The CHEM Study Story

The CHEM Study *Story*

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Foreword

One evening near the end of 1959, I was met at the Washington airport, upon arrival from the West Coast, by a zealous group who had a visionary plan to press upon me. Bradford R. Stanerson, Harry Kelly, and Arthur Roe, representing the American Chemical Society and the National Science Foundation, whisked me off to the Cosmos Club, where they described their idea for a new high school chemistry course, and persuaded me to assume the responsibility for its development. Although my heavy schedule as Chancellor of the University of California, Berkeley, and numerous other commitments should have made me decline this added responsibility, the unusual circumstances of our meeting and the ardor of the group led to my somewhat bewildered acceptance. This was the birth of the project whose history is so ably told in these pages by the participants themselves.

The CHEM Study Story is a complete chronicle of the events that were set in motion by that encounter. Because of the selfless devotion and hard work of its numerous participants, the CHEM Study can be considered beyond doubt a success story.

My acceptance of the responsibility for this project was contingent on its obtaining the services as Director of my long-time friend and a master teacher, J. Arthur Campbell, of Harvey Mudd College at Claremont, California. Art immediately accepted this assignment, and we agreed that the project should have a second center at Harvey Mudd College, in addition to the one at the University of California, Berkeley. It was he who suggested the descriptive name for the project—the Chemical Education Material Study, or, briefly, the CHEM Study.

Art and I drew up a list of prospective members for a Steering Committee, every one of whom (except one who would be out of the country) accepted the invitation and gave generously of his time throughout. (The members are listed in Appendix A-1.) At the first meeting of the Steering Committee, on January 9, 1960, in Berkeley, the objectives were conceived and an approximate time schedule was drawn up.

The general objectives of the Study were to develop new teaching materials for the high school chemistry course, including a textbook, laboratory experiments, and films. The more specific objectives were to diminish the then current separation between scientists and teachers in the understanding of science, to stimulate and prepare those high school students whose purpose was to continue the study of chemistry in college as a profession, to encourage teachers to undertake further study of chemistry courses geared to keep pace with advancing scientific frontiers, and thereby improve their teaching methods, and to further even in those students who would not continue the study of chemistry after high school an understanding of the importance of science in current and future human affairs. It was decided from the first to have the course be strongly based on laboratory experiments and be applicable to all students who take high school chemistry. Another basic tenet was that liaison with the other high school chemistry project, the Chemical Bond Approach (CBA), would be set up and maintained in order to achieve maximum benefits from having two courses.

In February 1960 I wrote to the initial proposed contributors describing the project and our tentative, very ambitious, time schedule (this letter is reproduced in Appendix H). Shortly thereafter, in a move that did much to insure the success of the undertaking, Art Campbell and I had lunch with George C. Pimentel at the Faculty Club in Berkeley and succeeded in persuading him to take time from his very productive research to serve as Editor of the CHEM Study textbook. It is just possible that my role as Chancellor helped induce a Berkeley faculty member to accept this demanding assignment. George performed with characteristic enthusiasm and did an extraordinary job.

The CHEM Study Story describes the dedicated efforts of the many contributors that led to the production of all the CHEM Study materials

—the text, laboratory manual, teachers guides, instruction pamphlets, achievement tests, related monographs, and films. A measure of the project's success is the wide adoption and use of these materials in the nation's high schools and their direct and indirect influence on the content of numerous recent texts and laboratory manuals that have been prepared by many authors. Another measure is the many foreign-language translations of the written materials and films. An interesting sidelight is that the income from the materials has exceeded the support funding from the Federal government; CHEM Study is in the unprecedented position of more than paying for itself.

CHEM Study has made it necessary and possible to upgrade much of the teaching of college chemistry—an effort that is still in progress—in order to meet the requirements of the better-prepared incoming students. It has widened the interest of college and university teachers in the problems of high school teaching. And it has put many high school teachers in closer touch with their collegiate and university colleagues. The high school teachers' presence on the writing teams served to keep the materials understandable and to assure the teachability of the course.

The support of the National Science Foundation made this project possible, and the great understanding and cooperation of its representatives minimized the problems of contractual relationships. Similarly, the support and cooperation of the Regents, administration, and business office of the University of California and of the authorities of Harvey Mudd College helped to remove administrative burdens from the CHEM Study staff.

Personally, I count my own contributions to the CHEM Study effort as among the most important and rewarding of my activities during the last decade.

Washington, D.C. GLENN T. SEABORG
February 3, 1969

Preface

This history has been compiled with the hope that it will be of value to those, now and in the future, who undertake curriculum development and improvement projects. It should also be of interest to the many people who, at one time or another, have worked on some aspect of CHEM Study, to see how the entire project developed. Finally, it may be of interest to some people merely to know how a substantial amount of their tax money has been spent in an extensive, nationwide effort to improve education.

The body of the report consists of five chapters in which the major goals, activities, and accomplishments of CHEM Study are described. For those seeking more detailed information, the appendixes include bibliographies, outlines and notes from writing and evaluation sessions, and other relevant documents.

We acknowledge the original contributions of the principal collaborators and the helpful comments made by Keith MacNab and Aubrey L. McClellan. We also acknowledge the efficiency of the secretaries (see Appendix A-5) from whose well-kept files the pertinent documents were readily retrievable.

Berkeley, California
1969

RICHARD J. MERRILL
DAVID W. RIDGWAY

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The CHEM Study *Story*

I

Goals and major activities

The Chemical Education Material Study is a program supported by the National Science Foundation through grants totaling approximately $2,800,000 through 1968 to the University of California, Berkeley, California, and to Harvey Mudd College, Claremont, California. The Study began in late 1959 after a committee (E)* appointed by the American Chemical Society suggested that there were many ways in which high school chemistry might be taught, and that at least two of them should be explored with the support of the National Science Foundation. One was the Chemical Bond Approach Project which had been working on a program for the past two years. CHEM Study was established to explore a second possible way of presenting a first course in chemistry.

The goals of CHEM Study, as set forth in its original proposal to NSF, have been:

(*a*) to diminish the current separation between scientists and teachers in the understanding of science;

(*b*) to encourage teachers to undertake further study of chemistry courses that are geared to keep pace with advancing scientific frontiers, and thereby improve their teaching methods;

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* Capital letters in parentheses refer to pertinent appendices. If a numeral follows the letter, it refers to the subdivision of the appendix cited.

(*c*) to stimulate and prepare those high school students whose purpose it is to continue the study of chemistry in college as a profession; and

(*d*) to further in those students who will not continue the study of chemistry after high school an understanding of the importance of science in current and future human activities.

In seeking to attain these objectives, the main activities of CHEM Study have been to produce, try out, refine, and publish course materials for use by high school chemistry teachers and students. The materials produced by the Study include a textbook, a laboratory manual, a teachers guide, two series of tests, two programmed sequences in mathematical skills (B), 26 motion pictures for classroom use (C-3), 17 motion pictures for teacher training (C-4), two films for dissemination of information, several short loop films and filmstrips based on the motion pictures, and teachers guides for all filmed materials. The Study has disseminated information about its work through newsletters (D) and voluminous correspondence, and by furnishing, on request, speakers and consultants for meetings and conferences of science teachers and school administrators. During the summers of 1960 and 1961 the Study conducted institutes to acquaint a total of about 125 teachers with its preliminary materials. Since 1961 it has, on request, provided course materials and consultant services to several hundred institutes and other teacher-preparation programs.

II

Generation, tryout, and refinement of course material

Members of the American Chemical Society committee (known as the Garrett committee after its chairman, A. B. Garrett) and representatives of the National Science Foundation met with Dr. Glenn T. Seaborg on one of his trips to Washington in the fall of 1959 and strongly urged him to accept responsibility for organizing and implementing the development of the second modern course in high school chemistry. Despite his busy schedule as Chancellor of the University of California at Berkeley, he said he would accept the chairmanship, provided a suitable director, such as Professor J. Arthur Campbell of Harvey Mudd College, could be persuaded to join him. Professor Campbell immediately agreed, and together they drew up a list of potential members for the Steering committee. All of those asked agreed to serve except one person who would be out of the country at that time (A-1).

At the first meeting of the Steering committee, held in Berkeley in January, 1960 (F), it was decided to try to prepare some material during the coming summer that could be tested in a small number of schools the following year. It was also resolved that outstanding secondary school teachers, university professors, and industrial chemists would form a group to collaborate on the material. A rough outline of an approach was made (G-1), and it was decided to produce a text, a laboratory manual, and a series of motion pictures, plus, possibly, some supplementary monographs and charts.

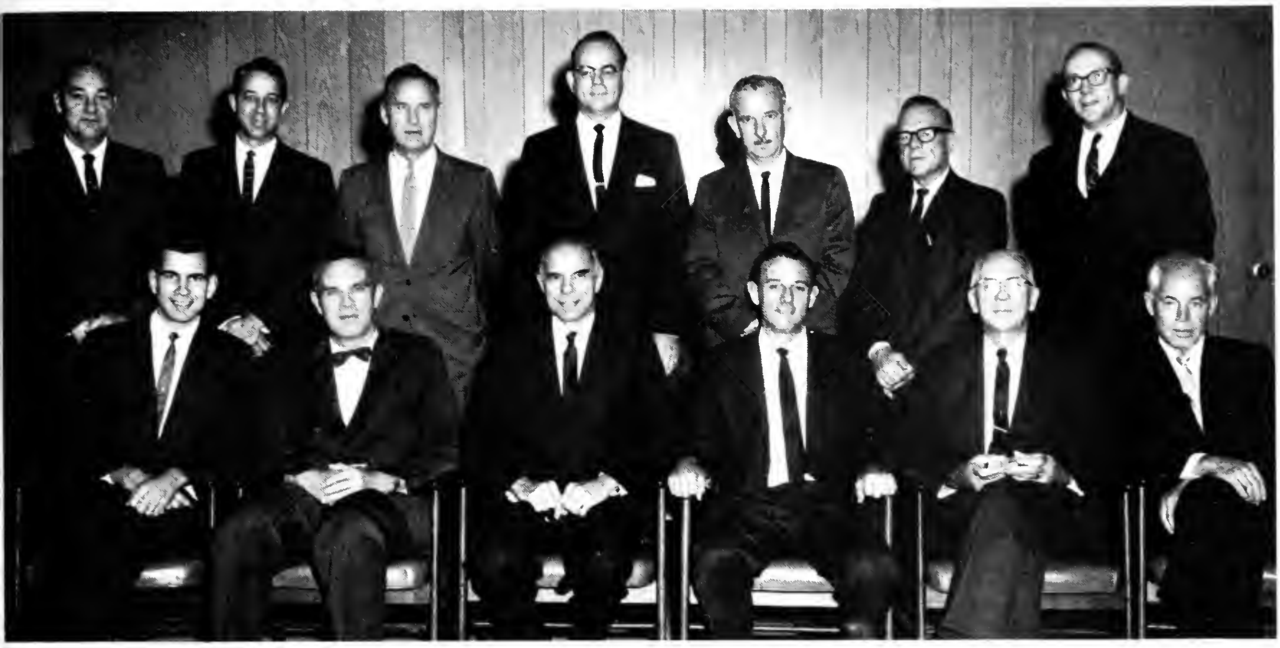
The first step, however, was to assemble a group of collaborators. The Steering Committee made some suggestions, and the director of the Study proceeded to contact exceptional secondary school and university persons (H). Everyone who was invited to participate agreed to do so. The group of contributors (A-2, 3) met for the first time at Harvey Mudd College in Claremont in April 1960 and spent four days in intensive discussion, hammering out an outline of the material and deciding on methods of proceeding (I).

The first organizational meeting of the contributors and the first summer writing conference were clearly the most crucial periods in the progress of the Study—the periods during which it was in fact made, but during which it could have disintegrated. Because these stages were so critical, it will be especially valuable to those undertaking similar projects to have a clear and detailed picture of just what happened. To this end, the accounts that follow were independently written by four of the most active participants in these sessions. Lest fine points or balance of viewpoint be lost, no attempt has been made to combine or condense these statements. At the unavoidable cost of enduring some repetition, it is hoped that the reader will be able to synthesize the four statements into an accurate picture of what did occur. The inclusion of several accounts may also compensate, in part, for the fact that although based on notes taken at the time, the accounts themselves were written five years after the events.

EARLY PLANNING AND WRITING

Early Planning of CHEM Study Materials, by J. Arthur Campbell

Throughout its history, CHEM Study has operated on a tight schedule with very close deadlines. The plan for 1960 was to write the materials during six weeks in the early summer. In August, they would be submitted to some twenty high school teachers for evaluation and possible commitment to try in their classes. By September 1 the materials would actually be duplicated and delivered to the teachers. Although its schedule was



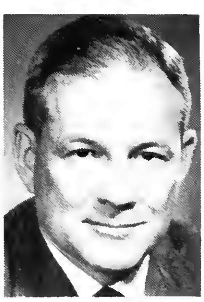
Top row, left to right: *Robert Rice, Robert Silber, Rolland J. Gladieux, Roy L. Whistler, J. Cecil Parker, H. Grant Vest, Cleveland Lane.* Bottom row, left to right: *Richard J. Merrill, J. Arthur Campbell, Glenn T. Seaborg, George C. Pimentel, Harvey E. White, David W. Ridgway.*

Bryce L. Crawford, Jr.

Henry Eyring

Donald H. McLaughlin

Kenneth S. Pitzer



Charles C. Price

CHEM Study Steering Committee and Staff Directors, Meeting in Washington, D.C., Oct. 17, 1964. (The members shown in the five individual pictures were unable to attend the meeting.)

ambitious, the Study never missed a deadline throughout the three-year program.

One reason that the deadlines for the preliminary editions were met was the meeting of potential contributors in April 1960. Approximately 25 high school teachers, university professors, and research chemists came to Claremont to discuss the over-all project and their possible contributions to it. For four days they met and discussed a rough outline (which they had received before coming to the meeting). They expanded this outline into a series of chapter outlines that would adequately present the most important chemical ideas that seemed suitable for high school students. The chapters were then divided into sections. Each contributor accepted responsibility for writing a single section and agreed to use the intervening two months to prepare for the summer writing session.

The discussion during the April session was especially penetrating. It produced incisive exploration of many alternative approaches, the generation of a large number of insights into the problems we would face, and proposals for their possible solutions. Excitement was high and areas of agreement and disagreement were vigorously explored. It seems safe to say that the four-day meeting in April saved two or three weeks of time in the summer because people were allowed to express their views, to hear countersuggestions, and then to "retire from the scene of battle" for a couple of months to cogitate the suggestions and countersuggestions before the actual writing began. This gestation period provided great opportunity for a more coherent flow of ideas, because each person had time to weave others' suggestions into his own pattern of thought. As a result, the writing group that met in June (and was composed of almost all the people who had attended the April meeting) was able to begin writing immediately. A complete first draft was produced in three weeks. Even this initial draft had considerable flow because of the April meeting, the gestation period, and the propinquity and cooperation of the writers during the June session. After the written materials were circulated and read by everyone, each person rewrote his own section, so that by the end of July the entire set of materials had been written twice.

Owing largely to the very high caliber of the contributors, but almost equally to their ability to cooperate and exchange ideas, a remarkably large part of these early materials appeared almost unchanged in the final edition of the CHEM Study text. Here are some of the questions that were thoroughly discussed during the early meetings:

(1) Should atomic structure and the nature of chemical bonding be discussed early or late in the course?
(2) Should the descriptive chemistry include a detailed discussion of some of the recently discovered "exotic" compounds, or should it adhere rather closely to the compounds that have relatively high stability under atmospheric conditions?
(3) To what extent should algebra, as used in the gas laws and in equilibrium calculations, be included in the course?
(4) To what extent should the gas laws themselves be treated, as contrasted with an approach based more directly on kinetic theory and molecular motions?
(5) To what extent should the text be based on laboratory experimentation already performed by the student?
(6) What is the most effective way of acquainting students with stoichiometry and getting them to the point where they can work with it readily?
(7) How useful is the mole concept, and is it reasonable to define the mole as a number rather than to continue to give its historical definition?
(8) To what extent should various interpretations of experimental observations be presented? For example, how many acid-base theories should be used in interpreting chemical reactions?
(9) To what extent should the treatment of the elements attempt to cover the whole periodic table in contrast to concentrating on a few selected elements?
(10) How much treatment of radioactivity should be included?
(11) What level of vocabulary should be used as compared with vocabulary usually found in books at the high school level?
(12) How much emphasis should be placed on industrial practice and practical applications of chemistry?

The answers we proposed to these questions are apparent after reading the early materials, as well as their later revisions. It will also be apparent that some of the answers changed as we had more and more experience with student reaction to the attempted solutions. It is still, however, a tribute to the perspicacity of the contributors involved in these early discussions that their initial decisions were so readily acceptable in the high school classroom and laboratory.

The most extensive revisions were required in the first few chapters. It was discovered in the first year that teachers tended to proceed very slowly through these early materials, partly because of the large number of ideas that were presented with minimal experimental background. These teachers did not understand that because all of these ideas were extensively explained later in the book, they could be initially surveyed in a rapid fashion. Some of the trial teachers, as a matter of fact, tried to move the material on bonding into the first few weeks of the course. In general, such transfers of material were not successful because of the close integration of ideas that had been achieved even in the first edition.

As a result of the slow initial coverage, the introductory material was changed by dropping a considerable number of ideas and reordering the sequence of many others. The early section of any book must succeed in setting the tone and preparing the student for the remaining material. Once this is successfully accomplished, greater freedom of organization is possible in later sections. The work on these early chapters was thus exceptionally intensive. It appears to have paid off, however, for many teachers now comment on the effective way the course begins.

During the first year or two of the Study, almost everyone who viewed the materials was concerned that they might be too advanced for high school students. Nevertheless, all the teachers who initially saw the materials found them sufficiently exciting to want to try them for at least one year in their classes. One year of experience convinced the teachers that they wished to continue, especially when their students did indeed find the ideas and the presentation commensurable with their ability to learn. Beyond question, however, it was the critical appraisal by the teachers and students that enabled the contributors and the editors to do such a masterful job of revising the materials and improving them with each subsequent edition.

The First Planning Conference and Writing Session, by Saul L. Geffner

APRIL 1960

The group that assembled at Claremont consisted almost equally of college professors and high school teachers of chemistry. In addition, some interested observers were also present. Each of us came to sunny California armed with his own preconceived notions somewhat neutralized by materials mailed to us before the meetings. These materials included (1) excerpts from the Garrett committee report on the possible reorganization of a high school chemistry course (E); (2) a report by J. Arthur Campbell on a possible organization of a high school chemistry course (G-1); and (3) a statement by George C. Pimentel on the goals of a high school chemistry course. At this first meeting it also would have been interesting to have had a report from a high school teacher stating his reactions to a modern course in chemistry. However, the high school people had ample time to speak their thoughts later at the meetings.

Four days of sessions were scheduled.

Saturday, April 2—Evaluation of the present status of high school chemistry by high school teachers.

Sunday, April 3—Statement of the goals of a high school chemistry course as envisioned by both college professors and high school teachers.

Monday, April 4—Development of a course outline and division of materials for further study in committees.

Tuesday, April 5—Reports of the committees on the content of the projected text.

I was impressed by the persons present at these meetings. Although I had worked previously with some of the college people (Campbell, Haenisch, and Steiner), the high school representatives were complete strangers to me. I was amazed at the speed with which everyone was integrated into a working body. Considering the diversity of backgrounds and points of view, a near miracle seemed to have been performed. The geographic distribution of contributors was weighted considerably in the direction of Californians and westerners, in general. I was the lone high school representative from the East. I do not want to exaggerate this point, but, from time to time, western chauvinism became a source of irritation, sometimes hidden and sometimes open. (I was generally amused by this, but some of my colleagues were not.) Finances may have dictated this arrangement, but the disproportion might have been equalized somewhat.

Despite the geographical imbalance, the selection of college professors represented a good cross-section of the different colleges and universities in terms of size and program. The college professors were, by and large, men of proven writing ability. (Later on this was to be another source of irritation to the high school teachers, but it was a necessary, calculated risk.)

The high school teachers generally came from moderate to good-sized urban high schools. However, there were no representatives from private or independent schools and only one teacher from the junior colleges. Thus, the choice of non-university people was somewhat restricted.

No attempt was made to include professors of education or curriculum specialists. Although these people would probably have created some problems, they might have been a source of help later on. I am not sure how much experience our college people had had with high schools and high school students. Their impressions were probably secondhand. Perhaps this is why they listened so carefully to the high school teachers who were present. Here a specialist in the theory of education might have been a helpful intermediary between the college and high school teachers.

I remember Dr. Seaborg's admonition that we must develop a course of study for *all* high school students, not merely for the select few. W. H. Freeman, as a member of the Steering committee, had expressed a similar feeling in a letter to the chairman and director of the Study some months before this meeting.

