl
(D) Br₂
(E) IF

32. Which of the following statements may correctly account for the fact that the boiling point of NH₃ (–33.4°C) is higher than that of PH₃ (–87.4°C)?

(A) The electronegativity of N is greater than that of P.
(B) The boiling point of elemental N is greater than that of elemental P.
(C) NH₃ molecules are more symmetrical than are PH₃ molecules.
(D) There is more hydrogen bonding in PH₃ than there is in NH₃.
(E) The van der Waals force between PH₃ molecules is greater than that between NH₃ molecules.

33. Which of the following statements may correctly account for the fact that the boiling point of H₂O is higher than that of H₂S?

(A) The electronegativity of S is greater than that of O.
(B) The boiling point of elemental O is lower than that of elemental S.
(C) H₂O molecules are more symmetrical than are H₂S molecules.
(D) There is more hydrogen bonding in H₂O than there is in H₂S.
(E) The van der Waals force between H₂S molecules is greater than that between H₂O molecules.
Questions 34 - 35 relate to the following information.

The force between two charged particles is given by \[ F = K \frac{q^+ q^-}{\varepsilon r^2}, \] where \( \varepsilon \) is the dielectric constant. The dielectric constant for water is 80.

34. If the dielectric constant for water were 8 instead of 80, it would be logical to predict that sodium chloride would

(A) be slightly more soluble in water
(B) be much more soluble in water
(C) be slightly less soluble in water
(D) be much less soluble in water
(E) have the same solubility in water

35. An explanation of this prediction is that if the dielectric constant of water were 8 instead of 80

(A) fewer water molecules would fit around a sodium ion
(B) more water molecules could enter the sodium chloride crystal
(C) the attraction between Na\(^+\) and Cl\(^-\) in solution would be greater
(D) ionic substances ionize more completely in solvents of low dielectric constant
(E) the solvation of Na\(^+\) and Cl\(^-\) would not be changed
PSSC ACHIEVEMENT TEST

DIRECTIONS

This is a 45-minute test containing 35 items. When you are told to begin, turn this page and immediately begin answering the questions.

Do not spend too much time on any one question. If a question seems to be too difficult, make the most careful guess you can, rather than waste time puzzling over it. Your score is the number of correct answers you mark.

Each of the questions or incomplete statements is followed by five suggested answers or completions. Select the one which is best in each case and blacken the corresponding space on the separate answer sheet. Make your marks heavy and black. Note the SAMPLE on your answer sheet. If you make a mistake or wish to change an answer, be sure to erase your first choice completely.

SAMPLE QUESTION

0 Which of the following is most directly measured by the use of a clock?

(A) Mass
(B) Time
(C) Length
(D) Density
(E) Force

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO
Questions 1 - 3 relate to the following information and diagram:

A certain stroboscope consists of a rotating disk with four slotted holes, as shown below. The disk is rotating at exactly five revolutions per second.

![Diagram of rotating disk with slotted holes and 5 rev/sec label]

1. The stroboscope "stops" the motion of a wheel, making it appear as in the diagram below:

![Diagram of stopped wheel]

The rate of rotation of the wheel is at LEAST

(A) 1.25 rev/sec
(B) 5.00 rev/sec
(C) 20.0 rev/sec
(D) 25.0 rev/sec
(E) 80.0 rev/sec

2. The stroboscope is used to take a single photograph showing pictures at several positions of a ball rolling along a level surface at a constant velocity of 4 meters per second. How far will the ball have moved between successive positions?

(A) 0.2 meters
(B) 0.8 meters
(C) 1 meter
(D) 5 meters
(E) 8 x 10 meters

3. If the stroboscope had speeded up while the photograph was made, without the experimenter knowing that the speed had changed, the

(A) pictures would have become blurred.
(B) ball would appear to have slowed down.
(C) ball would appear brighter in successive pictures.
(D) photograph would be unchanged.
(E) successive pictures of the ball would be farther apart.
Questions 4–7 relate to the following information:

The following chemical reaction, in which all the substances occur as gases, is observed to occur under conditions of fixed temperature and pressure:

7 grams of element X react with 16 grams of element Y to produce 23 grams of compound Z, with no X or Y left over.