A course outline was developed in a general meeting of all the contributors. Much of this outline was suggested by the college professors based upon their own convictions and the comments of the high school teachers. (This statement should not be construed to mean that the meeting was college dominated; nothing could be further from the truth. The opinions and judgments of the high school people were sought, encouraged, and, wherever possible, followed.) The fundamental philosophy of this meeting and the ones that followed was that both groups of teachers had their specific contributions to make. Many of the high school teachers had been disappointed with the difficulty of communication in previous meetings with college people and were surprised and relieved at the earnestness and sincerity with which their suggestions were received at this meeting. This atmosphere of mutual trust and reliance, I feel, was one of the chief factors that contributed to the success of CHEM Study.

Each working committee consisted of at least one college professor and several high school teachers. The college teachers were selected for a particular committee on the basis of their special interests and capabilities. The high school teachers were allowed to choose the area in which they wanted to work. Certain staff members visited all the committees to coordinate our efforts. Each committee reported its deliberations, which were then developed into a set of topical ideas to be fitted into the framework of a modern course in high school chemistry.

In the final meeting we evaluated our projected course. Again, the counsel of high school teachers was sought, although not enough time was allowed for discussion. This last session, probably the most important of the four, was much too hurried. As a result, the tentative course, or topical outline, covered far more material than a typical high school student exposed to a course in chemistry for the first time could handle. Too many of the college professors were just not cognizant of the problems facing high school teachers of chemistry. I set out for home somewhat apprehensive about the outcome of our work.

In forming a final impression of this first meeting, I realized that the college professors were obviously selected for their scholarship and writing skill. Yet, it was amazing how each personality differed, especially in his point of view. We were fortunate that our director had the necessary tact, forbearance, and understanding to deal with these diversities. This augured well for the future.

SUMMER 1960

The April sessions had been largely devoted to chalk and talk. The summer session of 1960 was devoted to writing a book (or enough of it) to be used during the same year in some 25 schools. In addition, we had to devise laboratory materials to support the text.

Before we convened, the materials we had prepared in April were evaluated by the Steering committee, notably by Professors Pitzer and Crawford, and by the CHEM Study staff. Their criticisms were contained in a letter mailed to all the contributors before the June meetings. The results of a questionnaire dealing with procedures followed by high school teachers of chemistry and the most effective experiments performed by students in high school chemistry classes were also made available.

For the first few days we were concerned with taking a fresh look at our April efforts in the light of the criticism and evaluation that had developed during the ensuing weeks. The course outline was revised and writing committees were set up. The committees were similar to the previous ones with some minor changes. One group was assigned to write lab experiments, which were passed on to the editor of the lab manual.

Each committee member had a specific writing assignment; the major portions were handled by the college people and the minor portions by the high school people. There was considerable discussion and interchange before any writing was completed and submitted to the editor of the text, who then met with the committees to discuss possible changes and revisions. The final copy was critiqued by a group of reviewers and returned to the editor with more comments. This was the last stage before the actual printing of the preliminary edition.

I recall that Dr. Seaborg met with each contributor to discuss his point of view. This was most encouraging. David Ridgway, our film producer, also met with each contributor to get his ideas for possible films. Again, this individualized treatment provided a most effective means for exchanging ideas.

The major problem during the first summer of work was meeting the deadlines. Because it was obvious that we could not complete the entire text, major emphasis was placed on the first section which became Volume I of the trial edition. It was decided that the editor and staff would complete the remaining volumes in the fall.

Upon evaluating the initial phases of the writing program, I feel that too many inexperienced people, particularly the high school people, were engaged in the actual writing. Much of their work had to be discarded. Their efforts might have been more fruitful in reviewing the writing of the college people on their committees. It is true that we had a group engaged in critiquing, but this group might have been enlarged with profit.

Considerable criticism was directed toward the policy of utilizing a one-man editorial staff. Much of the material submitted to the editor, it was claimed, was later unrecognizable in its final form. I do not feel qualified to take a position on this phase of the total operation. However, it is my considered judgment that the materials would not have been ready to be used in the fall of 1960, had not the total editorial responsibility been given to one person. Fortunately for CHEM Study, we had an editor with indefatigable energies catalyzed by determination rarely found in any one person. The efforts of the director and the staff in backing up the editor contributed in no small way to the success of the venture.

In my professional life, I never met a more determined group than the people who worked that first summer at Claremont. Everyone believed in what he was doing, although each was not equally satisfied with all the results. The integrity and sincerity of each contributor was evident in the final product.

Our primary goal had been to develop sufficient materials to test in the field by the fall of 1960. Apparently, we succeeded in accomplishing this feat, but was it a Pyrrhic victory? My own feeling, as a contributor and as a trial teacher, was that the first trial year was marked with too much tension and too much uncertainty. I recall that many of us who taught the material had difficulty with the introductory six chapters, perhaps the most sensitive part of the course. On the other hand, perhaps we just had to pass this hurdle and the sooner the better. Certainly, the success of CHEM Study seems to bear this out. Of course, we will never really know, but I believe that a somewhat slower pace might have lessened the number of false starts and provided a firmer beginning. Yet doesn't the Bible say that all beginnings are difficult? So why should CHEM Study have expected anything less?

The April 1960 and June 1960 CHEM Study Writing Sessions, by Edward L. Haenisch

The invited contributors included two liberal-arts college professors (Haenisch and Steiner); one state college professor (Hurley); four university professors (Geissman, Mahan, Rapoport, and Sienko); one representative of an atomic-energy laboratory (Katz); and ten high school teachers, of whom seven were from California (R. Campbell, Greenstadt, MacNab, Menesini, Nicholson, Parrish, and Tellefsen), one was from Utah (Davis), one was from New York (Geffner), and one had just ended his teaching in Indiana and was Educational Secretary of the American Chemical Society (Silber). This group gathered with the staff (J. Arthur Campbell from a liberal-arts college and Lloyd E. Malm and George C. Pimentel from universities) at Harvey Mudd College April 2–5, 1960. It was an enthusiastic, diversified group with experience in innovations in chemical education at various academic levels. Most of the college-university group had written texts or were in the process of doing so. Many of the high school teachers had participated in institutes with Pimentel at Berkeley. All were firmly convinced that a revision of secondary school chemistry was an absolute necessity. In the pleasant and intimate atmosphere of Harvey Mudd College, we soon became acquainted.

Pimentel chaired the usual preliminary discussions, giving everyone sufficient opportunity to voice strong personal feelings. There were no barriers to free expression for either the college or the high school teachers. Each person's opinion was respected. Almost everyone was hidebound by the traditional pattern of presenting atomic structure early in the course and of basing subsequent topics on this background. The necessity of adding a sound introduction to such topics as kinetics and energetics, and of providing a mathematical introduction to equilibrium was recognized. The importance of systematic descriptive chemistry, organized around basic principles was acknowledged.

Gradually, during four half-day sessions, the group crystallized the outline into the following division of topics:

(1) Introduction: Microscopic Description of Matter: The Particulate Nature of Matter.
(2) Atomic Structure and the Periodic Table.
(3) Molecules; Chemical Bonds.
(4) Reactions; Stoichiometry, Equilibrium, Energetics, Rates.
(5) Systematic Descriptive Chemistry.

One or two college-university teachers and two high school teachers were assigned to each topic. Fortuitously the college and university teachers volunteered for or received topics coinciding with their particular interests. This fact turned out to be an important catalyst in the subsequent organization and writing.

From two o'clock one afternoon until almost midnight, and from eight until twelve the next morning, these five groups met to prepare rather detailed outlines of their subsections and to argue out infinite possibilities. Naturally each group enthusiastically and zealously included too much material, and, in spite of the warnings by the high school contingent, overshot the level of presentation.

In a concluding session to review the efforts of the topic groups, there was enthusiasm for the entire project, sharp differences of opinion on proposed topics, modes of presentation and vocabulary, and, the camaraderie of pioneering authors. The contributors and staff adjourned with a sense of high anticipation for the June writing session.

The contributors and staff reassembled in early June with the loss of three of the April attendees—Katz, Menesini, and Rapoport. It was a rude but awakening shock to find out that the Steering Committee had not shared the enthusiasm for the proposed outline. Crawford's sharp comments about bonding concepts and Pitzer's emphasis on the experimental nature of chemistry had a profound influence on the final development of the course (J). Quickly, "Chemistry is an experimental science" and "presentation from on high" became much bandied but significant phrases.

In a short organizing session a new introductory section based on the candle (à la the Faraday lectures of more than a century ago) was approved and it was decided that atomic molecular structure should be discussed later in the book. Then the groups began the awesome task of trying to write a text and laboratory manual in three to four weeks and producing a revision in the remaining two weeks. The candle continued to be a source of much humor. "One mole" of candle, bent by the heat of the California sun to the shape of a question mark, hung on the door of Text Editor Pimentel throughout the session.

Laboratory Manual Editor Malm immediately started to devise and test experiments. This step was important since experiments were to be the necessary introduction to each major topic. One high school teacher from each group was assigned to the laboratory project. The ingenuity of the laboratory group and their persistent attention to safety practice are to be commended. The list of tried but discarded ideas was stupendous because it took a long time to convince the high school teachers that the idea of starting laboratory work on the first day of the course had even an iota of practicality.

The business of writing chapters without knowing what preceded the material or followed it was difficult. Vocabulary problems were acute. What definitions were to serve as the "party line"? What theories were to be accepted, e.g., acid-base, oxidation-reduction, bonding? A daily luncheon at the faculty club often lasted well into the afternoon as these questions were debated. I might mention that work ceased on Saturday and Sunday as we found that relaxation and change (many traveled over weekends) renewed our courage and inspiration to face the problems in the week ahead.

The writing caused much critical reexamination of fundamental ideas and the supporting experimental evidence. I, for one, learned more chemistry in the six-week writing session than I had learned in years of teaching. Many pet personal idiosyncrasies of the writers' styles disappeared, but not without argument and endless talk sessions.

An efficient typing and duplicating service made possible the rapid dissemination of the written chapters and experiments to the entire group. The high-school-age children of the contributors were kept busy running the duplicator and assembling the pages. Criticism of the material was freely given. Some comments hurt, but all were taken in stride and heeded. We discovered that the high school teachers were not adept, for the most part, as primary writers of text chapters. As critics and devisers of experiments they were invaluable.

About the middle of the six-week session, Professor Robert W. Parry of the University of Michigan joined the group as a critic of the material. With a fresh outside viewpoint, he made many worthwhile suggestions as the rewriting started. Pimentel assigned Geffner and R. Campbell as principal critics for the high school group. These men made estimates of the time required to present the proposed material to high school classes. It soon became apparent that enough material had been written to fill two years or more of class time. Preliminary deletion was agonizing, and not enough was done. This task had to be relegated to the next summer.

Many of the chapters did not get revised and a few were not even written during the first session. The prime chapters, however, got the full critical treatment and were reworked, a few for even a third or fourth time.

Probably the most neglected feature was the development of appropriate exercises and problems. When written at all, these were hurriedly and sketchily assembled. Many were inappropriate and, in the scrambling, cutting, and pasting, got placed in entirely wrong places in the book. This fact was verified by the cries of anguish from the teachers who used the material in their classes during the first and even the second year.

Reflection on the writing session and the ultimate treatment of the material produced makes two points clear: (1) it was wise that the opinions of the secondary school teachers about difficulty of concepts were not always accepted (if they had been, the notion of E°s, for example, might not be in the final version), and (2) the appointment by the Steering Committee of editors with power to make final decisions about the text and laboratory manual helped to make the final editions coherent. It is to the eternal credit of Pimentel and Malm that the contributors remained their friends. The CHEM Study materials are a monument to what committee writing coupled with extremely capable editorial work can accomplish.

The Planning, Generation, and Revision of the Course Materials, by George C. Pimentel

One of the main elements of strength in the various curriculum studies has been the enlistment of large numbers of authoritative contributors. The effective utilization of this reservoir of creativity is the key to the success of a project. On the one hand, there must be leadership and common direction. On the other hand, there must be encouragement to individualism and opportunity for originality. Only after all views have been heard and debated can a course of action be selected and accepted, even by those whose arguments did not prevail. Clearly this is a precarious path, and one can go astray because of a conflict of wills, or because of forgivable but real human frailties that personalize even an intellectual giant. To avoid foundering upon such irrelevant difficulties requires the development of an intangible set of human relationships that cannot be set into a pattern. These relationships provide the basis for an *esprit de corps* that permits the group's capabilities to exceed by far the sum of the abilities of its individual members.

Leadership and individualism, a common direction and opportunity for originality, all views heard and a course of action selected—these were all present in CHEM Study. How were they achieved? When did they evolve? What events shaped the strong *esprit de corps* that contributed so much to the excellence of the CHEM Study products? There is no telling for sure—all one can do is relate what happened. Then perhaps other groups setting out on a similar venture can sift the historical facts for what is relevant to their enterprise—indeed, to their individual members. Different people will find useful guidance in different events; some may find no guidance at all. Nevertheless, the tale is worth the telling, for marshaling the talents of a selected group of scientists to their maximum productivity is not guaranteed by arranging geographic proximity any more than a happy marriage is guaranteed by a bridal bouquet.

This account must be a personal one—to assume meaning, it must be told as seen through a different pair of eyes. The discussion does not concern the technical matters that were argued. It concerns the manner in which the pedagogic decisions were reached—the modus operandi by which the project reached its goal.

PRELIMINARY ISSUES

Steering Committee Chairman Seaborg and Director Campbell asked me to join the staff as Editor about March 1960. My interest in the proposed activity was preformed; it was based upon an earlier chairmanship of a curriculum-revision committee at the University of California, upon teaching experiments at the freshman level, and upon numerous rewarding contacts with chemistry teachers in San Francisco Bay Area high schools. Nevertheless, I felt great reservations on three counts.

First, the prospect of devoting a large block of time to a high school curriculum study carries serious implications in a scientist's professional career. A significant sacrifice of personal reward is involved when a scientist's attention is diverted from his research interests. Also, there may be material sacrifice, since the educational project may exert little influence toward advancement in a major university, and an interruption in research productivity may postpone advancement.

With these considerations in mind, I asked if I could be relieved of university teaching, if I could participate in the project without loss of credit toward sabbatical leave, and if I could maintain graduate research activity on a half-time basis. Chairman Seaborg, who was then Chancellor of the University, assured me that all these requests would be granted.

Second, the project was headed by a Steering Committee of preeminent scientists and educators with immediate direction of the project to be in the hands of J. Arthur Campbell. It seemed important to ask for a definition of my editorial responsibilities. I asked about the extent to which editorial decisions would be subject to review, the extent to which the course outline was predetermined, and the extent to which the Steering Committee might dictate details of technical content.

Dr. Seaborg indicated that the Steering Committee wished to offer its guidance through broad policy suggestions. Professor Campbell assured me that difficult editorial decisions would be reached through staff consultation, but that final responsibility would rest with the editor. He indicated, further, that the course outline was yet to be fixed on the basis of the considerations and reflections of the contributors.

Third, it was sobering to consider a coauthorship involving over twenty individuals, few of whom I knew even casually. However, in view of the favorable responses to my reservations, the importance of the activity justified, in my eyes, participation in the CHEM Study project.

THE FOUR-DAY OUTLINE CONFERENCE

The work of the project began with four days of meetings, April 2 to 5, 1960. Our goal was to agree on a first outline of the course. If the major decisions of content, sequence of topics, and writing assignments could be decided, the summer writing session would begin with significant momentum. During the first two days, however, we seemed to make little progress toward any general agreement. The university contributors, each a curriculum innovator in his own right, confronted each other with a barrage of convincing arguments advocating a bewildering array of alternate models that the course might follow. This discussion was not aided by the simultaneous necessity for becoming acquainted, for adjusting to the range of personalities, and for removing artificial communication barriers based upon such irrelevancies as age discrepancy, geographical parochialism, and university *vs* small-college outlook. The high school contributors participated freely in the discussion too, but it seemed that they often diverted discussion from course content to anticipated pedagogic difficulties.

By noon the third day it became clear that agreement upon an outline was not likely to evolve from the continued debate. The staff decided to attempt to frame a single outline based upon the three-day discussion and to present it to a smaller group of university contributors only in an "emergency" evening session. The outline that was presented to the smaller group was not immediately acceptable *in toto* to anyone, but it was strongly opposed by one individual in particular. In view of his general dislike for the proposal, this individual was finally asked to place on the blackboard for contrast his own idea of the optimum outline. He was not ready to do so, and therefore, he redirected his contributions into a more constructive vein. In retrospect, this incident remains vivid as a critical turning point. Thereafter, final agreement was reached rather smoothly, and it was finally possible to form writing teams and make rough topic assignments on the fourth day.

This four-day period was a necessary step in the development of the CHEM Study group structure, and it was one of the crucial periods. With a different group, perhaps the desired goal might have been reached in a shorter time, or perhaps it might not have been reached at all. It was surely a great benefit to the summer writing session that this introductory skirmish had been completed. In retrospect, it seems that two preliminary meetings would have been preferable, with the first meeting directed solely at getting acquainted and exchanging ideas in a very general context. Such an opportunity to "size each other up" would leave the next meeting free for work. The fact that the high school teachers were present from the start contributed immeasurably to the effectiveness of all the participants.

THE FIRST SUMMER WRITING SESSION

That June the group assembled in a dormitory at Harvey Mudd College for a six-week period to piece together the first draft of the book. Each of the six writing teams included at least one university writer and two high school teachers. Each team was assigned a set of chapters to write without any more knowledge of the detailed content of the preceding and following chapters than was contained in the rough outline framed in April. The staff (Campbell, Malm, and I) attempted to keep abreast of the progress in each group and to provide liaison between groups when needed, while interfering as little as possible with the groups' creative work. Thus each group, working individually, made its contribution to the first draft. Generally each team subdivided its responsibilities, with the high school contributors primarily evolving the laboratory material, while the university contributors built their depth of knowledge into the textual material.

The preliminary plan was to complete a first draft of the entire book in

Members of the staff evaluate the progress of the first writing sessions. Left to right: *David W. Ridgway, J. Arthur Campbell, George C. Pimentel, Lloyd E. Malm.*

three weeks and a first revision in the next three weeks. As sections of the first draft appeared, they were reproduced and distributed to the other writing teams. Each staff member studied each chapter and then held a critiquing session with the group that produced the material. This evaluation formed the basis for the second draft. Heaviest emphasis was placed on making the first seven chapters flow smoothly so that they would be ready for multilithing and classroom use at the end of the six-week period. The text chapters from Chapter 8 on were in progressively less useful form, even though each had been revised at least once. Lack of continuity in content and style was a natural result of the team approach. Consequently each of these chapters was revised once more by me after the end of the writing session. This task took the remainder of the summer and most of the fall term. The lab editor treated the lab manual in a similar way. By binding the text in three volumes and the lab manual in two, the materials arrived in the classrooms in parts during the first year. Despite some harrowing deadlines, each volume arrived just in time for classroom use.

Thus an entire course, a text and a carefully integrated laboratory manual, were produced in a single summer for use in the subsequent academic term. This minor miracle was the second crucial phase of CHEM Study, and probably the last phase in which there was room for any doubt that the desired goal might be achieved. It was accomplished primarily because of the round-the-clock dedication of the writing teams. The isolation of the group in the quiet Claremont atmosphere was a substantial aid. While presenting major style and continuity problems, the division of the large group into small and independent writing teams was a major factor in avoiding the disjointed prose that inevitably results from authorship by a committee.

The first year of trial use was accompanied by weekly meetings between the classroom teachers and the staff. Periodically the teachers were brought together to appraise and critique the material. Thus the second summer writing session was based upon intimate staff contact with the field use of the first edition.

THE SECOND SUMMER WRITING SESSION

The second summer writing session included most of the first-year contributors, with a few additional people to bring in fresh viewpoints. The most important new member was probably Dr. Aubrey L. McClellan, who joined the staff as editor of the prospective teacher's guide. To maintain continuity, the text revision was placed in the hands of a much smaller writing team. I revised Chapters 1–18 and Mahan revised Chapters 19–26. Geffner and Sorenson completed the text-revision team. They critiqued every word of the revision in the light of their own classroom experience. A similar small writing team under Malm revised the lab manual. The remainder (the majority) of the contributors worked on the first draft of the teachers guide. McClellan was in charge, and he divided his forces into smaller teams as used the previous summer.

THE THIRD REVISION

Again, regular staff meetings with teachers using the second revision were held during the second year of trial use. The periodic critiquing sessions included representatives from each of the centers (A-4) scattered over the nation. In the light of this contact with field use, another revision of all materials was conducted during the third summer of CHEM Study's existence. This revision was directed by three staff members: McClellan, Malm, and Pimentel, together with a carefully selected group of high school contributors, who included Davis, Geffner, MacNab, Nicholson, and Roberts. Roberts undertook the revision of two programmed units for self-teaching in the use of exponents and the slide rule that had been produced and tried out during 1961–62. He also examined the text to assure a systematic and deliberate introduction of chemical symbols with ample, though covert, repetition to ensure memorization. Some chapters were revised once more for the hard-cover edition, this last revision conducted entirely by the staff.

SUMMING UP

The crucial test of the procedure used to generate the CHEM Study materials is whether, in retrospect, one would have proceeded differently. In answering, one cannot disregard the known outcome: the breakneck schedule was met; the final product has won wide acceptance; and it has provided a major advance in the presentation of chemistry at the high school level. It is difficult to argue with success.

TRIAL AND REVISION OF COURSE MATERIAL

Following the April conference, the principals of 25 high schools were approached and asked if they would like to have their chemistry teachers attend a special session in Claremont, in August 1960, to become acquainted with the new materials. On the basis of this information the teachers could, if they wished, try out the course materials during the 1960–61 academic year. To facilitate feedback during the school year, most of the schools selected were located within 50 miles of either Claremont or Berkeley. To these and subsequently chosen trial schools (A-6), CHEM Study provided the course materials without charge, plus an allowance for purchase of extra supplies and equipment as needed. The teachers involved were paid by the Study both to attend the summer session and to participate in frequent meetings during the school year.

During this first trial year, weekly meetings were held with the teachers. At these meetings staff members worked with the teachers on the problems as they arose and received rapid feedback from the teachers concerning the most difficult and most successful parts of the material. Copious notes were taken at this stage so that the material could be revised as intelligently as possible during the summer of 1961. Amazingly few serious problems were found during this first year of trial use.

The composition of the trial groups varied all the way from highly selected single classes in some schools to the total school population taking chemistry in some of the other schools. There was little evidence even during this first year that lower-ability students had greater difficulty with this course than with a conventional course. There was considerable evidence that certain students sometimes did better, and other students sometimes did worse, than they would have done in a more conventional course. The enthusiasm of both teachers and students seemed to be high, because all the teachers continued to teach the course during the second year of the trial program. High enthusiasm and low teacher attrition continued through the trial years.

During the fall and winter of 1960–61, the staff, with the assistance of the Educational Testing Service, Inc., prepared, distributed, and analyzed the results of a series of multiple-choice, open-book achievement tests (B, L). These tests were designed to help teachers measure student performance in achieving the goals of the course and to indicate to the writers whether or not the presentation of the major ideas was clear.

Following an "agonizing reappraisal" session in June, most of the original contributors and a few new ones (A-3) convened at Berkeley for another six-week writing session. While the large group concentrated on drafting the teachers guide, the editors and associate editors (A-2) revised the text and laboratory manual. Again, the close deadlines and intensive work paid off, and each volume was ready by the time it was needed during the following school year.

One of the problems reported by teachers during 1960–61 concerned many students' lack of facility in mathematical skills and the lack of class time to teach these skills. In response to this problem, the staff prepared, during the summer of 1961, programmed instruction sequences dealing with exponential notation and the use of the slide rule. These remedial pamphlets were found to be useful during subsequent trial use and were later refined and published. The original test series was augmented, extensively revised on the basis of item analyses, and used again during 1961–62. Manufacturers of scientific apparatus were invited to produce a number of charts and demonstration devices which, it had become clear, would be particularly useful in the course.

Two summer institutes, one at Harvey Mudd College, and one at Cornell University, were held during the summer of 1961. About a hundred teachers attended these meetings, and all agreed that they wished to use the materials in their schools during the coming year. In addition, teachers from half a dozen other schools were permitted to use the materials in order to see whether it was feasible for a teacher without institute training to make successful classroom use of CHEM Study materials. Thus, the total number of schools during the second year was more than 130. Since several schools had more than one teacher using the materials, there were more than 140 teachers and over 12,000 students who participated in the program during the second trial year.

Most of these teachers were grouped around nine centers (A-4) spaced throughout the country, and again weekly or biweekly meetings were held between the teachers and staff members or other university chemists

Staff members and high school teachers discuss ways to revise and improve the course.

engaged as center directors by the Study. Again, the strengths and weaknesses of the materials were thoroughly discussed so that a "final" revision could be made during the summer and fall of 1962. Frequent written reports and two general evaluation meetings (K, M) facilitated the flow of information between the centers and the staff. At the January 1962 evaluation meeting, Professor Pimentel dramatically reaffirmed the staff's desire that the participants criticize freely when, after a few opening remarks, he produced and affixed a large piece of adhesive tape over his mouth.

The principal problem during the second trial year was, as in the first year, the tendency of teachers to proceed too slowly through the early parts of the material. As a result, it was decided to alter this portion in the final revision; fewer ideas were introduced, although the general emphasis and approach remained about the same. Certain material was made optional, including some of the laboratory experiments, but the strong laboratory emphasis was still maintained. A major gain in the second trial year was the use of the teachers guide as source material which the Study decided could allow a much larger number of teachers to teach the material during 1962–63 without special institute background.

During the summer and fall of 1962, Volume I was again rewritten to reduce the number of ideas presented and thus to assure a more rapid progression through this section of the course. The teachers guide was also completely rewritten and the tests again revised, this time without the services of ETS. Major progress was made on the films; some half-dozen had been produced during the first year. By the opening of school in the fall of 1962, 11 films were ready, and eight more became available during that school year. Another eight were completed during the 1963–64 school year, providing a total of 27 films designed for use in the course (C-3).

During the summer of 1962, eight NSF-supported institutes gave teachers intensive training with the materials. While the CHEM Study staff did not conduct these or subsequent institutes, it cooperated actively by providing course materials and the consultant services of staff members and contributors. Fifty outstanding teachers were chosen from among the 400 or so participants to serve as the supported trial teachers during 1962–63. Six new centers were established (A-4), and about twenty "solo" or non-supported teachers were chosen in order to obtain good geographical distribution of CHEM Study teachers who might later be called upon to provide consultant services.

During 1962–63, about 45,000 students and 700 teachers in some 550 schools used the trial editions of the course materials. About half of these teachers used the materials for the first time that year without any special institute familiarization. Feedback was obtained through reports solicited from individual teachers, the six new centers, and several of the 1961–62 centers that continued to function informally without financial support.

Final copy for the text and laboratory manual was prepared during the fall, and the last of it was submitted to the cooperating publisher by the end of December 1962. Copy for the teachers guide was sent in last, both to assure complete compatability with the text and manual, and to permit utilization of feedback up to the last possible minute. All three were published in time for quantity shipments to be made in July and August 1963. Final revisions of the tests and programmed sequences were also completed during the summer and early fall of 1963.

During the school year 1963–64, two trial forms of a new test series were written, tried out in mimeographed form in 50 schools, analyzed, revised, and published in early fall 1964. Teachers guides for all the films were put in final form and published. Two lecture films were produced for use in teacher-preparation programs. Minor errors that had inevitably crept into the printed course materials were corrected in the reprintings. Two filmstrips, based on two of the motion pictures, were produced and released to 50 trial schools for evaluation. A film, *Chem Study: Information for Educators*, was especially made for teachers and administrators who were contemplating the adoption of CHEM Study materials. It provides answers to the questions most asked by those considering the use of the CHEM Study materials. Another film, entitled *A Chance to Wonder Why*, was produced in the belief that parents and educators would like to have a more intimate glimpse of the kind of teaching that goes on in a CHEM Study classroom. This film was used extensively on television, and by the end of 1968 had been seen by more than eleven million viewers.

A series of in-service teacher-training programs grew out of a need that developed in the city and county of Los Angeles when CHEM Study was adopted for the 1965–66 year. Seventeen programs were videotaped and televised. The series was later transferred to 16mm film for use in any school. In cooperation with the Advisory Council on College Chemistry, a series of 8mm loops was excerpted from the CHEM Study films.

CONTENT, SEQUENCE, AND APPROACH

CHEM Study came into existence because the Garrett committee (E) and the Steering Committee (A, F) were convinced that chemistry courses commonly being offered in high schools were seriously deficient. Specifically, they felt that such courses typically (1) were preoccupied with having students memorize a great deal of chemical history, descriptive detail, and technology, much of which was out of date and/or relatively unimportant; (2) were not adequately emphasizing the necessity to understand the major unifying concepts and principles of modern chemistry; and (3) were virtually devoid of meaningful laboratory work, and actually were misinforming students about the nature of scientific investigation by having them carry out "cookbook" exercises.

THE TEXTBOOK

The content and structure of the textbook (B) include the following features:

(1) presentation of the experimental evidence upon which the main concepts and principles of modern chemistry are based, and discussion of how such evidence is obtained;
(2) discussion of the major concepts and principles that have grown out of the evidence;
(3) application of the concepts and principles in a variety of areas of chemistry; and
(4) inclusion of tabular data useful in applying concepts and principles in the solution of problems.

Choice of Experimental Evidence

The textbook presentation usually assumes and often refers to evidence that the student is expected to have gathered in the laboratory. Additional experimental evidence is usually presented in the text before discussion of the ideas that grow out of the evidence. In other cases, key experiments are described in the text, and may be supported by teacher demonstrations or experiments on film.

Clearly not all the evidence in support of any particular idea can be presented. Historical development is not generally used. Rather, experimental evidence (old or new) is chosen that is *sufficient* to permit induction of a principle to the level of sophistication needed at that point in the course, and *practical* for students to gather in the high school laboratory, or at least *understandable* to students in light of their background of knowledge and experience.

A case in point is the atomic theory, which is first introduced in Chapter

2 as an example of a widely useful scientific model. Pressure-volume data for gases, presented in the text and in a film, lead to the idea of the particulate nature of matter. The student's attention is then directed to differences between various gases, such as their densities (Experiment 6) and other properties including colors, solubilities, and reactions (demonstrations, film, and text). The model is thus expanded to include the concept of *different kinds* of particles. Further experiments with gases (text and film) show the regularity with which their volumes combine in ratio of small whole numbers. Several possible explanations are offered, with Avogadro's hypothesis being the simplest and most reasonable. To explain this hypothesis and the evidence produced so far, the existence of chemical subunits or atoms is proposed.

This model suffices for the brief introduction to chemical reactions, stoichiometry, and kinetic theory that follow. In considering condensed phases, particularly the properties of solutions, however, the model has to be expanded to encompass the electrical behavior of matter. Experiments (text, demonstration, film) lead to the concept of two kinds of electrical charge, which in turn permits the idea of ions to be introduced to explain the behavior of electrolytes (demonstration, film, Experiment 11).

The rudiments of atomic structure (positive nucleus plus electrons) are presented in Chapter 6 as a working hypothesis, but more complete exposition of evidence for structure is withheld until Chapter 14, "Why We Believe in Atoms." At that point, assumptions made earlier are questioned, and the following chemical evidence for the existence of atoms is presented:

The Law of Simple Multiple Proportions (text);
The Law of Combining Volumes (reviewed in text);
Electrolysis evidence (Experiment 25 and text).

The following physical evidence for atomic structure is then presented:

Experiments with "cathode ray" tubes, including Thomson's e/m determination (text);
Determination of e^- charge by Millikan's oil-drop experiment (text);
Determination of e/m for positive ions by mass spectrograph (text);
Determination of size of nucleus by the Rutherford scattering experiment (text);
Determination of size and arrangement of atoms in crystals and molecules by X-ray diffraction, microwave, and infrared spectroscopy (text and films).

Atomic spectra and ionization energies (text, films) are then presented in Chapter 15 as the principal experimental bases for electron energy levels in atoms.

There were several reasons for deferring detailed treatment of structure and bonding until relatively late in the course. First, very little of the evidence upon which these concepts are based can be directly observed by students in the high school laboratory. Second, a real understanding of much of the evidence demands a level of sophistication in physics and mathematics that very few high school students have acquired. Even when presented with the evidence described above, the student must accept a great deal on the authority of the teacher and the text. Finally, a great deal of important chemistry *based on evidence that students can collect and understand* can be developed without reference to such highly abstract concepts. It is intended that the student will develop sufficient understanding of how models derive from experiment early in the course, so that when he is later asked to accept evidence and interpretations that he cannot fully comprehend, he at least realizes that the ultimate "authority" in science is natural phenomena, not the teacher or the textbook.

Choice of Concepts and Principles

The criteria that were used in deciding which concepts and major principles to include and how strongly to emphasize each one may be summarized by a series of questions.

(1) Is the idea so important in modern chemistry, or is it so useful to chemists today that no first course could be considered complete without it?
(2) Can the idea be developed honestly in a way that is comprehensible to high school students?
(3) Is the idea essential to the development of other major ideas in this course or useful in their application?
(4) Can the idea be developed from experimental evidence that high school students can gather or at least understand?*

* Some of the early ideas about the content of the proposed text are found in the appendices to this report (E, G, J).

The editors and contributors were unanimous in calling for the prominent inclusion of some subjects, such as atomicity, kinetic molecular theory, the periodic table, equilibrium, acids and bases, and bonding. Here the only questions debated were manner of approach, sequence, and extent of treatment. There was extensive discussion among editors, contributors, and teachers who used the text in trial form about where in

Textbook Editor George C. Pimentel incorporates changes into the final edition of the text.

the text the treatment of bonding should come and how much nuclear chemistry and organic chemistry should be included. In the few cases where consensus was not reached after all the views were considered, the final decisions were made by the editor. A flow chart of the major ideas that were finally included may be found in Appendix G-2.

The following concepts were considered, but for the reasons given, were *not* included in the final edition.

(1) The quantitative use of colligative properties for determining molecular weights and for providing evidence for ionization was omitted, because ionization and molecular weights are adequately developed through other evidence. Omitting this concept also allowed the exclusion of molality, saving time for more fundamental ideas.

(2) The perfect gas equation, $PV = nRT$, was omitted because it is not particularly useful in developing other ideas included in the course. Instead, the pressure-volume, temperature-volume, and temperature-pressure relationships are presented and used in developing not only the kinetic theory of gas, but also the broader idea of the kinetic energy of molecules which is used in the study of reaction kinetics.

(3) In general, hard semantic differences were not emphasized. For example, the difference between weight and mass is not discussed because it was felt that the distinction would be of value only to the minority of students who subsequently take physics. Consequently, while still being consistent with common usage among chemists, the words "weight" and "weigh" are used throughout the text instead of "mass" and "determine the mass of."

(4) Lewis acid-base theory, although mentioned briefly in the preliminary editions, was omitted from the acid-base chapter of the final edition because no use was made of it later in the course. Furthermore, the structural concepts which would be necessary for an understanding of the theory were not developed until later chapters.

(5) Normality and equivalent weights are not discussed because it was felt that the beginning student has insufficient use for them. Problems in which these concepts might be useful are solved, instead, through use of balanced equations and the mole concept.

(6) The Bohr planetary model of the atom was omitted from the development of atomic theory because it is primarily of historical interest and is no longer useful to chemists. In addition, it was felt that because the planetary model is deceptively easy and intuitively satisfying, students could have difficulty later learning a model consistent with modern evidence of structure and quantum mechanics.

(7) Electronegativity was omitted because the relationship of its numerical values to charge distribution is not obvious. For the purposes of this course, it was felt that differences in ionization energy were sufficient to explain bond polarity.
(8) The Born-Haber cycle, included in the preliminary editions to analyze energy effects in bonding, was omitted from the final edition because the content needed pruning, and because it appeared that some students were drawing mistaken ideas about reaction mechanisms and bonding from it.
(9) Valence (as a noun) was not introduced because it has so many meanings. Instead, the terms ionic charge, oxidation number, bonding capacity, and coordination number are each introduced as needed. Likewise, the term electrovalence was not introduced because it is no longer generally used by chemists.

Some concepts and topics were not included originally, but were incorporated as the materials were revised.

(1) Detailed treatment of the combining volumes of gases was introduced to support atomic theory in Chapter 2, because it was felt that the original presentation of these topics was too arbitrary and authoritarian.
(2) Evidence for the existence and interaction of two kinds of electric charge was introduced in Chapter 5 to help students understand rudimentary atomic structure and properties of electrolytes.
(3) Discussion of the inert gases in Chapter 6 was modified to include the compounds of these elements that were discovered in 1962.
(4) The opposing drives toward low energy and toward randomness were used to explain solubility equilibria in Chapter 10.
(5) Additional discussion of nuclear reactions was included when it was noted that PSSC physics had ignored that topic.

Choice of Descriptive Chemistry

The choice of descriptive chemistry was made in order to emphasize the wide applicability of the chemical principles developed during the course and to demonstrate the dynamics of chemical reactions and the structural interpretation of properties. A few topics such as nuclear chemistry, biochemistry, and the chemistry of the earth, the planets, and the stars were added because they are currently glamorous. Other topics were included because they are particularly adaptable to laboratory investigation by the high school student.

To permit flexibility in the use of the material, while continuing to emphasize fundamentals, a variety of topics was included in the final one-third of the text. Because it is assumed that few classes will have time to cover all of the descriptive material in the text, a considerable amount of "descriptive chemistry" is also embodied in the chapter questions and problems throughout the book.

THE LABORATORY MANUAL

The laboratory program was designed (1) to help students gain a better idea of the nature of scientific investigation by emphasizing the "discovery approach," and (2) to give students an opportunity to observe chemical

Students discover scientific principles by organizing and interpreting data gathered in the laboratory.

systems and to gather data useful for the development of principles subsequently discussed in the text and classwork.

The laboratory manual is closely integrated with the textbook. Instructions require the student to use his observations and data to answer questions that are designed to check his understanding of the experiment. While the student does not design the approach or apparatus, he must become increasingly independent in organizing and interpreting data as the course proceeds. The importance of quantitative measurements in chemistry is made evident throughout the lab program. Listed below are some of the requirements for the experiments.

(1) Relevance of data produced to the course.

(2) Safety.

(3) Simplicity of procedure and apparatus needed.

(4) Adaptability to a 45 to 50-minute period length.

(5) Economy, both of money and of class time.

As changes in sequence and emphasis were made in the text during the trial years, the laboratory manual evolved correspondingly. New experiments were added, and some were deleted or made optional. Procedures were modified when trial use by both teachers and students showed changes to be necessary. The criterion of safety was apparently established even in the original preliminary lab manual. Through the fall of 1964, no serious accidents in completing experiments had been reported to the staff, although a few potential hazards were discovered and eliminated. The most serious hazard was not recognized until 1964, when the lab manual was in use by more than 100,000 students. It was pointed out that benzoyl peroxide could become explosive if slightly contaminated with moisture. The minute amounts used by students to initiate polymerization in optional Experiment 29a were not dangerous, but the material is too unstable for larger quantities to be stored in a high school laboratory. A notice was sent to all schools known to be using the lab manual in quantity, and a newsletter article warning of the hazard and suggesting substitution of a safe paste form of the reagent was also published.

All of the experiments were found to be adaptable to a class period of 45 to 50 minutes, provided the laboratory was available to the class on successive days so that unfinished experiments could be continued.

THE TEACHERS GUIDE

The objectives of the Teachers Guide and the nature of its content are well summarized in its preface:

> The theme of the Guide is support. The support is of a practical detailed nature for day to day use, plus background support to help in preparation and in giving a deeper understanding to your talented pupils. In addressing such a varied audience with this dual purpose, an important first decision is the level and intensity of approach. We adopted the plan of defining our audience as a lone teacher (isolated from other chemistry teachers) with somewhat less than ideal training, teaching in a poorly equipped school. We realize a majority of readers will not have all these problems—but it is relatively easy for them to skip what is not needed. It is quite difficult for the teacher in the situation described to supply something we omit.

The guide was written in time to be used during the second trial year. Its present content is based in large part on the needs for help expressed or implied by teachers during the trial years. Experience bore out the assumption that the guide, to be of maximum use to the teacher, must be immediately available and must have the material in explicit form for ready reference. The sheer volume of the guide prevents any teacher from using it as a minute-to-minute source of information during class, but it does provide accurate information when needed in a hurry.

Each chapter of the guide includes a brief statement of intent and approach, an outline of the text content, a list of new concepts to be presented, a suggested time schedule, a development amplifying (but not repeating) the content of the text, detailed instructions for preparation of the experiments and discussion of expected results, briefly annotated references to supplementary articles, books, and films, background discussion of the subject matter, all text exercises and problems worked out in detail, and suggested quiz questions.

Because the manner of classroom presentation implied by the CHEM Study approach differs substantially from the procedures to which many teachers are accustomed, the teachers guide is often explicitly directive about method as well as content. Although the staff knowingly assumed the risk that teachers might either react against the guide or lose initiative and become overdependent on it, neither of these untoward consequences occurred to any noticeable extent. On the contrary, teachers have been outspokenly enthusiastic in their comments about the guide, and there is ample evidence that the materials are being used imaginatively.