4. Under the same conditions, 14 grams of element X react with 32 grams of element Y. How much of compound Z will be produced?
   (A) 14 grams
   (B) 30 grams
   (C) 32 grams
   (D) 39 grams
   (E) 46 grams

5. Under the same conditions, 14 grams of element X and 123 grams of element Y are mixed. How many grams of compound Z will be produced by the reaction?
   (A) 14 grams
   (B) 23 grams
   (C) 32 grams
   (D) 46 grams
   (E) 137 grams

6. Under the same conditions, 24 grams of element X and 48 grams of element Y are mixed. What will be the composition of the end-products of this reaction?
   (A) 72 grams of compound Z only
   (B) 69 grams of compound Z only
   (C) 17 grams of element X, 32 grams of element Y and 23 grams of compound W
   (D) 3 grams of element X and 69 grams of compound Z
   (E) none of the above

7. At the same temperature and pressure, 7 grams of element X occupy the same volume as do 8 grams of element Y. One can therefore conclude that the ratio of the number of molecules in the 7-gram sample of X to the number in the 8-gram sample of Y is
   (A) 7:8
   (B) 8:8
   (C) 8:7
   (D) 15:7
   (E) 16:7

GO ON TO THE NEXT PAGE
Questions 8 - 13 relate to the following information and graph:

An object is moving along a straight line. The graph shows its displacement from the starting point as a function of time. Various sections of the graph are identified by the letters A, B, C, D, and E.

8. The displacement of the object at the end of the first seven seconds is
   (A) 4 meters
   (B) -4 meters
   (C) 4/7 meters
   (D) 7/4 meters
   (E) \(\sqrt{65}\) meters

9. Which section of the graph represents a constant velocity of +4 meters per second?
   (A) A
   (B) B
   (C) C
   (D) D
   (E) E

10. Which section of the graph represents a time during which the object was at rest?
    (A) A
    (B) B
    (C) C
    (D) D
    (E) E

11. What was the average velocity of the object during the first six seconds?
    (A) 4 meters/sec
    (B) -4/6 meters/sec
    (C) 0 meters/sec
    (D) 6/4 meters/sec
    (E) 4/6 meters/sec

12. Which section of the graph represents a period of positive acceleration?
    (A) A
    (B) B
    (C) C
    (D) D
    (E) E

13. What was the instantaneous velocity of the object at the end of the fifth second?
    (A) 4 meters/sec
    (B) 2 meters/sec
    (C) 4/6 meters/sec
    (D) 0 meters/sec
    (E) -4/6 meters/sec
Directions: The items in this part of the test consist of five lettered answer choices followed by a list of numbered questions. For each question select the one lettered answer which is most closely related to it and blacken the corresponding space on the answer sheet. An answer may be used once, more than once, or not at all.

Questions 14-18 relate to the following information and diagrams:

Several identical springs and several identical masses are used to perform acceleration experiments on a frictionless surface. It is found that a single spring, when extended by an amount $x_0$, gives an acceleration $a_0$ to a single mass.

Single spring: unextended

Single spring: extended $x_0$

Two springs connected end-to-end: unextended

Two springs connected end-to-end: extended total amount $2x_0$

Two springs connected side-by-side: unextended

Two springs connected side-by-side: extended $x_0$

(A) $\frac{1}{2} a_0$
(B) $a_0$
(C) $2a_0$
(D) $4a_0$
(E) Cannot be determined without additional information

14. What acceleration would be produced on a single mass by two springs connected side-by-side and extended by an amount $x_0$?  
15. What acceleration would be produced on a single mass by two springs connected end-to-end and extended by a total amount $2x_0$?  
16. What acceleration would be produced on two of the masses tied together if two springs are connected end-to-end and extended by a total amount $2x_0$?  
17. What acceleration would be produced on two of the masses tied together if four springs are connected side-by-side and the combination is extended by an amount $x_0$?  
18. Two springs are connected side-by-side; this combination is then connected end-to-end to an identical combination. What acceleration would be produced on a single mass if this arrangement of springs is extended by a total amount $2x_0$?
Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one which is best in each case and blacken the corresponding space on the answer sheet.