THE ACHIEVEMENT TESTS

Tests were prepared for the dual purposes of helping teachers evaluate student achievement and helping the Study evaluate the effectiveness of its materials and approach. Some samples from the tests are given in Appendix L.

Development of these special tests was considered important from the outset because the objectives, content, and emphasis of the CHEM Study course were quite different from those measured by tests that teachers were accustomed to preparing. In addition, the assumption that most teachers have neither the time nor the specialized skill needed to write good tests was verified when each participant in the first two summer institutes was asked to submit a few questions. Not only were a small percentage of these questions considered by the staff to reflect the objectives and content of the course adequately, but most measured only recall of isolated facts.

A multiple-choice format was chosen because of its adaptability and ease of scoring and analysis. Recognition that no single type of question could measure all the desired kinds of student achievement adequately led to the inclusion of additional suggested quiz questions of various types in the Teachers Guide.

The tests were designed to allow students to refer to their text, lab manual, notes, charts, etc. This provision was intended to continually impress students, teachers, and the test writers that simple recall of detailed factual information is not a major goal of the course. Questions that may be answered by rote memory or by simple definition are avoided. Instead, the questions attempt to measure whether a student can interpret experimental data and whether he understands significant concepts and can apply them to situations similar, but not identical, to ones he has previously encountered. A series of questions is often asked about a single system which had been previously described. The questions often require a student to choose the single incorrect response among four correct ones, thus requiring him to read as little misinformation as possible in the test.

The tests were initially designed to have an intended average raw score of 50%. For later series, including the two final published series, the intended average was raised to 60%, both for purposes of morale and in recognition that the expected peak random-answer score would be 20%. Early 45-minute tests included 35 questions, but experience showed that too many students did not finish, so the length was reduced to 30 questions. Each series consists of five tests covering three or four chapters each, a 50-question (two-part) semester final (Chapters 1–9) and a 50-question (two-part) end-of-course test (Chapters 1–17).

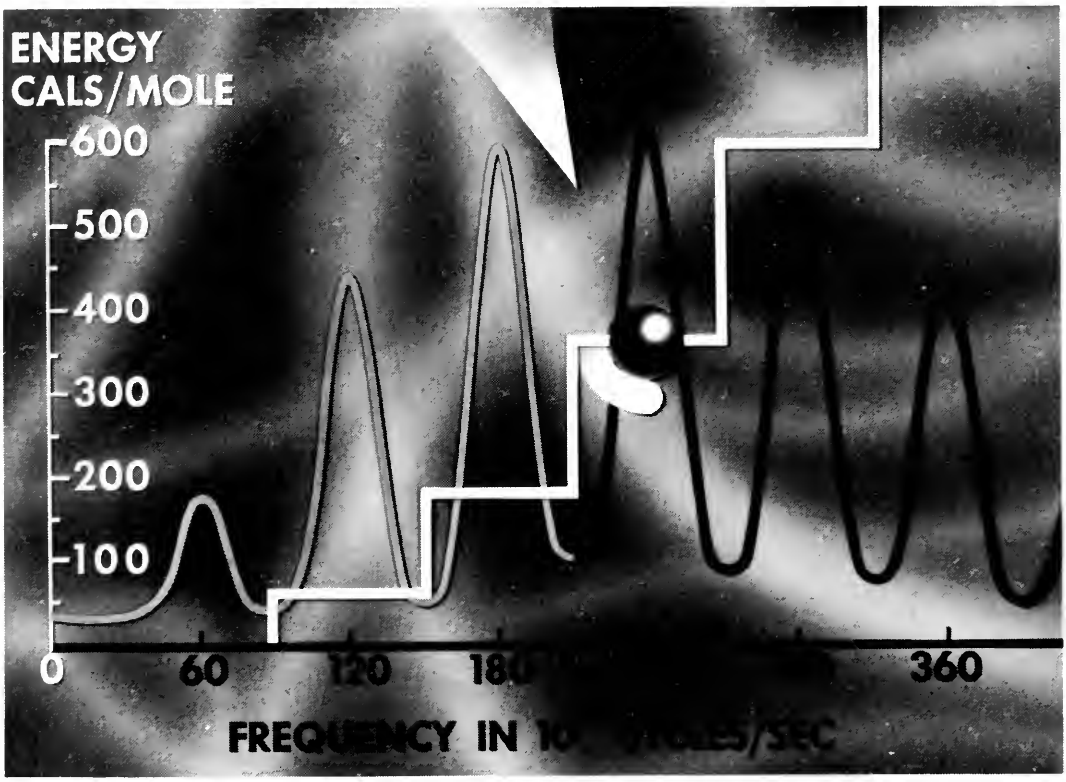
Item analyses were made to determine (1) difficulty, (2) distribution of responses, and (3) the "discrimination index" or biserial *r* correlation between a student's choice of any response and his comparative performance on the whole test. The mean, mode, standard deviation, and split-halves coefficient of reliability were also determined for each test. The general results showed that tests were somewhat more difficult than intended, and therefore had to be revised and made easier.

OTHER PRINTED MATERIAL

Two self-help instruction pamphlets, *A Programmed Sequence on the Slide Rule* and *A Programmed Sequence on Exponential Notation*, were developed in response to teachers' reports during the first trial year that their students were deficient in these mathematical skills. The pamphlets are designed as remedial, single-track programs to develop the skills needed in manipulating numbers. Serious consideration was also given to the possibility of developing a series of supplementary monographs. Because a number of monograph series were already in production or projected by various publishers, it was decided that the Study would not undertake such a project. Instead, a more passive role of suggesting appropriate topics and encouraging independent authors to write monographs was assumed. By the summer of 1965, two books, Glenn T. Seaborg's *Man-Made Transuranium Elements* and J. Arthur Campbell's *Why Do Chemical Reactions Occur?*, had been written as extensions of the CHEM Study course materials; both were published by Prentice-Hall.

THE FILMS (C)

Early in the project it was decided that films should be made available that could effectively show experiments and present concepts that the teacher would find difficult or impossible to demonstrate in the classroom. In many cases, it was desirable to introduce experimental evidence through film demonstrations for experiments that are too elaborate, expensive, time consuming, dangerous, or otherwise impractical for the teacher or students to perform. Examples of such experimental evidence and the films in which they are presented are the combining volumes of gases (*Gases and How They Combine*), family similarities in reactions of elements (*Chemical Families*), and measurement of ionization energies (*Ionization Energy*). In other cases, animation has proved to be an extremely valuable way to present and aid the understanding of difficult concepts.



Animation is used to present and aid the understanding of molecular spectroscopy.

Reaction mechanisms (*Introduction to Reaction Kinetics; Catalysis; Mechanism of an Organic Reaction*) and structure and bonding (*The Hydrogen Atom—As Viewed By Quantum Mechanics* [*advanced and standard versions*]; *Chemical Bonding*) are topics in which animation is effectively used. To help convey the nature and excitement of research, sometimes prominent scientists are shown at work (*A Research Problem: Inert (?) Gas Compounds; Vanadium—A Transition Element; Crystals and their Structures; Molecular Spectroscopy; Transuranium Elements*). In other cases (*Equilibrium*), it was decided that the viewer's attention could be better focused on the subject matter with less distraction if no on-screen personality appeared.

In general, the same criteria were used in choosing content for the films as were used for the text and laboratory manual. Each film is designed to be closely integrated with the course, and is intended to be used to supplement the text and lab manual at a specific point. Some films are primarily designed to save class time by clarifying difficult ideas that are central to the course. Others are intended to enrich the course by exploring subject matter which, while not essential to the mainstream of the course, is nevertheless enlightening. Examples of "mainstream" films are *Electric Interactions in Chemistry; Chemical Families; Equilibrium; Chemical Bonding.* Examples of "enrichment" films are *Synthesis of an Organic Compound; Bromine—Element from the Sea; Biochemistry and Molecular Structure.*

In a few cases, film content was suggested or modified by significant events which occurred while the project was underway. One such event was the first synthesis of compounds of some of the inert gases in 1962. The film *Chemical Families* in which the inertness of these gases is used as evidence in establishing the periodic relationship of chemical properties had just been completed. One statement in the narration was deleted and a section was added to the film to show several of the new inert gas compounds and their reactions. The point was made that as research continues, new information may modify our ideas, or it may support them as in this case where the original concept of chemical families was, if anything, strengthened by the new development.

The new inert-gas research also affected the Study's plans for a film on low-temperature chemistry. The presence of a British chemist who was engaged in cryogenic research at the University of California offered a unique opportunity to introduce an international flavor as well as to convey the nature and excitement of research in the film *A Research Problem: Inert (?) Gas Compounds.* Current developments in high-temperature chemistry and in cancer research also provided appropriate subject matter for the films, *High-Temperature Research* and *Biochemistry and Molecular Structure.*

Before producing new films, existing chemistry films were reviewed in hopes of finding either whole films or portions that could be used. In most cases, the films reviewed were either technically inadequate or outdated, differed substantially in content and emphasis from what was desired for CHEM Study, or included too much advertising. In cases where small amounts of footage were deemed usable, it was considered easier to produce new footage than to obtain rights to the existing material. In one case, however, two existing films, *Vibration of Molecules* and

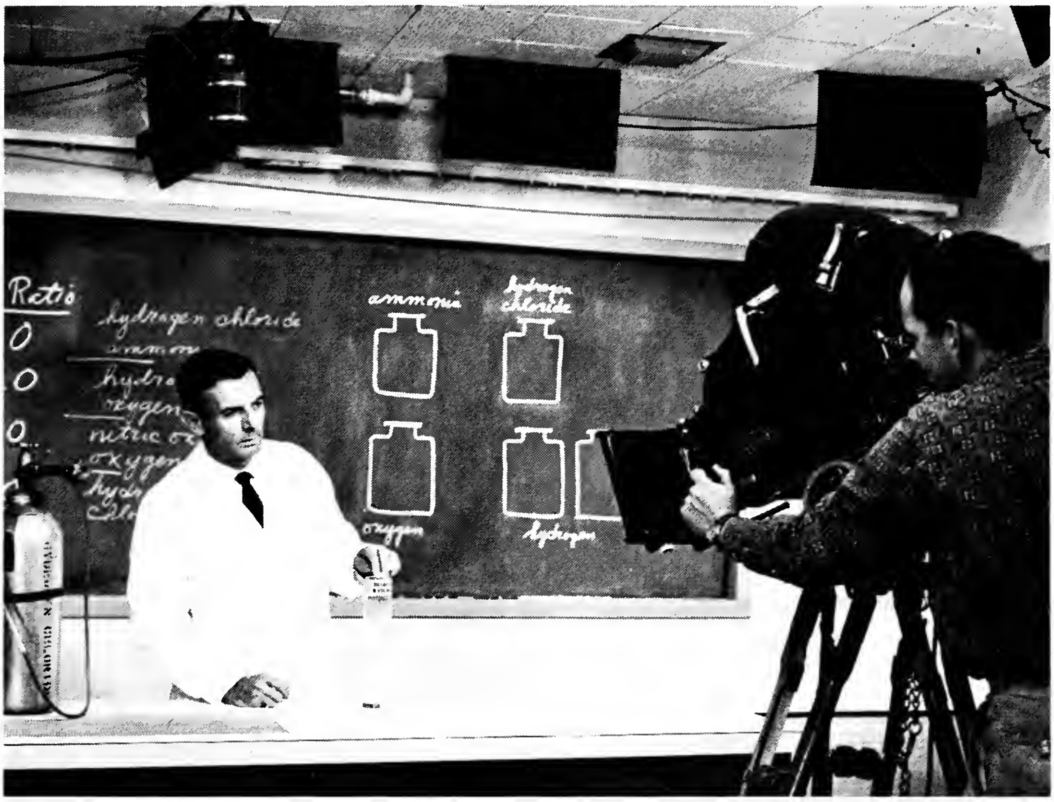
An Introduction to Reaction Kinetics, recently produced by the American Chemical Society, were adopted and made a part of the CHEM Study film series by the purchase of nonexclusive rights to them. Two others, *Catalysis* and *Nitric Acid*, were produced by CHEM Study in cooperation with the Manufacturing Chemists' Association.

The length of the films was influenced by considering the classroom situations in which they were expected to be used. In every case, decisions had to be made as to how many concepts should be presented and to what depth they should be developed. Judgments often had to be made as to whether including additional ideas or going into greater depth would increase the value of a film, or blunt its impact by distracting students from the fundamental points presented. In one instance, the problem was solved by producing two versions, standard and advanced, of *The Hydrogen Atom—As Viewed by Quantum Mechanics.* By purposely limiting the number of ideas presented in each of the films in the series, the maximum length was held to 24 minutes. This time limit permits pre- and post-showing discussions that enhance the effectiveness of the film whether it is used in conjunction with the CHEM Study course or in some other context.

The total number of films to be included in the series was initially limited to 40. This took into account the limited time available for showing films in the high school course and the experience of the Physical Science Study Committee. It was learned that schools using the PSSC films (most of which were somewhat longer than the CHEM Study films) showed an average of 15 films per year. Using this information as a guide, it was decided that the number of films finally produced would be determined by the number of places in the course where supporting films seemed most needed. Some initially suggested films on such subjects as the candle and equilibrium constants were not made because they did not seem necessary or because their subject matter was incorporated into other films. Determination of both the length of the individual films and the number in the series was felt to be consistent with the intended use of the films—as instructional tools rather than as substitutes for the teacher.

Once the main film series was complete, the Study produced a few filmstrips based on the motion pictures and then experimented with adapting portions of several of the films into silent "single-concept" loop films. The few filmstrips and film loops that were produced were well received by the teachers who used and evaluated them. Rather than to begin another major project, however, it was decided to leave the possible further development of these promising supplementary teaching aids to commercial producers who might become interested in them.

Among CHEM Study's later activities was the development of some audiovisual aids for teacher education. In 1964, two half-hour lectures by Professor Pimentel were filmed, one on the structure of the hydrogen



Professor Pimentel explains the structure of the hydrogen atom in a half-hour filmed lecture developed for a special teacher-training program.

atom and one on chemical bonding. In 1965–66, CHEM Study materials were widely adopted in the city and county of Los Angeles. Many of the teachers had been unable to attend CHEM Study institutes, yet they were called upon to teach the CHEM Study program. To aid in training these teachers, a series of 13 brief lectures was developed and televised with J. Arthur Campbell, George C. Pimentel, Henry Rapoport, and Richard J. Merrill participating on behalf of CHEM Study. In addition, two half-hour televised panel discussions provided an opportunity for an exchange of ideas between the CHEM Study staff and the high school teachers. The televised programs were transferred to 16mm film. These, combined with the two Pimentel lecture films, constitute the CHEM Study teacher-training series, which was made available for purchase or rental.

CHANGES IN RESPONSE TO FEEDBACK

As described earlier, the Study went to great lengths to gather and evaluate feedback from the teachers and students who used the materials during the trial years. Summaries of the proceedings of two of the major evaluative sessions are included in Appendices K and M. Some of the more significant difficulties reported are given below, along with the steps taken to alleviate them.

(1) An almost universal problem, or symptom perhaps, was the slow rate of progress through the first five or six chapters. This appeared to be partly due to the unavoidable process of adjustment, by both teachers and students, to a new kind of teaching and learning. Nevertheless, real attempts were made to reduce the number of new concepts introduced in this initial overview. The metric system was moved to an appendix. Rules for systematic naming of inorganic compounds were deleted. Less emphasis was placed on the gas laws. Much of the early discussion of types of solids was postponed until Chapter 17. Treatment of hydration of ions was delayed until Chapters 11 and 17. Discussion of rotational and vibrational energy of molecules was shifted to Chapter 7. A laboratory exercise in construction of molecular models was dropped. On the other hand, because it was discovered that students had difficulty understanding uncertainty in measurements, considerably more information on this subject was added both to Chapter 1 and to an appendix.

(2) Many teachers felt that the initial presentation of atomic theory and structure in the early chapters was too dogmatic. Therefore, combining volumes evidence was introduced and interpreted in text, and the film *Gases and How They Combine* was produced. Likewise, experimental evidence for the existence and behavior of electric charges was introduced before the discussion of the electron-proton model of the atom.

(3) Reported student deficiencies in mathematical skills led to the development of two self-instruction pamphlets, *A Programmed Sequence on Exponential Notation* and *A Programmed Sequence on the Slide Rule.*

(4) Some teachers pointed out the need for some "drill" or at least some opportunity to make immediate application of concepts as

they are introduced. As a result, the number of exercises in the body of the text was considerably increased, the questions at the ends of chapters were revised, and suggested quiz questions were developed.

(5) General problems with reading difficulty and vocabulary were reported but were hard to reduce to specifics. Review sections were added to some chapters. A glossary was not added, lest students revert to old habits of memorizing definitions rather than trying to understand ideas. Instead, new terms, formulas, etc., were carefully programmed into the text to help students understand terms by using them.

(6) It was felt that the qualitative idea of entropy, introduced by analogy in Chapter 9, should either be used further or be omitted. Further use of the concept in Chapter 10, in explaining solubility equilibria, resulted.

(7) Suggestions that industrial processes should not be completely ignored led to the use of processes for manufacture of sulfuric acid as examples of chemical calculations in Chapter 13 and the production of the film *Bromine—Element from the Sea*. Many end-of-chapter problems involving industrial processes were also added.

(8) General difficulties with the acid-base chapter led to extensive revisions in the treatment of that subject. The concept of the strength of electrolytes was more clearly developed, and the brief discussions of non-aqueous acids and Lewis acid-base theory were dropped.

(9) Relatively minor changes were made in most of the experimental procedures as difficulties in the classroom were reported. Two experiments in solubility were eliminated, several of the original experiments were made optional, and two new ones (10 and 16) were added.

(10) Tests were revised as statistical analysis and teachers' comments identified certain items as too difficult, ambiguous, or poor in discrimination.

(11) Specific criticisms of the films were handled, where possible, in the teachers guide. In two instances, changes were made in the films themselves.

In a sense, the entire Teachers Guide was a result of feedback from teachers. Changes in the Teachers Guide that originated from teachers' suggestions are far too numerous to specify. Since it was not subject to the textbook's limitations of length and depth of treatment, the Teachers Guide could include almost anything that would be reasonably useful to the teacher in conducting the course.

A final noteworthy point about feedback is that most of it was positive. While most of the trial teachers were not reticent about offering specific criticisms, they generally responded with enthusiasm, approval, and appreciation for what had been done. For this reason the basic structure, philosophy, and style of the materials were refined but not fundamentally

Teachers and students helped evaluate the laboratory material. (Pictured here are Joseph E. Davis, Jr., and students at Claremont High School.)

altered as the project moved ahead. In addition, it can surely be said that the teachers' and students' sustained enthusiasm spurred the staff and contributors on to greater efforts.

DISSEMINATION OF INFORMATION

Widespread interest in the work of the Study prompted a sustained effort to disseminate information about it. Display cases were made and shipped, on request, to conferences of science teachers. Speakers were provided for such conferences, and for summer institutes requesting them. A 20-minute "newsreel" film for the purpose of presenting basic information about the project was completed late in 1961 and used extensively.* Sample sets of each trial edition of the course materials were made available for purchase, and in some cases were made available without charge, particularly to summer institute participants. The volume of outgoing correspondence (not including multiple copies of form letters) in late 1962 exceeded 400 letters per month, a considerable portion of them being in response to requests for information.

The NEWSLETTER was started in November 1960, and was issued seven times during the following two years. By 1963, the frantic pace of activities had moderated sufficiently that one or two issues per year sufficed. The first issue (November 1960) and the issue (January 1963) announcing the publication of the course materials in hardback form were sent to all United States high schools on general mailing lists as well as to those individuals from whom the staff had received specific inquiries. By late 1963 the NEWSLETTER mailing list had grown to about 15,000 names, and the process of mimeographing, sorting, and affixing labels by hand had become entirely unwieldy. The list was, of necessity, transferred to an automatic addressing system, which because of its efficiency and ultimate economy, should have been used much sooner.

PERSONNEL AND FACILITIES

Following the report of the Garrett committee (E), the first step in the formation of CHEM Study was the organization of a Steering Committee.

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* Two new films, *CHEM Study—Information for Educators* and *A Chance to Wonder Why*, to serve this purpose were completed early in 1966.

This task was undertaken by Dr. Glenn T. Seaborg, who at that time was Chancellor of the University of California, Berkeley, and Professor J. Arthur Campbell, Chairman of the Department of Chemistry, Harvey Mudd College, Claremont, California.* The original membership (A-1) included prominent educators, chemists from universities and industry, a Regent of the University of California, and representatives of the publishing and educational film industries.