Questions 19 - 22 relate to the following information and projectile graph.

The graph below shows the path of a projectile fired by a toy cannon. In answering the related questions, assume frictional forces to be negligible.

19. The speed of the projectile as it leaves the toy cannon is the same as its speed at
   (A) T
   (B) Y
   (C) S
   (D) Z
   (E) none of the above.

20. The horizontal component of the momentum of the projectile after it leaves the muzzle of the toy cannon is
   (A) greatest at point X.
   (B) greatest at point T.
   (C) greatest at point Y.
   (D) greatest at point Z.
   (E) the same at all points.

21. The vertical component of the momentum is zero at
   (A) X
   (B) T
   (C) Y
   (D) Z
   (E) none of the above.

22. The momentum of the projectile as it leaves the toy cannon is the same as its momentum at
   (A) T
   (B) Y
   (C) S
   (D) Z
   (E) none of the above.
Questions 23 – 25 relate to the following information and diagram:

Two racing cars of masses $M_1$ and $M_2$ are moving in circles of radii $R_1$ and $R_2$ as shown. Their speeds are such that they each make a complete circle in the same length of time $T$.

23. The ratio of the angular speed (measured in degrees of arc per second) of the first car to that of the second car is
   (A) 1:1
   (B) $M_1 : M_2$
   (C) $M_2 : M_1$
   (D) $R_1 : R_2$
   (E) $R_2 : R_1$

24. The ratio of the speed measured in meters per second of the first car to that of the second car is
   (A) 1:1
   (B) $M_1 : M_2$
   (C) $M_2 : M_1$
   (D) $R_1 : R_2$
   (E) $R_2 : R_1$

25. The ratio of the centripetal acceleration of the first car to that of the second car is
   (A) 1:1
   (B) $M_1 : M_2$
   (C) $M_2 : M_1$
   (D) $R_1 : R_2$
   (E) $R_2 : R_1$

GO ON TO THE NEXT PAGE
Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one which is best in each case and blacken the corresponding space on the answer sheet.

Questions 26 - 30 relate to the following graph and information:

The graph above shows the force applied to a 2-kilogram body initially at rest but free to move on a horizontal frictionless surface.

26. Which one of the following graphs best represents the acceleration of the body during the first meter of travel?

(A) ![Graph A](image)

(B) ![Graph B](image)

(C) ![Graph C](image)

(D) ![Graph D](image)

(E) None of the above graphs

27. After the body has moved a distance of 1 meter its kinetic energy is

(A) 1 joule.

(B) 2 joules.

(C) 3 joules.

(D) 4 joules.

(E) 19.6 joules.

28. After the body has moved a distance of 2 meters its kinetic energy is

(A) 1 joule.

(B) 2 joules.

(C) 4 joules.

(D) 5 joules.

(E) 6 joules.

29. After the body has moved a distance of 3 meters its kinetic energy is

(A) 1 joule.

(B) 2 joules.

(C) 4 joules.

(D) 5 joules.

(E) 6 joules.

30. After the body has moved a distance of 4 meters its kinetic energy is

(A) 1 joule.

(B) 2 joules.

(C) 4 joules.

(D) 5 joules.

(E) 6 joules.
Questions 31 - 35 relate to the following information and diagram:

Five small identical metal balls are hung from insulating silk threads and are handled only by the threads. They are not allowed to touch each other during the following experiment. It has previously been found that none of the balls is affected by a magnet, and it has been calculated that the gravitational force between any two of the balls is negligible. Two of the balls at a time are brought near each other, and the following observations are recorded:

1. Metal balls II and V exert no force on one another.
2. Metal balls I and III repel one another.
3. All other pairs of metal balls attract one another. For example, ball I attracts II, IV, and V.

In answering the questions, allow for the possibility of electrostatic induction.