In February 1960, shortly after the first Steering Committee meeting, an invitation (H) was sent to about two dozen chemists known for the high quality of their accomplishments as high school teachers, university teachers, research chemists, and writers. This group participated in the planning session (I) in April 1960, and in the writing sessions during the summers of 1960 and 1961. Several of these persons also served the Study on a full-time or part-time basis during 1960–63 in various editorial and administrative capacities. The high school contributors also served as trial teachers during this period.

Professor George C. Pimentel of the University of California, Berkeley, joined the original staff as Assistant Director and Editor of the textbook. He also assumed the responsibilities of principal investigator (chief responsible officer for the project at the University of California) when Dr. Glenn T. Seaborg left Berkeley to become Chairman of the Atomic Energy Commission. (Pimentel also took over as Director when Campbell went abroad in 1963.) Professor Lloyd E. Malm† of the University of Utah became Assistant Director and Editor of the laboratory manual. Dr. Aubrey L. McClellan, a senior research chemist with Chevron Research Corporation, joined the Study in September 1960 as Editor of the Teachers Guide.

During 1960–66, the staff varied in size and in composition according to the availability of persons and the nature of the tasks. A list of the members and their principal duties is given in Appendix A. A staff of film specialists (A-2) was also assembled.‡

In June 1962, Dr. Richard J. Merrill was chosen from the 1961–62 trial teachers to be Executive Director. Most of the generation and tryout

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* Following his appointment as chairman of the Atomic Energy Commission, Dr. Seaborg continued as Chairman of the Steering Committee. Professor Campbell served as Director of the Study through August 1963.

† Professor Malm died in Salt Lake City, May 25, 1966.

‡ Most of these people went on to other jobs as the major part of the film program neared completion in 1963.

of new materials was then reaching its culmination, and administration, dissemination of information, and long-term evaluation became important continuing activities of the Study. By contracting on a short-term basis for the services of writers, film production and book publishing specialists, film collaborators, speakers, and other consultants, the staff was kept relatively small and could concentrate on holding the entire project together and moving it ahead.

Mr. David W. Ridgway, a film producer who had worked with Encyclopædia Britannica Films, Inc., in the production of many science films, was chosen to direct CHEM Study's film program. As well as contributing directly to the artistic quality of the films, he was instrumental in selecting other film specialists for the staff and qualified commercial firms for the production work. He was also able to facilitate communication between scientists and film technicians. Because he was not a scientist, he could, by asking incisive questions, help insure that the concepts presented in the films would be clear to the intended audience.

The Study's decision to utilize the services and facilities of existing commercial film production firms was based on several considerations. The temporary nature of the project and the limited number of films to be produced, made building a large organization and investing a great deal of time and money in equipment and facilities unwise. It was also foreseen that collaborators from various universities located in various parts of the country would be engaged to bring specialized scientific knowledge to specific films. Since they would need to be directly involved in making the films, it became apparent that it would save time and money, and in general be more efficient, to have the production work done at locations convenient to the collaborators. One room at Harvey Mudd College was converted into a temporary studio at minor expense for experimentation and shooting of films that primarily involved the resident staff.

The problem of finding script writers for the CHEM Study films was not easily solved. Extensive investigation was made of commercial film producers all over the country. Script writers with sufficient knowledge of chemistry and the nature of science were simply not to be found on the staffs of such film production organizations. It was finally decided to add two more chemists and two more film specialists to the staff in 1961–63. The development of scripts followed no standardized pattern. The major responsibility for generating a script was usually assigned to one individual, but flexibility was maintained and in each script the creative efforts of several chemists and film specialists were combined with those of the collaborator.

The quality of secretarial and clerical assistance to the Study has been of vital significance. From its outset, the project has been characterized by almost unbelievably rapid production of materials and very efficient communication. This was due in large part to the skill and dedication of secretaries and typists (A-5) who sensed the importance of the project and were willing and able to type, proofread, wield a stapler, and care for innumerable details long after 5:00 P.M.

III

Production, publication, and distribution

As soon as it became clear that the Study would result in publication of a textbook, a laboratory manual, and a teachers guide, several significant decisions were made by the Steering Committee. They decided that all copyrights, the complete control of content, and the ultimate disposition of publishing rights would remain with the Regents of the University of California, the principal recipient of the NSF grant. In this sense, CHEM Study would act as its own publisher. At the same time, however, it was realized that the services of a professional publisher would be needed in such matters as copy editing, designing, book manufacturing, warehousing, distributing, and billing.

Publishers were invited to submit bids, and on the basis of bids received, W. H. Freeman and Company of San Francisco was selected as the "cooperating publisher" for a period of five years. Under the terms of the original contract, CHEM Study paid for the production of the books and paid the publisher a fee for warehousing and handling them. Receipts from the sales of the books were turned over to the University of California. Funds not needed for reprinting were returned to the National Science Foundation, and ultimately to the United States Treasury. The prices of the text and the laboratory manual were established at the average value for such materials on the market in 1961–62, so that the normal competitive market would not be upset. The editors and contributors were paid a salary for their services, but received no royalties from the published materials. Early in 1966, by common agreement with the University, the publisher, and NSF, the contract for publication was amended to transfer the responsibility for financing and arranging reprintings of the textbook, laboratory manual, and teachers guide to the publisher. This was done to eliminate the need for the University to maintain a revolving fund of income to finance reprintings, to simplify the process of arranging for reprintings, and to permit reduction of the continuing functions of the CHEM Study staff to an absolute minimum.

The rather unorthodox author-publisher relationship was prompted for two reasons. First, the Study felt that its goal of improving the teaching of high school chemistry could best be served if the course materials were published in the exact form decided upon by the Study, without being influenced by how popular the books might be. Thus, while it was intended that the CHEM Study materials be appropriate for use by most students who normally take high school chemistry, no attempt was made to make the book "all things to all teachers." Instead, it was hoped that the materials would serve as a model to be considered by other authors and publishers in developing new materials.

The second reason for this publishing arrangement was to assure that a very liberal policy would be maintained in granting permission to other authors to use and adapt portions of the course materials. When such permission was granted, the Study did not attempt to control or endorse the new materials, but merely required that the use or adaptation was professionally responsible and involved a creative contribution. In its five-year agreement with the publisher, CHEM Study retained the right to dispose of the publishing rights at the end of that period by any of several means, including the possibility of placing the materials in the public domain.

CHEM Study's experience in negotiating its publication and distribution agreements underlines the importance of *starting early* in such matters. The Steering Committee made the basic decisions about publishing in July 1960, before the first preliminary edition had even been drafted. A notice to publishers was sent out in October 1960. Following further deliberation by the Steering Committee, bids were invited in May 1961. On the basis of bids received in June 1961, negotiations with W. H.

Freeman and Company began in July, culminating in the signing of the publishing contract in July 1962, a full year later. In addition to the staffs of CHEM Study and of W. H. Freeman and Company, direct negotiations necessarily involved representatives of the University business office and legal staff. Continuous communication was maintained with representatives of NSF, who reviewed and approved this contract and each of the other publishing and distribution agreements.

An essential ingredient was good faith on the part of all concerned. Once it became clear that no major difficulties would arise, the publisher cooperated fully in proceeding with the more urgent preliminary tasks of publication before the contract was actually executed. This sort of cooperation continued as arrangements for reprintings often had to be made before the contract amendments providing for them had been fully executed. In every case, however, verbal agreement was reached regarding the essentials before any irreversible steps were taken.

More conventional arrangements for publishing the tests and programmed sequences were negotiated directly with W. H. Freeman and Company. For these smaller items the convenience to users in being able to order all of the materials from the same publisher was felt to be the prime consideration. CHEM Study receives a small royalty (for transmittal to the Government) on the programmed materials. The tests are not considered to be a competitive item; therefore, in order to keep the cost to users as low as possible, no royalties are collected.

Of the many manufacturers of scientific apparatus invited to cooperate in producing charts and special equipment, only the Welch Scientific Company and Central Scientific Company initially expressed any sustained interest. Both firms produce and distribute several charts which are based on the textbook. These materials are copyrighted by the Regents of the University, but their content is, for all practical purposes, in the public domain. No control over their distribution is exercised by the Study, and no royalty is collected.

Film production was normally accomplished under a standard contract. One serious contractual problem did arise in connection with the two films financed jointly by CHEM Study and the Manufacturing Chemists' Association. The contract with the producer provided that, "If changes are requested by CHEM Study, the cost of these changes will be paid by CHEM Study." Serious misunderstanding resulted, and protracted negotiations continued long after the films were completed. This could have been avoided had the contract included a provision defining what constitutes "changes," and specifying that charges for such changes would have to be agreed upon in writing in advance.

The process of selecting a film distributor began in the fall of 1961, when a survey was made of all available lists of film distributors in the United States. Consideration had previously been given to the possibility of placing all of the filmed materials in public domain. This would have allowed any organization or individual to reproduce the materials, excerpt them, use sections out of context, or even use them for advertising purposes. There would have been no control over the use of the materials. The use of nonexclusive distribution methods was also considered, but rejected because it was realized that a nonexclusive distributor would have little incentive to conduct previews, service prints, or display at meetings, and could not even be required to guarantee service to users.

Therefore, in December 1961, 36 film distributors were contacted by letter to determine their interest in distributing the CHEM Study films. Thirteen organizations expressed interest and were then asked to provide specific information about their abilities, functions, and facilities. These replies provided a list of ten firms interested and capable, in varying degrees, of handling the task.

On April 28, 1962, the Steering Committee considered criteria for the selection of the best organization and selected three firms for final consideration. The criteria provided that the firm selected must have had experience in the sale and rental of films on a national basis. Proposed prices to users for sales and rentals were compared, as were proposed methods of giving publicity to the films. Whether the companies considered had competing chemistry films was also a factor. Evidence of ability to provide consistently satisfactory service was given heavy weight in the final selection. After several months of negotiating, writing, and rewriting, a five-year contract was made with Modern Learning Aids, a division of Modern Talking Pictures, Incorporated.

UTILIZATION IN OTHER COUNTRIES

Since its beginning in 1960, the work of CHEM Study has been the object of considerable interest to chemists and educators in other countries. For the first three years, the staff dispensed information freely in response to numerous requests, but deferred consideration of requests for permission to translate until the course materials were published in definitive form. Mindful that its materials and general approach would not necessarily meet the needs or fit the organization of foreign educational systems, the Study has not taken the initiative in matters of foreign utilization.

By 1965, the English language edition of course materials was being used in many parts of Canada, India, New Zealand, and Australia. In India, the Study authorized the production of an inexpensive offset edition of its course materials by the National Council of Educational Research and Training. This edition was partially funded by the United States Department of State.

In authorizing translations, the Study has moved with considerable deliberation and caution. In every case it has sought assurance that sufficient demand exists among scientists and educators to warrant a translation, and that the translations produced will be accurate, of good literary quality, and readily available to prospective users. To date, all arrangements for foreign translation and publication have been made on a nonexclusive, limited-time basis.

Through December 1968, the Study had authorized the following translations:

Chinese (text, laboratory manual, teachers guide, tests), Ministry of Education, Taipei, Taiwan, Republic of China.

French (text, laboratory manual, teachers guide, tests), Centre de Psychologie et de Pedagogie, Montreal, Canada.

Gujarati (text), Translation Trust, Gandhi Smriti, Bbhavnagar-1 (Gujarat), India.

Hebrew (text, laboratory manual), The Weizmann Institute, Rehovoth, Israel.

Hindi (text, teachers guide, laboratory manual), Madan Mahal General Stores, Raipur, India.

Italian (adaptation of portions of the text and laboratory manual), OECD—Ministry of Public Instruction (Prof. A. Liberti), Istituto de Chimica Analitica, Universita di Napoli, Naples, Italy.

Japanese (text, laboratory manual), Kyoritsu Shuppan Co., Ltd., 7, Sangen-cho, Bunkyo-ku, Tokyo, Japan.

Korean (text, laboratory manual, teachers guide), Tamgu Dang Publishing Co., 36-2, Kyun Ji-Dong, Chongro-Ku, Seoul, Korea.

Portuguese (text), Fundacao Calouste Gulbenkian, Lisbon, Portugal; (text, laboratory manual), IBECC (UNESCO), Instituto Brasiliero de Educacao, Ciencia e Cultura, Sao Paulo, Brazil.

Spanish (text, laboratory manual, teachers guide), San Magin 26, Barcelona-6, Spain and Editorial Reverté, S.A., Panuco 141-A, Mexico 5, D.F.; (programmed sequences), Departamento de Instruccion, Ponce, Puerto Rico.

Thai (text, laboratory manual), Science Society of Thailand, Chulalongkorn University, Bangkok, Thailand.

Turkish (text, laboratory manual, teachers guide, tests), The Ford Foundation, Mithatpasa Cadclesi 63/1, Yenisehir, Ankara, Turkey.

A Russian translation of the CHEM Study text appeared in 1968. It had not been authorized. Its preface contained the following statements:

> "The book is distinguished for its teachability, rigor, and orderly presentation. It is the first time in the history of scientific literature that difficult concepts of genetics and thermodynamics are presented so simply and so clearly, thanks to the excellent examples and illustrations.
>
> "We are hoping that this book we are offering the reader, translated into Russian at the recommendation of the greatest scientists of the Academy of Science of the USSR and the Academy of Pedagogic Sciences of the RSFSR, will be of great use for improvements in our learning process, and further accomplishments."

Since English has become widely accepted as a science language, CHEM Study films are often used internationally in their English versions, although many have been translated into foreign tongues. Spanish translations of twenty of the CHEM Study films were completed in 1965 and 1966 by the Regional Technical Aids Center (RTAC), a part of the United States Department of State located in Mexico City. As of December 1968, this agency was proceeding to translate the remaining six films.

Also during 1966–1967 the following number of film translations was completed under the aegis of the Organization for Economic Cooperation and Development (OECD), Paris: Danish (2); French (5); German (5); Swedish (7). In addition, during 1967 Esso Standard Italiana of Rome financed the translation of ten CHEM Study films into Italian. These are distributed on loan as a public service by Esso Standard Italiana, or will be sold on a nonprofit basis in Italy.

In every instance where films were translated, assurance was required that the narrations be fluent and scientifically accurate. Furthermore, evidence was required that educational or national authorities in the requesting countries desired the films. The translations were always made by nationals of the requesting country and were checked independently by chemists whose native language was the language of the translation.

IV

Evaluation

A great deal of operational evaluative information was gathered by CHEM Study during its first three years. The means by which much of the information was gathered, and the uses to which it was put in revising the materials, are described in Chapter 2 of this book. A major concern during these trial years was whether the CHEM Study materials were appropriate for "average" chemistry students as well as for exceptionally bright students.

A series of SCAT (School and College Ability Tests) was given to students in trial classes during 1960–62. As was expected, these tests substantiated general observations which had been made by others before, that most of the students who select high school chemistry are in the upper half of the general school population in ability. Comparisons were then made between SCAT scores of the tested students and scores of the same students on CHEM Study achievement tests. To some it may have been a surprise that there was little correlation between the two. Actually, within this sample the measured correlation between SCAT scores and the scores of the CHEM Study achievement tests was +0.5, a rather low correlation. It was observed that students receiving high SCAT scores in a significant number of instances received relatively low scores on the

Table 4-I *Ability and achievement questionnaire*

	Choices and per cent responding		
1. The expected ability range of students in my CHEM Study group is ________ average for chemistry students in my school.	*Above*	*At*	*Below*
Total group (N = 379)	28	67	5
2. My students' achievement, in terms of CHEM Study goals, has been generally ________.	*Excellent*	*Good*	*Inadequate*
Total group (N = 373)	22	74	4
Subgroup A: Teachers using the course for the second or third time (N = 74)	26	69	5
Subgroup B: Teachers using the course for the first time (N = 299)	21	75	3
Subgroup B-1: First-time users with CHEM Study Summer Institute (N = 133)	22	76	2
Subgroup B-2: First-time users indicating self-study of materials as only preparation (N = 86)	18	80	2
Subgroup C: Teachers reporting students' ability range *below* average for chemistry students in their schools (N = 18)	0	72	28
3. My students' achievement in satisfying me has been generally ________ than that of comparable students in conventional classes I have taught.	*Better*	*About same*	*Poorer*
Total group (N = 360)	69	26	5
Subgroup A (N = 72)	75	22	3
Subgroup B (N = 289)	68	27	6
Subgroup B-1 (N = 132)	65	33	2
Subgroup B-2 (N = 84)	68	27	5
Subgroup C (N = 18)	33	55	11
4. My students' interest and enthusiasm have been generally ________ than those of comparable students in conventional classes.	*Higher*	*About same*	*Poorer*
Total group (N = 366)	77	20	3
Subgroup A (N = 73)	75	22	3
Subgroup B (N = 293)	77	20	3
Subgroup B-1 (N = 133)	84	14	2
Subgroup B-2 (N = 91)	75	23	2
Subgroup C (N = 17)	41	47	12
5. As compared with conventional classes having comparable students, the drop-out rate in my CHEM Study classes has been ________.	*Higher*	*About same**	*Lower*
Total group (N = 367)	8	62	30
Subgroup A (N = 71)	8	59	32
Subgroup B (N = 296)	8	62	30
Subgroup B-1 (N = 128)	9	55	37
Subgroup B-2 (N = 89)	9	63	28
Subgroup C (N = 15)	7	67	27

* These figures include a substantial percentage of responses to the effect that no drop-outs were permitted from any chemistry classes.

CHEM Study exams. Conversely, some students who did not do well in the SCAT tests received quite high CHEM Study grades. None of the comparisons indicated that the course was disproportionately difficult for chemistry students who have average or below average ability as measured by SCAT tests.

In January 1963, a questionnaire was sent to all the approximately seven hundred teachers who were then using the CHEM Study materials in quantity. The survey was designed chiefly to gather further evidence on the question of appropriateness, and also to learn whether teachers who had not received specialized institute preparation in the use of the materials were experiencing any unusual difficulties. The items and percentage distribution of the 390 teachers who responded are shown in Table 4-I.

These responses are rather subjective, and perhaps the only point they conclusively establish is that the great majority of responding teachers who tried CHEM Study that year liked the program. Even such a seemingly objective measure as lower drop-out rates may reflect the "Hawthorne effect," which tends to color the results whenever people know they are part of an experimental program. Nevertheless, the data in Table 4-I certainly suggest that the course is not completely over the heads of poorer chemistry students, and that they may well be learning more than they would have learned in a conventional class. For the average and above-average chemistry students, there is every reason to believe that the approach and materials are stimulating and appropriate.

The same 1963 questionnaire also asked teachers, "On the basis of your experience with CHEM Study, what do you consider to be areas in which your preparation has been marginal or inadequate?" The following areas were mentioned by the number of teachers indicated:

Physical chemistry	83
Mathematics	34
Thermodynamics	33
Equilibrium	27
Reaction kinetics	17
Bonding	16
Atomic structure	12
Electrochemistry	12
Philosophy and approach	9

Many of the teachers who mentioned mathematics specified calculus and indicated that it was needed to understand some of the background material discussed in the Teachers Guide. Few teachers reported serious problems, and many stated that summer institutes, self-study, and reference to the teachers guide had helped them, at least partly, to overcome their deficiencies.

Results of the first two 1962–63 achievement tests showed no significant differences between the average scores of students whose teachers had received specific CHEM Study summer institute preparation and students of teachers whose only special preparation was independent study of the course materials. A difference of one to three points did appear, however, in favor of students whose teachers had taught the CHEM Study program for at least one year.

The foregoing evidence of achievement test performance and high teacher enthusiasm, coupled with the increasingly extensive adoption of the materials, encourage the belief that the course materials are effectively usable by good teachers with or without special institute training.

Another presumed measure of the appropriateness of the course is its effect on enrollments in chemistry courses and post-chemistry science

Table 4-II

Percentages of students taking science courses, 1961–1965 (grades 10–12, 267 schools, average total enrollment 325,000)

	1961–62	*1962–63*	*1963–64*	*1964–65*
Students taking chemistry	13.2	13.6	13.6	13.3
Chemistry students taking CHEM Study (in schools having some CHEM Study classes)	44.0	47.3	59.6	66.9
Students taking biology	27.8	28.1	26.9	26.7
Biology students taking BSCS (in schools that had some BSCS classes)	37.0	36.3	40.4	63.6
Students taking physics	6.4	6.1	6.4	6.4
Physics students taking PSSC (in schools that had some PSSC classes)	67.4	71.2	73.4	73.3
Students taking a post-chemistry science course other than physics (advanced biology, chemistry, physics, and physiology were most frequently mentioned)	1.4	1.6	1.7	2.1

courses over a period of years. In the fall of 1964, a survey to gather information about enrollment trends was made of all high schools (some 700) that had used the materials for two full years or more. About half the schools responded, and usable data were received from 267 schools, whose grades 10–12 enrollment in 1964–65 totaled 358,000.