31. The above observations show that
   (A) I and III are not electrically charged.
   (B) I and III carry electric charges of the same sign.
   (C) I and III carry electric charges of opposite sign.
   (D) II, IV, and V all carry electric charges of sign opposite to the charge on I.
   (E) II, IV, and V carry electric charges of the same sign as that on I.

32. All of the observations are consistent with the assumption that
   (A) none of the five balls carries an electric charge.
   (B) II and V carry electric charges of opposite sign.
   (C) II carries no electric charge.
   (D) II is the only one of the balls that carries an electric charge.
   (E) I is the only one of the balls that carries an electric charge.

33. On the basis of all of the observations, it is certain that
   (A) V repels I, II, III, IV.
   (B) V exerts no force on any other of the balls.
   (C) V attracts I, II, III, IV.
   (D) V attracts I, III, and IV, but exerts no force on II.
   (E) none of the above statements is true.

34. On the basis of all the observations the most complete conclusion concerning metal ball IV is that it
   (A) carries electric charges of the same sign as the charge on I.
   (B) is neutral.
   (C) carries electric charges on the opposite sign to the charge on I.
   (D) is either neutral, or carries electric charges of the same sign as the charge on I.
   (E) is either neutral, or carries electric charges of the opposite sign to the charge on I.

35. On the basis of Observation I above, which is true for all observed separations of the balls, any net charge carried by V must be
   (A) positive.
   (B) negative.
   (C) zero.
   (D) of opposite sign to any net charge on II.
   (E) of the same sign as that of any net charge on II.
APPENDIX B
ATTITUDES TOWARD SCIENCE AND SCIENTIFIC CAREERS

Reaction Inventory *

NAME ____________________________ School ____________________________

First Last

Instructions: Please give your reactions to the following list of statements regarding science, scientists, and scientific careers. Work rapidly. Record your first impression—the feeling that comes to mind as you read the item.

Draw a circle around AA if you completely agree with the item.
Draw a circle around A if you are in partial agreement.
Draw a circle around N if you are neutral.
Draw a circle around D if you partially disagree.
Draw a circle around DD if you totally disagree.

Example:
AA  A  N  D  DD  100. In the springtime Paris is more beautiful than New York.
                     (Since A is circled, this indicates that you are in slight agreement.)

AA  A  N  D  DD  1. Science is a systematic way of thinking.

AA  A  N  D  DD  2. The development of new ideas is the scientist's greatest source of satisfaction.

AA  A  N  D  DD  3. Scientists are too narrow in their views.

AA  A  N  D  DD  4. The scientist will make his maximum contribution to society when he has freedom to work on problems which interest him.

AA  A  N  D  DD  5. Scientists should be looked upon as "subjects for suspicion."

AA  A  N  D  DD  6. Scientific investigations are undertaken as a means of achieving economic gains.

AA  A  N  D  DD  7. To become a scientist requires superior ability.


AA  A  N  D  DD  9. Scientists are willing to change their ideas and beliefs when confronted by new evidence.

AA  A  N  D  DD  10. Scientists are "longhairs."

33. The engineer serves a more practical purpose in society than does the research scientist.

34. There is much self-satisfaction to be received from work as a scientist.

35. A scientist's life is full of adventure.

36. Science helps us to understand our environment.

37. Scientists are against formal religion.

38. Scientists often have physical deformities which render them unfit for other work.

39. Science and its inventions have caused more harm than good.

40. One cannot have a normal family life and be a scientist.

41. American scientists are largely responsible for our country's status among nations.

42. Scientific work is monotonous.

43. The working scientist believes that nature is orderly rather than disorderly.

44. The modern world is dominated by science.

45. Scientists are often willing to sacrifice the welfare of others to further their own interests.

46. Scientists are usually unsociable.

47. Curiosity motivates scientists to make their discoveries.

48. The chief reward in scientific work is the thrill of discovery.

49. Americans place greater value on the practical applications of scientific discoveries than on the discoveries themselves.
11. The complexity of science hides its cultural values.

12. Modern science is too complicated for the average citizen to understand and appreciate.

13. Scientists possess too much power in our society.

14. It is undemocratic to favor exceptional scientific talent.

15. The monetary compensation of a Nobel Prize winner in Physics should be at least equal to that given popular entertainers.

16. Scientists are shy, lonely individuals.

17. For me, training for a career in science is not worth the time and effort required.


19. Scientists are more emotional than other people.

20. Scientists are honored persons who stand very high in popular prestige.

21. To appreciate modern society fully, a person must understand the importance of science.

22. Scientists are an "odd" lot.

23. Science is the greatest unifying force among nations.

24. Scientific work is boring.

25. I don't have the intelligence for a successful scientific career.

26. Scientific findings always lead to final truths.

27. Science is primarily responsible for the frequent changes which occur in our manner of living.

28. Scientists are "eggheads."

29. Scientific work requires long years of labor and self-discipline.

30. Science is an attitude towards life and environment.

31. Our foremost scientists are primarily concerned with their own thoughts and ideas.

32. Science has done little for the average citizen.
Table XX. Summary of Mean Class Changes on Various Attitude Statements

<table>
<thead>
<tr>
<th>Group</th>
<th>Treatment Classes Difference of Means</th>
<th>Chemistry Classes Difference of Means</th>
<th>Physics Classes Difference of Means</th>
<th>Difference of Differences</th>
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<td>0.292</td>
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<td>-0.322</td>
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<tr>
<td>III</td>
<td>0.559</td>
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<td>0.454</td>
<td>0.460</td>
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<tr>
<td>V</td>
<td>0.096</td>
<td>0.248</td>
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<tr>
<td>VI</td>
<td>0.493</td>
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1. **Science is a Systematic Way of Thinking**

<table>
<thead>
<tr>
<th>Group</th>
<th>Treatment Classes Difference of Means</th>
<th>Chemistry Classes Difference of Means</th>
<th>Physics Classes Difference of Means</th>
<th>Difference of Differences</th>
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<tr>
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<td>III</td>
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<tr>
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7. **To Become a Scientist Requires Superior Ability**

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<th>Group</th>
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<th>Chemistry Classes Difference of Means</th>
<th>Physics Classes Difference of Means</th>
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9. **Scientists are Willing to Change Their Ideas and Beliefs**
Table XX (continued)

<table>
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<tr>
<td>II</td>
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<td>-0.348</td>
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</tr>
<tr>
<td>III</td>
<td>-0.186</td>
<td>0.174</td>
<td>-0.360</td>
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<tr>
<td>IV</td>
<td>0.324</td>
<td>-0.413</td>
<td>0.737</td>
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</tr>
<tr>
<td>V</td>
<td>-0.102</td>
<td>0.436</td>
<td>-0.538</td>
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<td>-0.701</td>
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<tr>
<td>VI</td>
<td>-0.045</td>
<td>0.745</td>
<td>-0.790</td>
<td>0.223</td>
<td>-0.268</td>
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</table>

12. Modern Science is too Complicated for the Average Citizen to Understand and Appreciate

<table>
<thead>
<tr>
<th>Group</th>
<th>Treatment Classes</th>
<th>Chemistry Classes</th>
<th>Difference of</th>
<th>Physics Classes</th>
<th>Difference of</th>
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<tbody>
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<tr>
<td>I</td>
<td>-0.223</td>
<td>-0.417</td>
<td>0.194</td>
<td>-0.037</td>
<td>-0.186</td>
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<tr>
<td>II</td>
<td>0.095</td>
<td>-0.348</td>
<td>0.443</td>
<td>-0.054</td>
<td>0.149</td>
</tr>
<tr>
<td>III</td>
<td>-0.554</td>
<td>-0.507</td>
<td>-0.047</td>
<td>-0.097</td>
<td>-0.457</td>
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<tr>
<td>IV</td>
<td>-0.308</td>
<td>-0.039</td>
<td>-0.269</td>
<td>-0.333</td>
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<tr>
<td>V</td>
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<td>0.285</td>
<td>-0.218</td>
<td>0.600</td>
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<td>VI</td>
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<td>-0.278</td>
<td>-0.037</td>
<td>0.121</td>
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14. It is Undemocratic to Favor Exceptional Scientific Talent