Table 4-II summarizes the information gathered in this survey in terms of percentages of students enrolled in grades 10–12. During 1961–64 the percentage of chemistry students taking CHEM Study in these schools rose steadily from 44% to 67%. These figures suggest a pattern of initial introduction of the materials to a few classes—perhaps specially selected ones—followed by a spreading of use to more and more classes in a given school.

Table 4-III indicates that percentage enrollments in biology, chemistry,

Table 4-III
100% CHEM Study, 1961–1965 (109 schools)

	1961–62	*1962–63*	*1963–64*	*1964–65*
Students taking chemistry	11.6	12.2	12.3	12.1
Students taking biology	30.4	29.2	28.0	27.8
Students taking physics	5.6	5.0	5.3	5.6
Students taking post-chemistry science courses other than physics	1.3	1.6	1.8	2.1

and physics in these schools were in an approximate ratio of 4:2:1, respectively. The percentages for these subjects remained constant during the first four years of the Study. Table 4-III summarizes the percentages for the 109 schools sampled in which CHEM Study was the *only* chemistry course used from 1962 through 1965. Any effect CHEM Study might have on percentage enrollments would presumably be strongest in these schools. As with the entire sample, physics and chemistry percentage enrollments in these schools remained constant. Lack of any trend in these percentages suggests that introduction of CHEM Study had no effect on chemistry or physics enrollments.

The relatively small enrollment in post-chemistry science courses other than physics (typically second-year courses in biology or chemistry, physiology, science seminar, and the like) did increase by 50% during the four-year period in the schools surveyed. While there were probably other reasons, this significant increase suggests that the CHEM Study course is successful in stimulating interest in further study of science.

COLLEGE ENTRANCE TESTS

The effect of CHEM Study on admission to colleges is another matter that concerned the members of the project from the beginning. As early as the second trial year, it became clear that students with CHEM Study preparation were at a significant disadvantage in writing the chemistry test of the CEEB (College Entrance Examination Board), administered by ETS (Educational Testing Service). Various estimates were made of the size of the handicap, with some indication that the best students were most handicapped. Data from the 1962–63 CEEB test were interpreted by ETS to show an average handicap of about 40 points out of an average score of about 580.

This problem was the subject of a great deal of correspondence and several conferences involving the CEEB Chemistry committee and staff members of ETS and CHEM Study. In order to prevent or at least minimize any untoward effects of the handicap, ETS each year informed college admissions officers that the performance of CHEM Study and CBA (Chemical Bond Approach) students on this exam should be interpreted with caution. CHEM Study took every possible opportunity to inform schools about the discrepancy and urged that transcripts and letters of recommendation for students taking the exam be annotated to call admissions officers' attention to the problem.

Comparison of the 1961–1964 CEEB chemistry examinations with the CHEM Study materials left little doubt that the contents and emphases differed substantially. Much of the descriptive chemistry covered by the CEEB exam is absent from (or is treated optionally and quite late in) the CHEM Study course. Significant differences in terminology are evident. Many of the concepts stressed in CHEM Study are not tested in these exams at all. ETS took the position that, rather than prepare separate tests for students in CHEM Study or CBA courses, it would modify the CEEB exams to the point at which a handicap could no longer be demonstrated. Results of the exams administered in the spring of 1965 suggested that the handicap had been substantially reduced as a result of such modification.

On the basis of the 1966 results, the CEEB announced, "It is now proper to regard the College Board Biology, Chemistry, and Physics Achievement Tests as equally appropriate for students of the newer courses and for students of the more traditional courses in high school science."

The question of whether or not any single examination can adequately measure a student's performance in a variety of kinds of high school courses cannot be answered conclusively. A more pertinent question is whether or not such an exam can accomplish its purpose of predicting success in college courses. Diversity in freshman college chemistry courses will probably always make this a hard question to answer quantitatively.

PERFORMANCE AT COLLEGE

One of the goals of CHEM Study was to better prepare those students who go on to take chemistry courses in college. Consequently, several surveys were conducted to assess the comparative performance of CHEM Study prepared students in college freshman chemistry courses. As early as the fall of 1963, these students were entering the University of California, Berkeley, in numbers sufficient to provide a valid statistical sample. An analysis of results of the screening test for admittance to the accelerated freshman chemistry course at Berkeley showed that CHEM Study students performed substantially better than conventionally prepared students (CHEM Study Newsletter, Feb. 1964). Once in the course, the disproportionately high fraction of CHEM Study students who qualified continued to enjoy a slight advantage. While entrance requirements for all students at Berkeley are rather demanding, there was no evidence that the CHEM Study students constituted an unusually bright group. Their high school chemistry grades had, because of higher grading standards, averaged somewhat lower than those of conventional chemistry students, and relatively fewer of the CHEM Study students reported having been sectioned into advanced or honors chemistry classes in high school.

It is proper to note that the qualifying examination for the accelerated course was written by Professor Pimentel who also taught the course. The exam was not believed to have a pro-CHEM Study bias, however, except in the sense that physical chemistry and quantitative relationships were emphasized, as they were to be emphasized in the course itself. On the corresponding test given the next year by Professor Bruce Mahan, the advantage enjoyed by a larger number of CHEM Study students was even greater than in 1964. It was also found that the CHEM Study students taking the regular freshman chemistry sequence at Berkeley performed as well as the conventional chemistry students, even though a larger fraction of the former had been "skimmed off" into the accelerated course.

A STUDY OF THE ACHIEVEMENT OF CHEM STUDY STUDENTS AFTER REACHING COLLEGE

A study was made late in 1965 and early in 1966 of the relative achievement in college freshman chemistry of some 7,500 students. Included in the study were those who had studied CHEM Study, CBA and conventional high school chemistry.

Questionnaires were sent to universities, and students were asked to indicate whether they had studied CHEM Study or some other type of chemistry. An early inspection of the returns revealed that a number of students had indicated they had had CHEM Study, but investigation showed that they had attended schools which had not been teaching CHEM Study. These latter were then tallied as conventional students. Four per cent of the students were found who had had CBA. Since this sample was so small and scattered, the CBA students were eliminated from the statistics.

Information was gathered as to the number of selective and nonselective or regular courses in freshman chemistry which were given at each one of the participating universities.

Chart 1 lists the universities. The number after each university is the number of freshman chemistry classes at each. The university listed as "Tech School" requested that its name not be published because the university has rules about making grade information public.

Chart 1

Universities which furnished information and number of first-year chemistry courses at each, academic year 1964–65

U. of Colorado	4	Oberlin C.	1
Colorado State U.	2	Oregon State U.	4
U. of Detroit	1	U.S. Naval Acad.	1
U. of Florida	2	Villanova U.	2
Harvey Mudd C.	1	Tech. School	1

7,500 students in study

96% CHEM Study, 4% CBA

Some of the universities are highly selective as to their requirements for preparation in science. Others having a much higher percentage of students in non-science courses have less rigid science entrance requirements. Not only was the emphasis which each college or university put on science considered important, but also of importance was whether the freshman chemistry course considered was open to all students or whether a special examination was required for entrance. Those where a qualifying entrance examination was required are designated as "Selective." Those which were open to any first year student are designated as "Regular."

In this study, statistics were gathered with regard to a large number of variables. Some of these variables were found to be insignificant. If there was a difference of less than ± 0.03 in grade point average (GPA), the variable was considered insignificant. The insignificant variables are listed in Chart 2. The fact that certain of these variables appeared to be insignificant may be a surprise to some observers.

Chart 2

Insignificant variables ($< \pm 0.03$ *in GPA differences*)

1. Interval between HS and college course.
2. Size of HS graduating class.
3. Size of HS chemistry class.
4. Time scheduled for HS chemistry.
5. Time in HS chemistry lab.
6. Taking of HS physics.

The statistics as to the percentage of students that completed their freshman chemistry course at college were considered important and were studied in detail. Chart 3 sets forth this information. The percentage of CHEM Study students completing their first year college chemistry course was calculated and compared with the percentage of conventionally trained students who completed their first year. The percentage of students completing a course ranged from 36% in the lowest instance to 100% in the highest. The chart shows that in three of the selective courses the CHEM Study trained students got through the course better than conventional students, that is, with 10% fewer drop-outs or failures. In six cases there was no distinction between conventional and CHEM Study students. The situation in regular courses was different. Again more CHEM Study students survived than did conventionally trained students, but there were two instances where conventionally trained students fared better in regular courses. The possibility must be considered that the so-called regular courses are more conventionally oriented than are the selective courses.

Chart 3

Successful completion of courses by CHEM tudy students, compared with that by conventional students

Type of course	*More than 10% higher*	*Within ±10%*	*More than 10% lower*
Selective	3[a]	6 (3 100%)	0
Regular	4	3	2

Range of percents surviving: 36%–100%

[a] Number of courses.

Chart 4 shows the drop in GPA from high school to college. It seems to be generally true that most students' grades go down when they go from high school to college. However, the study showed that CHEM Study trained students did not drop as much in their college chemistry grades as did the conventionally trained students.

Chart 4

Average drop in GPA (HS to college)

Semester	*CHEM Study*	*Conventional*
1	0.56	0.79
2	0.65	0.85
3	0.66	0.82

In Chart 5, figures are given for students in selective and regular courses with results given for a sequence of first, second, and third semesters or, in some instances, a first, second, and third quarter. The freshman grade-point average in chemistry of CHEM Study trained students was divided by the grade-point average for conventional students in selective and regular courses. The figures show that in five of the selective courses, in first semester, CHEM Study students had at least a 10 per cent advantage. In three selective courses there was neither advantage nor disadvantage. In one selective course CHEM Study students were at a disadvantage. In the second semester, CHEM Study students in two selective courses did better, in six selective courses there was no noticeable difference, and in no course did CHEM Study students do more poorly. In the third quarter, in one course the CHEM Study students were doing better, in three they were approximately the same as the conventional students, and again in no instance were the CHEM Study students at a disadvantage.

Chart 5

Results in first three semesters or first three quarters (GPA/HS GPA) of (CHEM Study/conv.)

Course	*Sem./qtr.*	*> 1.1*	*1 ± 0.1*	*< 0.9*
Selective	1	5	3	1*
	2	2	6	—
	3	1	3	—
Regular	1	2	5	3
	2	4	4	1
	3	1	2	1

* Avg. CHEM Study HS GPA 0.2 lower than conv.

In regular courses where a more conventional type of chemistry is likely to be taught, CHEM Study students did not have an advantage.

Chart 6 compares the GPA of CHEM Study students with the GPA of conventionally trained students, again separated into selective and regular courses. Once again it is observed that in the selective courses the CHEM Study student, on the whole, did considerably better than the non-CHEM Study student. In the regular courses this was not true.

Chart 6

Comparison of grade-point averages (CHEM Study GPA—conventional GPA)

Course	*Sem.*	*> +0.2*	*±0.2*	*< −0.2*
Selective	1	6	2	1
	2	4	4	—
	3	2	1	1
Regular	1	1	6	3
	2	3	4	2
	3	1	—	3

From the data presented, one may draw the following conclusions:

1. There is little or no statistical difference in accomplishment between conventionally trained and CHEM Study trained students in regular college chemistry courses, probably because the regular courses tend to be more traditionally oriented.

2. There is no question but that CHEM Study students have a distinct advantage in selective courses.

3. The improved completion record of CHEM Study students in college chemistry courses suggests that they are more persistent, hence more interested in chemistry, due to their backgrounds. This record indicates that it is just as advantageous for the marginal student to have had CHEM Study as it is for the best.

Better preparation of students for college chemistry was one of the goals of CHEM Study. It is nevertheless a fact that only a small minority of high school chemistry students go on to take even one college-level chemistry course. A much broader goal of the Study was to further in all students an understanding of the nature of science and its importance in human activities. The materials and the whole pedagogical approach of the project reflect this objective, but little was done to try to directly assess its attainment. Some preliminary work was done in developing, trying out, and refining items for a test to measure understanding of science and attitudes toward science, with particular reference to chemistry. This project was not carried through, however, partly because of the general phasing out of all of the Study's activities, and partly because the staff felt that further efforts along this line would not be particularly fruitful.

The possibility of a large-scale, comprehensive evaluation organized and conducted by an agency external to and relatively disinterested in CHEM Study was seriously considered on several occasions. Two means of instigating such an evaluation were explored. In June 1962, a memorandum was sent to 15 testing and evaluation agencies inviting proposals and outlining the kind of information that such a study might be expected to produce. Responses were, for the most part, either negative or not indicative of ability of the agencies to do the job. This line of exploration was dropped. The Study then asked the ACS (American Chemical Society) to carry out an evaluation. An ad hoc committee was organized to consider the feasibility of such an undertaking. Although the committee agreed that evaluation was desirable, they felt that course content improvement groups within the Study could best accomplish this by expanding their own testing programs and utilizing outside services as necessary.

Acting on the basis of the ACS committee's recommendation, the Study proceeded to attempt to assess (by the means already discussed) its effects on high school science enrollments, and on comparative performance in freshman chemistry courses.

V

Extending the influence

CHEM Study has sought to influence the content and methods of high school chemistry courses through the development of new course materials. A long range goal of the Study has been to stimulate the development of other new materials and the substantial revision of those already available to high school chemistry teachers. To this end, the Study has maintained a liberal policy regarding permission to use and adapt portions of its copyrighted materials.

From a study by R. J. Gladieux prepared for CHEM Study Steering Committee, May 10, 1967, it was found that of ten new high school chemistry textbooks published between 1963 and 1967, five followed the general philosophy and content of CHEM Study with high fidelity. Three of the books were influenced somewhat by CHEM Study, as indicated by the inclusion of some up-to-date material on phases of matter, the mole concept, energy, rate and equilibrium characteristics of chemical reactions, and orbitals. Two of the ten were completely traditional in format and content.

Over the years, the staff and Steering committee devoted a great deal of thought and discussion to the question of how to maximize the long-term beneficial effects of the project. For the most part the Study was perceived as a temporary task force rather than a permanent organization.

It was realized that long-term continuing activity by CHEM Study might have the unfortunate effect of deterring other individuals and groups from creating new materials for commercial publication. By late 1964, the Study was actively seeking means of terminating its activities and at the same time stimulating the development of a variety of new materials for high school chemistry courses.

Several alternative plans of action were given serious consideration. One was to place the copyrighted materials in the public domain. Another was to simply sell all rights to the text, laboratory manual, and teachers guide to a single publisher. A third was to continue publication of the materials in their original form, announce that they would not be revised, and continue the liberal permission-to-copy policy described earlier. A fourth possibility was to authorize a limited number of revisions.

The public domain alternative was felt to be inappropriate, because to put an already popular book into the public domain might have unforeseen and drastic consequences for publishers of high school chemistry books. This course of action might also be considered by some to be a substantial gift to CHEM Study's cooperating publisher.

The possibility of simply selling the rights, including the revision rights to the books, to a single publisher was rejected because it seemed unfair and unwise for one publisher to receive the entire benefit of the momentum of the project without CHEM Study's exercising some control over the future revisions. On the other hand, to control the revisions would amount to perpetuating CHEM Study. The third alternative, of continuing to publish the materials, was also rejected. The disadvantage here was that CHEM Study would have to continue to function to grant permissions and supervise the revisions. This course of action might also have resulted in insufficient pressure on publishers to produce outstanding materials to compete with CHEM Study, as well as insufficient encouragement to teachers to change to more up-to-date content and methods.

In October 1965 the Steering Committee decided to invite publishers to submit proposals for revising the text, laboratory manual and teachers guide under the following conditions:

(1) Revision rights would be granted to not fewer than two or to more than three publishers. CHEM Study reserved the right to reject any or all proposals.

(2) No one publisher would be authorized to publish more than one of the two or three revised versions.

(3) Selection of publishers for the two or three revisions would be based principally on the qualifications of the authors they would propose. The main criteria would be the scientific competence, writing ability, and teaching experience of the chemists and teachers composing the proposed revision teams, as evidenced by their published works and reputations as teachers. Evidence of these competencies was to accompany each proposal. Other important criteria were the reputation and ability of the publisher to perform in accordance with its stated intentions.

(4) Selection of proposals would not be based on financial considerations, but a standard flat fee of $35,000 would be charged for the rights to each authorized revision. CHEM Study would collect no royalties on the published revisions and would retain no rights to subsequent revisions or their eventual disposition.

(5) Proposals were to include statements concerning the nature of the revisions contemplated by the new authors. The statements would not be taken as restrictive commitments, but rather as indications of intention. They would serve to assure CHEM Study of the authors' and publishers' intentions to effect substantial revisions as distinguished from a mere reprinting with minor changes.

(6) The title, cover design, and CHEM Study colophon used in the original publications would not be used in the revised editions, but no other restrictions would be placed on use of the original content. Identification with CHEM Study would be accomplished by use of a statement or phrase to the effect that the new book had been authorized, but not necessarily endorsed, as a revision of the materials originally produced by the Chemical Education Material Study under grants from the National Science Foundation.

(7) Publishers submitting proposals were to understand that the printing and distribution of the CHEM Study books in their original form (with correction of minor errors as discovered) would continue as long as there was significant demand for them. CHEM Study would not authorize an additional revision of the CHEM Study books under their original titles and would not reactivate its writing group to produce books in the foreseeable future.

Proposals would be considered ineligible that included in their writing teams any of the current members of the CHEM Study staff or Steering committee. Former staff members, editors, writers, trial teachers, center directors, and others who had been associated with CHEM Study in the past were eligible to participate in proposed revising teams.

(8) The liberal policy under which CHEM Study had in the past been willing to grant nonexclusive permission to publishers to use and adapt substantial portions of its printed materials was suspended and would be terminated at such time as revisions to the new books were authorized.

(9) March 1, 1966, was set as the deadline for receipt of proposals.

This plan had a number of distinct advantages over other alternatives. It offered some assurance that the CHEM Study materials would be built upon creatively, thus extending in both time and quality the benefits of the vast amounts of time, effort, and money that had gone into the original project. At the same time, it averted the very real possibility that the CHEM Study materials would be used by an overwhelming majority of schools and thus become, unintentionally and unfortunately, a "national curriculum" or a "new orthodoxy." This course of action returned the initiative for publishing chemistry materials to private enterprise, but in doing so it also encouraged a new pattern of author-team composition. Finally, it enabled CHEM Study to terminate practically all of its activities promptly.

The decision to limit the number of authorized revisions to three was based on several considerations. It was felt that this number would give maximum assurance of a variety of revisions in terms of their different directions and levels of sophistication. At the same time, the number was small enough to provide real incentive to the publishers whose proposals were chosen and real value to the rights they bought. The option of choosing only two proposals was left open in case only two were deemed acceptable. In such a case it would have been unfortunate either to have to reject two good proposals because of lack of a third, or to accept an inferior third proposal just to enable two good ones to be authorized.

The Study received seven proposals. These were evaluated by the staff and Steering Committee. The Steering Committee's decision was reviewed by a committee of chemists who had not been associated with CHEM Study. Revision rights were granted to D. C. Heath and Company, Houghton Mifflin Company, and Prentice-Hall, Inc. The D. C. Heath (Raytheon) revision, *Chemistry: Experiments and Principles*, and the Houghton Mifflin revision, *Chemistry, An Investigative Approach*, appeared in 1968.

The Prentice-Hall revision, *Chemistry: Experimental Foundations*, appeared early in 1969.

The Freeman edition, *Chemistry—An Experimental Science*, will continue to be available as long as there is significant demand for it.

At the time this history was written, no arrangement had yet been made for ultimate disposition of the publishing rights to the unrevised textbook and other printed materials, nor had any plan been worked out for eventual disposition of the film distribution rights. It seemed likely, however, that these matters would be settled by the same criteria used for the disposition of revision rights to the printed materials.

It may come as a surprise to some that by 1967 the net income returned to the United States Treasury from the sale of CHEM Study books and films exceeded the $2,800,000 total of NSF grants to the project. By January 1969, more than three quarters of a million copies of the CHEM Study text and over a million copies of the laboratory manual had been sold. By this same date, more than 24,000 copies of the films had been sold, and there had been 106,000 individual film rentals on a subscription basis. These figures represent a coverage of about half the high schools and about half the chemistry students in the United States. To break even, let alone show a profit, was never a goal of the Study. It just happened. When one adds this achievement to the deliberate and unusual efforts to phase itself out of existence, CHEM Study surely has some claim to uniqueness among government-financed educational projects.

Some evidence of the impact of CHEM Study and CBA can be gained from the prefaces to several first-year college texts which have appeared since CHEM Study and CBA have come into wide use.

> "The rapid development of high school and upper-level college chemistry courses is placing unprecedented pressures for change in the basic freshman course." (*Basic Principles of Chemistry*, Gray and Haight, W. A. Benjamin, 1967.)
>
> "During the past decade, the level of chemistry instruction has been raised at a rate without parallel in recent history . . . Much of the credit belongs to the new high school chemistry programs and the innovators who boldly tried new approaches to the learning process, . . . the first-year college chemistry course is now confronted with better-prepared students and has an expanded and more complex body of knowledge to present." (*Chemistry: Principles and Properties*, Sienko and Plane, McGraw-Hill, 1966.)
>
> "This is a textbook . . . intended for students who have had an

introductory high school chemistry course. Its design is based on my experience with such a group, which included students who had had a 'standard' high school course, one of the two newer courses generated by CHEM Study and CBA, and a few who had had a second high school course designed for advanced placement in college. Writing a book which emphasizes fundamental principles and builds on previous experience presents some difficult problems." (*University Chemistry*, Mahan, Addison-Wesley, 1965.)

"Any doubt that general chemistry is undergoing a revolution can be resolved by comparing the present edition of this text with its predecessor, written a scant six years earlier. This sweeping change is the result of three converging factors:

1. The exponential expansion of chemical knowledge;
2. The remarkably improved background in chemistry and allied fields of the entering college freshman;
3. The emergence of bold and innovative approaches to the twin problems of teaching and learning in science." (*College Chemistry*, 3d edition, Sisler, VanderWerf, and Davidson, Macmillan, 1967.)

Many problems of high school science education remain unsolved. Typical pre-service teacher preparation leaves much to be desired. Chemistry, physics, and biology too often remain pedagogically isolated from one another. Social and economic implications of the advancement of science are not always made clear to students. Much remains to be done in developing appropriate experiences and materials for students who are not college bound.

Some critics of CHEM Study will argue that it quit too soon—that it should have used its resources and momentum in attacking these and other problems as well. Perhaps the critics are right. But perhaps the accomplishments of CHEM Study will be utilized and built upon by others whose interests and talents better suit them to attack these unsolved problems. It is probably safe to say that if anyone has time in the year 2000 to study the history of chemical education in the twentieth century, he will conclude that the work of the CHEM Study was competent, that it had a significant and salutary impact, and that it was badly needed. Whether or not it sufficiently met the needs of the time will depend on what further efforts it stimulated.

Appendixes

A

CHEM Study Personnel

A-1

STEERING COMMITTEE

Glenn T. Seaborg, *Chairman*
Chairman, Atomic Energy Commission
Washington, D.C.

J. Arthur Campbell
Chairman, Chemistry Department
Harvey Mudd College
Claremont, California

Bryce Crawford, Jr.
Dean, Graduate School
University of Minnesota
Minneapolis, Minnesota

Warren Everote (1960–61)
Vice-President, Research and Production
Encyclopædia Britannica Films
Wilmette, Illinois

Henry Eyring
Dean, Graduate School
University of Utah
Salt Lake City, Utah

W. H. Freeman (1960–61)
President, W. H. Freeman and Company
San Francisco, California

Rolland Gladieux
Director of Math and Science
Kenmore Public Schools
Buffalo, New York

Cleveland Lane
Assistant to the President
Goodrich-Gulf Chemicals, Inc.
Cleveland, Ohio

Donald H. McLaughlin
Regent, University of California
San Francisco, California

Carl G. Nieman (Deceased April 29, 1964)
Professor of Chemistry
California Institute of Technology
Pasadena, California

J. Cecil Parker
Head, Education Field Service Center
University of California
Berkeley, California

George C. Pimentel
Professor of Chemistry
University of California
Berkeley, California

Kenneth S. Pitzer
President, Rice University
Houston, Texas

Charles C. Price
Director, Department of Chemistry
University of Pennsylvania
Philadelphia, Pennsylvania

Robert A. Rice
Assistant to the Director, Lawrence Hall of Science
University of California
Berkeley, California

Robert L. Silber
Educational Secretary
American Chemical Society
Washington, D.C.

H. Grant Vest
Secretary, Trustees of State Colleges
219 State Services Building
Denver, Colorado

Roy L. Whistler
Professor of Chemistry
Purdue University
Lafayette, Indiana

Harvey E. White
Professor of Physics
Director, Lawrence Hall of Science
University of California
Berkeley, California

A-2

STAFF DIRECTORS

J. Arthur Campbell
Director (through August 1963)

Lloyd E. Malm (Deceased May 25, 1966)
Editor, Laboratory Manual

Richard J. Merrill
Executive Director
(June 1962 through December 1965)

George C. Pimentel
Principal Investigator, Director
(September 1963–)
Editor, Textbook

David W. Ridgway
Director of Film Activities
Executive Director (January 1966–)

Staff Contributors
(*through Summer 1963*)

Joseph E. Davis, Jr.
Associate Editor, Laboratory Manual
Miramonte High School
Orinda, California

June Ewing
Staff Consultant for Films
Bloomington, Indiana

Charles Finance
Film Producer
Encyclopædia Britannica Educational Corporation
Hollywood, California

Hal Geer
Staff Writer for Films
Warner Brothers—7 Arts
Hollywood, California

J. Leland Hollenberg
Staff Consultant for Films
University of Redlands
Redlands, California

Keith MacNab
Associate Editor, Teachers Guide, Textbook
Sir Francis Drake High School
San Anselmo, California

Aubrey L. McClellan
Editor, Teachers Guide
Chevron Research Corporation
Richmond, California

Margaret Nicholson
Associate Editor, Laboratory Manual, Textbook
Acalanes High School
Lafayette, California

A-3

CONTRIBUTORS TO PRINTED MATERIALS

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Miramonte High School
Orinda, California

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East Lansing, Michigan

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Forest Hills High School
Forest Hills, New York

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University of California
Los Angeles, California

Melvin Greenstadt
Fairfax High School
Los Angeles, California

Carl Gruhn
South Pasadena High School
South Pasadena, California

Edward L. Haenisch
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Crawfordsville, Indiana

Rolfe H. Herber†
Rutgers University
New Brunswick, New Jersey

C. Robert Hurley
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Sacramento, California

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Lemont, Illinois

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Beverly Hills High School
Beverly Hills, California

Bruce H. Mahan
University of California
Berkeley, California

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Lafayette, California

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Palo Alto, California

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University of Michigan
Ann Arbor, Michigan

Henry Rapoport
University of California
Berkeley, California

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San Francisco, California

Michell J. Sienko
Cornell University
Ithaca, New York

Robert L. Silber
American Chemical Society
Washington, D.C.

Harley L. Sorensen
San Ramon Valley Union High School
Danville, California

Luke E. Steiner
Oberlin College
Oberlin, Ohio

Moddie D. Taylor†
Howard University
Washington, D.C.

Robert L. Tellefsen
Napa High School
Napa, California

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* Present at first organizational meeting (April, 1960) only.
† Present at second (1961) summer writing conference only.
‡ Present at both summer writing conferences, but not at first organizational meeting.

A-4

CENTER DIRECTORS

(Unless otherwise noted, the center was at the university with which the director was affiliated.)

1960–62

Lloyd E. Malm
Professor of Chemistry
University of Utah
Salt Lake City, Utah
(*Harvey Mudd College Center*)

George C. Pimentel
Professor of Chemistry
University of California
Berkeley, California

1961–62

Francis T. Bonner
Professor of Chemistry
State University of New York
Stony Brook, New York
(*Long Island Center*)

Gregory Choppin
Professor of Chemistry
Florida State University
Tallahassee, Florida

Edward L. Haenisch
Chairman, Dept. of Chemistry
Wabash College
Crawfordsville, Indiana

L. Carroll King
Professor of Chemistry
Northwestern University
Evanston, Illinois

Paul R. O'Connor
Professor of Chemistry
University of Minnesota
Minneapolis, Minnesota

David M. Ritter
Professor of Chemistry
University of Washington
Seattle, Washington

Irwin Siegelman
Professor of Chemistry
University of Pennsylvania
Philadelphia, Pennsylvania

1962–63

James Hall and Charles Shull
Professors of Chemistry
Colorado School of Mines
Golden, Colorado

W. Thomas Lippincott
Professor of Chemistry
Ohio State University
Columbus, Ohio

Earl P. Murphy
Professor of Chemistry
St. Louis University
St. Louis, Missouri

Leonard Nash
Professor of Chemistry
Harvard University
Cambridge, Massachusetts

Robert W. Parry
Professor of Chemistry
University of Michigan
Ann Arbor, Michigan

Wendell M. Slabaugh
Professor of Chemistry
Oregon State University
Corvallis, Oregon

A-5

SECRETARIES AND CLERICAL ASSISTANTS

AT HARVEY MUDD COLLEGE

Terry Finance
Ruth Hayter
Ann Holstein
Julie Lewis
Betty Lumpkin
Lola Maxwell
Marcia L. Myers
Sue R. Thomas

AT THE UNIVERSITY OF CALIFORNIA, BERKELEY

Susan Arbuckle
Ann Brooks
Grace H. Christie
Patricia Cross
Viola Doizaki
Susan Erdei
Charlotte Gluck
Nora Grigsby Lee
Evelyn S. Ledyard
Barbara Jane Rocke
Dorothy Schatten
Patricia Summers

A-6

OFFICIAL TRIAL TEACHERS

Over 700 teachers used the CHEM Study materials for one or more years during 1960–63. Those listed here were chosen by CHEM Study and supported as official trial teachers to participate extensively in the trial program. Many other teachers not listed made significant contributions to the feedback that resulted in improvements to the materials.

ARIZONA

Hobert L. D. Coffer
Camelback High School
Phoenix

CALIFORNIA

Barbara Amberson
Lompoc Unified High School

Don E. Baker
Santa Ana High School

Ella Ballou
Skyline High School
Oakland

H. W. Baum
Alhambra High School
Martinez

Wilbert Bolliger
Ganesha High School
Pomona

Walter Brooks
Santa Ana College

Robert Campbell
Miramonte High School
Orinda

Joseph Carter
Anaheim High School

Harry E. Choulett
Berkeley High School

Richard Clark
San Marino High School

Frank Crosby
Live Oak Union High School
Morgan Hill

Joseph Davis, Jr.
(guest instructor)
Claremont High School

Frances Dealtry
Lowell High School
San Francisco

Elwyn Dorman
Saratoga High School

George Ellis
North Hollywood High School

Paul Engelcke
Palo Alto High School

Robert Etcheverry
El Cerrito High School

Robert French
Pioneer High School
Whittier

Everett Gellerman
Andrew Hill High School
San Jose

Clifford Georgison
Terra Linda High School
San Rafael

Martin Glasser
Monterey Union High School

Melvin Greenstadt
Fairfax High School
Los Angeles

Carl Gruhn
South Pasadena High School

James R. Jasperse
Leigh High School
San Jose

Leo Kallan
El Camino College

Blaine Lemmon
Hillsdale High School
San Mateo

Richard Lungstrom
La Sierra High School
Carmichael

Lawrence D. Lynch, Jr.
Beverly Hills High School

Keith MacNab
Sir Francis Drake High School
San Anselmo

David Marsh
Gardena High School

Laurence Martens
Oakland City College

Richard Merrill
Ramona High School
Riverside

Merrill Merritt
Woodland High School

Kenneth Monroe, Jr.
Webb School
Claremont

Margaret Nicholson
Acalanes High School
Lafayette

Clyde Parrish
Cubberley High School
Palo Alto

Delbert Pfeifer
Pomona High School

Clifford Phillips
Monte Vista High School
Spring Valley

Francis Pottenger, III
Whittier High School

Eugene Roberts
Polytechnic High School
San Francisco

Robert Roemmele
Santa Fe High School

Frank Savstrom
Los Altos High School

Harley Sorenson
San Ramon Valley Union High School
Danville

Robert Tellefsen
Napa Senior High School

Boyer W. Voisard
Woodrow Wilson High School
Long Beach

Marian West
Castlemont High School
Oakland

COLORADO

Eugene D. Bard
South High School
Pueblo

Robert Fatzinger
Arvada Senior High School

Al Grohe
Littleton High School

Henry M. Lujan
Palmer High School
Colorado Springs

Sister Carlos Marie
Holy Family High School
Denver

Bill McDaniel
Abraham Lincoln High School
Denver

Albert R. Rich
Thomas Jefferson High School
Denver

FLORIDA

Reginald D. Butler, Jr.
Pensacola High School

Bruce E. Cleare
Leon High School
Tallahassee

John W. Dunn
Escambia High School
Pensacola

James G. Evans
William R. Boone High School
Orlando

Leila McMullian
Marianna High School

Millard Roberts
Melbourne High School

GEORGIA

C. A. Collins
Albany High School

Robert M. Sims
Westminster Schools
Atlanta

Harry Taylor
North Fulton High School
Atlanta

HAWAII

Theodore Ozawa
McKinley High School
Honolulu

Mrs. Gordon L. Pickering
Iolani School
Honolulu

ILLINOIS

Vaughn Armer
Oak Park and River Forest High School

Robert Carmichael
Highland Park High School

Carl W. Clader
New Trier Township High School
Winnetka

Brother L. Martin
St. Patrick High School
Chicago

Floyd A. Mittleman
Evanston Township High School

Vernon S. Stenoien
Maine Township High School
Des Plaines

Robert L. Walker
Lyons Township High School
La Grange, Illinois

Bernard E. Welch
Niles Township High School
Skokie

INDIANA

William Fletcher
Broad Ripple High School
Indianapolis

Gladys Good
Arlington High School
Indianapolis

William J. Graney
Arsenal Technical High School
Indianapolis

Charles A. Hawthorne
George Washington High School
Indianapolis

Russell Hicks
Arlington High School
Indianapolis

William Inskeep
University High School
Bloomington

George Johnson
Culver Military Academy

Francis R. Lane
Jefferson High School
Lafayette

Mary Lou Lyons
Harry E. Wood High School
Indianapolis

Joseph B. Myers
Crispus Attucks High School
Indianapolis

K. L. Retherford
Warren Central High School
Indianapolis

Marie Van Horn
Shortridge High School
Indianapolis

IOWA

Rex T. Morrison
Theodore Roosevelt High School
Des Moines

KANSAS

Charles F. Schwarz
Wichita High School South

Benjamin Zerger, Jr.
Salina Senior High School

KENTUCKY

Robert J. Dils
Paul G. Blazer High School
Ashland

LOUISIANA

Edward S. Jenkins
Southern Laboratory School
Baton Rouge

MASSACHUSETTS

John C. Hall
Newton High School
Newtonville

Stewart Sargent
Marshfield High School

Elizabeth G. Tite
Tantasqua Regional High School
Sturbridge

Philip Weld
Phillips Academy
Andover

MICHIGAN

Sister M. Albertus
Dominican High School
Detroit

John R. Anderson
Cousino High School
Warren

Sam Ascher
Pershing High School
Detroit

James R. Banks
Everett High School
Lansing

John C. Donovan
Lamphere High School
Madison Heights

William Lecington
Belleville High School

Benjamin Ray
Bentley High School
Livonia

MINNESOTA

Karl Aaberg
Mankato Senior High School

Edmund C. Bray
St. Paul Academy

L. R. Lussenhop
Robbinsdale Senior High School

Ted Molitor
Alexander Ramsey High School
St. Paul

Robert Rainey
South High School
Minneapolis

Eraine Schmit
Central High School
St. Paul

Charles M. Thiele
Hopkins High School

MISSOURI

Robert O. Bassman
Horton Watkins High School
St. Louis

Kenneth Fast
Webster Groves High School

Elmer Headlee
Kirkwood High School

Robert S. Waggoner
Cleveland High School
St. Louis

NEBRASKA

Calvin F. DeLano
Westside High School
Omaha

NEW HAMPSHIRE

Emile Rocheleau
Monadnock Regional High School
Keene

NEW JERSEY

Sister Francis Eileen
Aloysius High School
Jersey City

Albert Zabady
Bloomfield High School

NEW MEXICO

B. K. Graham
Artesia High School

NEW YORK

Herbert Bassow
The Fieldston School
New York

Jacob Brodkin
Plainview Senior High School

Edgar Clemens
Ithaca Senior High School

Lawrence Daressa
Port Jefferson High School

Saul Geffner
Forest Hills High School

Sidney P. Harris
William Cullen Bryant High School
Long Island

J. G. Harwell
The Bronx High School of Science

Gerard Kass
Northport High School

Bert Kleinsinger
The Bronx High School of Science

Seymour Kopilow
Farmingdale High School

Joseph G. Musselman
Brooklyn Preparatory School

Julius Raphael
Stuyvesant High School
New York

Earl L. Vandermeulen
Port Jefferson High School

NORTH CAROLINA

E. Worth Campbell
South Mecklenburg High School
Pineville

NORTH DAKOTA

A. Robert Pederson
Central High School
Fargo

OHIO

Herbert L. Cramer
Girard High School

William L. Koch
Rutherford B. Hayes High School
Delaware

William D. Myers
Simon Kenton High School
Lees Creek

Paul Primeau
Gilmour Academy
Gates Mills

David Schmitkons
Clearview High School
Lorain

John H. Snider, Jr.
Urbana High School

OKLAHOMA

Austin Ketcher
Stilwell High School

OREGON

Walter R. Dickson
North Salem High School

J. Philip Gustafson
Oregon City Senior High School

Glen L. Hampshire
Jefferson High School
Portland

Richard L. Hutchens
Clackamas High School
Milwaukie

Jule F. Kasper
North Eugene High School

PENNSYLVANIA

Stephen Edgerton
William Penn Charter School
Philadelphia

Thomas D. Evans
Spring-Ford Senior High School
Royersford

Harold Ferguson
Harriton H. S. of Lower Merion
Rosemont

Kenneth Jackman
The Hill School
Pottstown

Ellis S. Kocher
Radnor Senior High School

Harry Kuner
Lincoln High School
Philadelphia

Lewis Marderness
Reading Senior High School

Joseph S. Schmuckler
Haverford Township Senior High School
Havertown

Paul M. Zorn
William Tennent High School
Johnsville

SOUTH CAROLINA

Robert W. Gettys
Spartanburg

A. Mason Turner
Orangeburg High School

SOUTH DAKOTA

Alfred A. Halsted
Yankton Senior High School

TENNESSEE

John Pechonick
Jackson High School

TEXAS

Larry O'Rear
Wm. Adams High School
Alice

UTAH

Lane Compton
Highland High School
Salt Lake City

La Mon Neubert
Bountiful High School

VIRGINIA

Elizabeth Cofer
Francis C. Hammond High School
Alexandria

WASHINGTON

Clair D. Douthitt
Chief Sealth High School
Seattle

Jerry Kent
Renton High School

Royal B. Leach
Lincoln High School
Tacoma

Wendell McCain
Edward S. Ingraham High School
Seattle

David Poulsen
Bellevue High School

Vance Reeves
Clover Park High School
Tacoma

Celia Scott
Shoreline High School
Seattle

Lee Strenge
Woodrow Wilson High School
Tacoma

Donald Urwiler
Ranier Beach Senior High School
Seattle

WEST VIRGINIA

Jonathan Paugh
Moorefield High School

WISCONSIN

Robert Gorges
North High School
Sheboygan

PUERTO RICO

Luis Pino
Ponce High School

A-7

COLLABORATORS ON FILMS

Richard M. Badger
California Institute of Technology
Pasadena
Vibration of Molecules

Robert Brasted
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Minneapolis
Vanadium—A Transition Element

J. Arthur Campbell
Harvey Mudd College
Claremont, California
Acid-Base Indicators
Chemical Families
Crystals and Their Structures
Electric Interactions in Chemistry
Electrochemical Cells
Gas Pressure and Molecular Collisions
Molecular Motions

Bryce Crawford, Jr.
University of Minnesota
Minneapolis
Molecular Spectroscopy

David Dows
University of Southern California
Los Angeles
Shapes and Polarities of Molecules

Philip Eaton
University of Chicago
Mechanism of an Organic Reaction

June S. Ewing, M.S.
CHEM Study Staff
Electrochemical Cells

Henry Eyring
University of Utah
Salt Lake City
Introduction to Reaction Kinetics

Theodore A. Geissman
University of California
Los Angeles
Synthesis of an Organic Compound

Paul W. Gilles
University of Kansas
Lawrence
High Temperature Research

J. Leland Hollenberg
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Redlands, California
Electric Interactions in Chemistry
Chemical Families
Bromine—Element from the Sea

James E. Magner
Dow Chemical Company
Bromine—Element from the Sea

Bruce Mahan
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Berkeley
Ionization Energy

John Overend
University of Minnesota
Minneapolis
Molecular Spectroscopy

Linus Pauling
California Institute of Technology
Pasadena
Vibration of Molecules

George C. Pimentel
University of California
Berkeley
A Research Problem: Inert (?) Gas Compounds
Chemical Bonding
Equilibrium
Gases and How They Combine
The Hydrogen Atom: as Viewed by Quantum Mechanics (standard and advanced)
Pimentel Discusses the Hydrogen Atom
Pimentel Discusses Chemical Bonding

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Catalysis

Henry Rapoport
University of California
Berkeley
Mechanism of an Organic Reaction

Donald E. Rounds
Pasadena Foundation for Medical Research
Biochemistry and Molecular Structure

Glenn T. Seaborg
Atomic Energy Commission
Transuranium Elements

Harry H. Sisler
University of Florida
Gainesville
Nitric Acid

J. J. Turner
Cambridge University
Cambridge, England
A Research Problem: Inert (?) Gas Compounds

B

Published Material

Chemistry, An Experimental Science. San Francisco, W. H. Freeman and Company, 1963. 466 pages, 219 illustrations (clothbound).