<table>
<thead>
<tr>
<th>Group</th>
<th>Treatment Classes</th>
<th>Chemistry Classes</th>
<th>Difference of</th>
<th>Physics Classes</th>
<th>Difference of</th>
</tr>
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<tbody>
<tr>
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</tr>
<tr>
<td>I</td>
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<td>0.371</td>
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<tr>
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<td>-0.425</td>
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<tr>
<td>VI</td>
<td>0.226</td>
<td>0.221</td>
<td>0.005</td>
<td>0.132</td>
<td>0.094</td>
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</table>
Table XX (continued)

<table>
<thead>
<tr>
<th>Group</th>
<th>Treatment Classes Difference of Means</th>
<th>Chemistry Classes Difference of Means</th>
<th>Difference of Differences</th>
<th>Physics Classes Difference of Means</th>
<th>Difference of Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
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<td>0.095</td>
<td>0.083</td>
<td>0.000</td>
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<tr>
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<td>0.492</td>
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<tr>
<td>III</td>
<td>-0.035</td>
<td>-0.612</td>
<td>0.577</td>
<td>-0.560</td>
<td>0.525</td>
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<tr>
<td>IV</td>
<td>0.234</td>
<td>0.329</td>
<td>-0.095</td>
<td>0.011</td>
<td>0.223</td>
</tr>
<tr>
<td>V</td>
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<td>0.218</td>
<td>0.225</td>
<td>-0.201</td>
<td>0.644</td>
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<tr>
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<td>0.166</td>
<td>0.325</td>
<td>0.059</td>
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</table>

20. Scientists are Honored Persons Who Stand Very High in Popular Prestige

24. Scientific Work is Boring

26. Scientific Findings Always Lead to Final Truths
<table>
<thead>
<tr>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
</tr>
<tr>
<td>II</td>
</tr>
<tr>
<td>III</td>
</tr>
<tr>
<td>IV</td>
</tr>
<tr>
<td>V</td>
</tr>
<tr>
<td>VI</td>
</tr>
</tbody>
</table>

34. **There is Much Self-satisfaction to be Received from Work as a Scientist**

<table>
<thead>
<tr>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
</tr>
<tr>
<td>II</td>
</tr>
<tr>
<td>III</td>
</tr>
<tr>
<td>IV</td>
</tr>
<tr>
<td>V</td>
</tr>
<tr>
<td>VI</td>
</tr>
</tbody>
</table>

36. **Science Helps Us to Understand our Environment**

<table>
<thead>
<tr>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
</tr>
<tr>
<td>II</td>
</tr>
<tr>
<td>III</td>
</tr>
<tr>
<td>IV</td>
</tr>
<tr>
<td>V</td>
</tr>
<tr>
<td>VI</td>
</tr>
</tbody>
</table>

42. **Scientific Work is Monotonous**

<table>
<thead>
<tr>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
</tr>
<tr>
<td>II</td>
</tr>
<tr>
<td>III</td>
</tr>
<tr>
<td>IV</td>
</tr>
<tr>
<td>V</td>
</tr>
<tr>
<td>VI</td>
</tr>
</tbody>
</table>
Table XX  (continued)

<table>
<thead>
<tr>
<th>Group</th>
<th>Treatment Classes Difference of Means</th>
<th>Chemistry Classes Difference of Means</th>
<th>Difference of Differences</th>
<th>Physics Classes Difference of Means</th>
<th>Difference of Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>0.987</td>
<td>0.197</td>
<td>0.790</td>
<td>0.074</td>
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<td>0.343</td>
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<td>-0.094</td>
</tr>
<tr>
<td>V</td>
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<td>-0.094</td>
<td>0.249</td>
<td>0.252</td>
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<tr>
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<td>-0.059</td>
<td>0.100</td>
<td>0.170</td>
<td>-0.129</td>
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</tbody>
</table>

43. The Working Scientist Believes that Nature is Orderly Rather than Disorderly

47. Curiosity Motivates Scientists to Make Their Discoveries

48. The Chief Reward in Scientific Work is the Thrill of Discovery