Laboratory Manual for Chemistry, An Experimental Science. San Francisco, W. H. Freeman and Company, 1963. 138 pages, 69 illustrations (paperbound).

Teachers Guide for Chemistry, An Experimental Science. San Francisco, W. H. Freeman and Company, 1963. 785 pages, 35 illustrations (paperbound).

Open-Book Achievement Examinations (Series 1963–64 and Series 1964–65). San Francisco, W. H. Freeman and Company. 9 booklets (paperbound). *See Sample in Appendix M.*

A Programmed Sequence on the Exponential Notation. Eugene Roberts. San Francisco, W. H. Freeman and Company, 1962. 31 pages (paperbound).

A Programmed Sequence on the Slide Rule. Eugene Roberts. San Francisco, W. H. Freeman and Company, 1962. 64 pages (paperbound).

Film Transcripts: CHEM Study Chemistry Films. New York, Modern Learning Aids, 1964. 170 pages (paperbound).

Teachers Guide to the CHEM Study Chemistry Films. New York, Modern Learning Aids, 1964. 102 pages (paperbound).

C

Films

C-1

CRITERIA FOR SELECTING FILM TOPICS

Certain criteria should prove to be helpful in selecting topics for the CHEM Study course. The following list cannot be conclusive. The criteria will vary in importance. However, if each point in the list is given consideration, the film topics selected may be more likely to achieve maximum usefulness. As a general rule, only films should be made that will do things which the teacher cannot do as well in the classroom. Each film must be pertinent to the course. It should do things impractical or impossible to do in the classroom. There is a special category for the inspirational film.

PERTINENT TO THE COURSE

This is a relative matter, so the question must be asked, "How important to the course are the concepts?"

"Does the topic give an opportunity to present basic principles?"

IMPRACTICAL OR IMPOSSIBLE TO DO IN THE CLASSROOM

A. Present phenomena which cannot be seen at all and therefore require animation.
B. Show objects which can best be seen on the screen because they are:
   a. Too small
   b. Too large
   c. Too fast in motion
   d. Too slow in motion
   e. Too dangerous
   f. Too time-consuming to set up or to perform
   g. Too distant from the classroom (e.g., factories or sources of raw materials)
   h. Not readily available or impractical to bring into classroom (e.g., heavy equipment)
   i. Too expensive.

INSPIRATIONAL

In this category may be considered the utilization of great personalities who may be presented on screen, or general topics useful for promoting interest in chemistry.

FILMS AS TEACHING TOOLS

Films should be considered as teaching tools for the teacher. If a film is a good teaching tool, the teacher should never be in a position to say, "I don't have time to show the film." If the film is good, the teacher should say, "I won't have time to teach the course *unless* I use the film."

If a teacher says that he does not have time to use a film, this means that the film is at fault, or that the teacher has not accurately appraised the film.

PROPOSAL OF TOPICS FOR FILMS

Anyone interested in CHEM Study may propose a topic for film. Proposals may come from any member of the CHEM Study staff, from contributors to the course, from teachers using the course, from students in any of the classes in which the course is being taught, or from any individual who has an interest in improving the teaching of chemistry at the high school level. Any topic which is proposed will be given consideration by the CHEM Study staff. The CHEM Study staff will make the final decision as to whether any topic shall be made into a film and will determine the priority which shall be given to any topic.

C-2
COMMENT ON CRITERIA FOR SELECTING FILM TOPICS

September 23, 1960

Mr. David W. Ridgway
CHEM Study
West Dorm
Harvey Mudd College

Claremont, California

Dear Dave:
Thanks for your letter of September 21 and the enclosed draft of "Criteria for Selecting Film Topics." I feel this is an excellent statement of criteria. I have a few suggestions which you may wish to consider.

1. "PERTINENCE"

(a) I suggest adding to the first sentence, merely for clarification, the underscored words "How important to the course are the concepts *treated in the film?*"
(b) You might wish to add another question: "Can the topic be woven into the content of the course as defined by the text?"

2. "IMPRACTICAL OR IMPOSSIBLE"

I am not at all sure of myself in this suggestion: it may look awkward in print. Still, it is a fact that some teachers will not feel competent (or will feel so, but aren't) to discuss certain topics because of background deficiencies. Then they may prefer to use a film as a "teacher substitute." It suggests adding a category C, such as:
C. Discuss concepts or modern developments of chemistry in areas where some high school teachers may feel their own training is inadequate.

3. "INSPIRATIONAL"

In addition to inspiring students by letting them look at great personalities, we can inspire them by letting them hear about scientific advances which are important because of the impact on our lives. You see the difference—on the one hand, we have as a focal point an *individual*—on the other hand, we may also place the focus on the *story* of how a key scientific advance came about—usually involving more than one individual, more than one laboratory, more than one scientific contribution. I guess I am really adding to something already in your write-up in the expression "or general topics useful for promoting interest in chemistry." This expression sounds like an afterthought whereas I feel the "how-the-advance-was-made" type of story may be the more effective inspirational tool. I would like our suggestion of this aspect of the inspirational film to sound more enthusiastic and more forceful so it is more likely to evoke ideas.

4. "FILMS AS TEACHING TOOLS"

I think the language here might antagonize some of our high school teachers but the message is important. What about changing to something more like "If a film is a good teaching tool, the teacher's reaction will not be 'I don't have time to show the film.' If the film is really good, the teacher will say, '. . . etc., same as is. . . .' "

5. "PROPOSAL OF TOPICS"

Why not add a more invitational note in your second sentence? "*We hope proposals will come* from members of the CHEM Study staff, from contributors, . . . etc. . . . "

Looking forward to seeing you next month.

Sincerely yours,

George C. Pimentel

GCP:eg
cc: J. A. Campbell

C-3

DESCRIPTION OF FILMS AND CORRELATION WITH CHEMISTRY TEXTS

The films have been designed with two main purposes in mind: (1) To introduce into the classroom important experimental evidence which is difficult or impractical to introduce through student experiments and live demonstrations. (2) To clarify, through animation, the mental models of structure and of dynamic processes which help scientists and students make sense out of the experimental evidence. Most of the films serve both purposes. In addition, several of the films attempt to convey the nature and excitement of scientific research.

All of the films are integrated with the CHEM Study Textbook, Laboratory Manual, Teachers Guide and tests. They will be useful in other contexts as well. The Teachers Guide for each film presents a summary, a statement of purpose, suggested pre-showing and post-showing class activities, a detailed outline of the film content, and supplementary material which may be useful to the teacher. Film Teachers Guides, in a bound volume, are provided by MLA without charge to all who subscribe to five or more films in any one year and to every purchaser of one or more films. Additional volumes may be purchased from MLA for $2.00 each.

The relatively short running times of these films (12 to 24 minutes) encourages pre and post showing discussion and enhances their usefulness in a variety of types of courses at both the high school and college levels.

You can make the films an integral part of your course by ordering them one of three ways. You may purchase them outright; you may lease to buy; or you may purchase a subscription.

CHEM Study film purchasers are eligible for NDEA Title III funds.

The individual purchase prices for 16mm-sound films are indicated under the film descriptions and are subject to quantity discounts. The films are also available for subscription.

GASES AND HOW THEY COMBINE

Collaborator: Professor George C. Pimentel, University of California, Berkeley.

First, some properties that distinguish gases are shown. Then, the volumes of ammonia and hydrogen chloride that combine are measured quantitatively. The volume ratio is found to be 1.0. In a similar way, simple integer volume ratios are measured for the combination of hydrogen and oxygen, of nitric oxide and oxygen, and of hydrogen and chlorine. These simple integer ratios lead, logically, to Avogadro's Hypothesis.

#4103 22 min. In color $165

GAS PRESSURE & MOLECULAR COLLISIONS

Collaborator: Professor J. Arthur Campbell, Harvey Mudd College, Claremont, California.

The film explores the relationship between gaseous pressure and molecular collisions. The effects of varying the number of molecules per unit of volume and of varying the temperature are studied. The experimental study of the relative rates of effusion of hydrogen, oxygen, carbon dioxide and sulfur hexafluoride leads to the quantitative relationship between molecular weight, molecular velocity and absolute temperature. Mechanical models illustrate the experimental observations.

#4106 21 min. Black & white $120

ELECTRIC INTERACTIONS IN CHEMISTRY

Collaborators: Prof. J. Leland Hollenberg, University of Redlands, Redlands, California, and Prof. J. Arthur Campbell, Harvey Mudd College, Claremont, California.

Observations of two spheres suspended from the terminals of a high voltage generator remind us of the principles that opposite charges attract, like charges repel, and uncharged bodies have no electric interaction. To determine quantitatively the effect of distance on electric force, a sensitive balance measures the force between two charged spheres. The distance is varied and the electric force is calculated from changes in balance readings. A graph of electric force against distance suggests the equation $Fr^2 = k$ (a constant), and the tabulated data confirm this relation. To illustrate the applications in chemistry of these principles, the migration of positive and negative ions and their mutual precipitation are shown in time-lapse photography and in animation.

#4109 21 min. In color $165

CHEMICAL FAMILIES

Collaborators: Prof. J. Leland Hollenberg, University of Redlands, Redlands, California, and Prof. J. Arthur Campbell, Harvey Mudd College, Claremont, California.

Starting with a display of actual samples of over 70 elements, the film demonstrates methods by which chemical similarities among the elements have provided the basis for dividing them logically into families. By experiment and observation, the elements are classified as metals or non-metals, and some are found to be difficult to classify. Experimentally it is shown that, under the same conditions,

Title		Gases and How They Combine	Gas Pressure and Molecular Collisions	Electric Interactions in Chemistry	Chemical Families	Molecular Motions	Vibration of Molecules	Introduction to Reaction Kinetics	Equilibrium	Catalysis	Acid-Base Indicators	Electrochemical Cells	Nitric Acid	Crystals and Their Structures	Molecular Spectroscopy	The Hydrogen Atom–as Viewed by Quantum Mechanics	Ionization Energy	Shapes and Polarities of Molecules	Chemical Bonding	A Research Problem–Inert (?) Gas Compounds	Synthesis of an Organic Compound	Mechanism of an Organic Reaction	Bromine Element from the Sea	Vanadium–a Transition Element	High Temperature Research	Transuranium Elements	Biochemistry and Molecular Structure
Film No.		4103	4106	4109	4112	4115	4118	4121	4124	4127	4130	4133	4136	4139	4142	4148-9	4151	4154	4157	4160	4163	4166	4169	4172	4175	4178	4181
CHEMISTRY–AN EXPERIMENTAL SCIENCE The Chemical Education Material Study 1963	Chapter	2	4	5	6	7	7	8	9	8	11	12	12	14	14	15	15	16	16	16	18	18	19	22	22	23	24
A BASIC COURSE IN CHEMISTRY Liptrot and Pode Mills & Boon, London, 1964	Unit	13	2	9	11			14	14	14	C	9	6	6		11	11	15	11	6	15	15	10	11	6	11	15
	Section	1	34	5	1			7	9	7		10	12	39		3	9	1	9	54	6	15	14	1	51	9	10
CHEMICAL SYSTEMS The Chemical Bond Approach Committee McGraw-Hill, 1963	Chapter	3	8	5	10	8	8	17	17	17	16	14	17	11	10		10	7 18	7	10 8	18	18	13	13	12	13	
CHEMISTRY Choppin and Jaffe Silver Burdett, 1965	Chapter	3	2	6	7	6		14	15	14	17	18	27	20	After 20	10	11	11 20	11	7	30	30	7	25	24	32	31
CHEMISTRY Garrett, Richardson, and Kiefer Ginn & Co., 1964	Unit				VII																						
	Chapter	10	13	7	9	13		17	17	17	16	18	23	8 13	9	7	8	14 16	8	12	30	30	20	38	38	26 38	31
CHEMISTRY: A MODERN APPROACH Hogg, Bickel, Nicholson, and Wik Van Nostrand, 1963	Unit																					IX					
	Chapter	18	5 17	8	21 41	6 7		28	28	28	35	39	48	9 23	10	24	24	23	23	42	30 32	32	43 44	41	23	53	32
CHEMISTRY–A MODERN COURSE Smoot, Price, and Barrett Charles Merrill Books, 1965	Chapter	12	9 12	18	7	9		19	19	19	16 19	18	19	11	8 23	6 8	8	8	8	9	20	20	17	21	20	24	21

*After Unit 7

Text		4103	4106	4109	4112	4115	4118	4121	4124	4127	4130	4133	4136	4139	4142	4148-9	4151	4154	4157	4160	4163	4166	4169	4172	4175	4178	4181
TITLE		GASES AND HOW THEY COMBINE	GAS PRESSURE AND MOLECULAR COLLISIONS	ELECTRIC INTERACTIONS IN CHEMISTRY	CHEMICAL FAMILIES	MOLECULAR MOTIONS	VIBRATION OF MOLECULES	INTRODUCTION TO REACTION KINETICS	EQUILIBRIUM	CATALYSIS	ACID-BASE INDICATORS	ELECTROCHEMICAL CELLS	NITRIC ACID	CRYSTALS AND THEIR STRUCTURES	MOLECULAR SPECTROSCOPY	THE HYDROGEN ATOM–AS VIEWED BY QUANTUM MECHANICS	IONIZATION ENERGY	SHAPES AND POLARITIES OF MOLECULES	CHEMICAL BONDING	A RESEARCH PROBLEM–INERT (?) GAS COMPOUNDS	SYNTHESIS OF AN ORGANIC COMPOUND	MECHANISM OF AN ORGANIC REACTION	BROMINE ELEMENT FROM THE SEA	VANADIUM–A TRANSITION ELEMENT	HIGH TEMPERATURE RESEARCH	TRANSURANIUM ELEMENTS	BIOCHEMISTRY AND MOLECULAR STRUCTURE
CHEMISTRY AND YOU Baker, Bradbury, Eichinger, and Sigler Lyons and Carnahan, 1966	UNIT	3	3	6	5	3		7	7	7	6	6	11	4		5	5	4	5	*	13	13	9	14	14	10	17
	TOPIC	4	3	1	1	3		1	3	2	2	3	3	6		2	4	3	5		5	6	3	5	5	4	1
CHEMISTRY FOR THE SPACE AGE Posin and Shampo Lippincott, 1964	CHAPTER	6	6	6	6	2		13	13	13	13	11	13			6	19	8	8	16	20	20	15	17	17	3	22
CHEMISTRY IN ACTION Rawlins, Struble, and Gatewood D. C. Heath, 1961	UNIT							3	4	3					3									9	9		
	CHAPTER	11	4	25	35						20	21	24	41		13	15	15	15	9	30	30	36			47	32
CHEMISTRY: PRINCIPLES AND CONCEPTS Sturchio, Nechamkin, and Dorfman Prentice-Hall, 1966	APPENDIX																			XII							
	CHAPTER		7	14	5	8		16	17	16	14	15	20	8	5	4	4	5	5		23	23	20	19	19	19	23
CONCEPTS IN CHEMISTRY Greenstone, Sutman, and Hollingworth Harcourt, Brace, and World, 1966	CHAPTER	8	8	13	5	8 10	10	10	17	10	14	18	25	8		3	3	6	6	25	35	35	23	29	29	22	38
ELEMENTS OF CHEMISTRY Boylan Allyn and Bacon, 1962	UNIT																									8	
	CHAPTER	12	12	4	5	3		17	17	17	16	15	32	14 19		4	6 19	15	6	31	39	39	34	22	22		41
MODERN CHEMISTRY Metcalfe, Williams, and Castka Holt, Rinehart, and Winston, 1966	CHAPTER	10	9	13	5	11		20	21	20	14	22	28	11		4	5	12	6	*	18	18	30	26	26	31	19

Above chart shows where CHEM Study films can be used effectively with a number of popular texts some gases are chemically reactive, while others are inert. The fact that elements with atomic numbers one less and one more than the atomic numbers of the inert gases are highly reactive, provides the clue for finding the halogen and alkali metal families. The film demonstrates how atomic numbers have provided the key to the ordering of the elements in the periodic table. A suffix to the film demonstrates a recently discovered reaction between xenon and fluorine.

#4112 22 min. In color $165

MOLECULAR MOTIONS

Collaborator: Prof. J. Arthur Cambell, Harvey Mudd College, Claremont, California

Many properties of matter such as fluidity, vaporization and rates of chemical reactions, indicate that molecular motion must be occurring, and that the freedom of motion increases in going from the solid to the liquid to the gaseous state. The concepts of translational, rotational, and vibrational molecular motions allow the interpretation of the observed properties. The use of animation and dynamic models makes clear how the observed properties depend on the types of motion occurring at the molecular level.

#4115 13 min. In color $105

VIBRATION OF MOLECULES

Collaborators: Professor Linus Pauling, and Professor Richard M. Badger, California Institute of Technology, Pasadena. Produced in cooperation with the American Chemical Society.

All animation. The film shows the relationship between the structure of a molecule and its vibrational motions. Water, carbon dioxide, and methane are discussed in detail. The forms of the vibrations have been accurately calculated from spectral data. All vibrations have been slowed down by a factor of 10^{14}. The effect of molecular collision, or absorption of light, on molecular vibrations is illustrated. Determination of the number of possible vibrations and the analysis of complex vibrations in terms of simple harmonic motions are explained.

#4118 12 min. In color $90

INTRODUCTION TO REACTION KINETICS

Collaborator: Professor Henry Eyring, University of Utah, Salt Lake City. Produced in cooperation with the American Chemical Society.

All animation. The film illustrates the mechanisms of some simple chemical reactions. It explains the effect of temperature, activation energy, geometry of collision, and catalysis upon the rate of reaction. The reaction between hydrogen and chlorine, and hydrogen and iodine are used to illustrate the concepts of the film. The speed of the action has been slowed down by a factor of 10^{14}. Potential energy curves clarify the relationship between the energy required for a reaction to occur and the relative position of the reaction particles before, during, and after the collision.

#4121 13 min. In color $105

EQUILIBRIUM

Collaborator: Professor George C. Pimentel, University of California, Berkeley.

The film deals with three questions: What is chemical equilibrium? How does the chemist recognize it? How does he explain it? In answering the questions the film stresses the dynamic nature of equilibrium. Radioactive iodine tracers are used to demonstrate the dynamic molecular behavior of the substances at equilibrium in a closed system. An analogy in terms of fish population in two connected bowls, and animation using molecular models, present the concepts with striking simplicity.

#4124 24 min. In color $180

CATALYSIS

Collaborator: Professor Richard E. Powell, University of California, Berkeley. Produced in cooperation with the Manufacturing Chemists' Association.

The film emphasizes that catalysts are typical chemical reactants, being unique only in that catalysts are regenerated during the reaction. It demonstrates and interprets three simple catalyzed reactions: the decomposition of formic acid, using sulfuric acid as catalyst; the reaction between hydrogen and oxygen, using pure platinum as catalyst; and the reaction between acidified benzidine and hydrogen peroxide using peroxidase in human blood as catalyst. Animation shows what takes place on the molecular level in a catalyzed reaction. Potential energy curves show the relationship between uncatalyzed and catalyzed reactions.

#4127 17 min. In color $135

ACID-BASE INDICATORS

Collaborator: Professor J. Arthur Campbell, Harvey Mudd College, Claremont, California.

Proton-donor-acceptor theory is used to interpret the experimental behavior of acid-base indicators. Experiments and animation show the effects on indicators of changing acidity. Equilibrium constants of four indicators are determined and the indicators arranged in order of decreasing acid strength. The competition among bases for protons is shown by mixing the indicators and showing that each changes color at different total acidity.

#4130 19 min. In color $150

ELECTROCHEMICAL CELLS

Collaborators: Prof. J. Arthur Campbell, Harvey Mudd College, Claremont, California, and June S. Ewing, M.S., CHEM Study Staff.

The construction and operation of an electrochemical cell are shown. Time lapse photography of the changes at the electrodes, and animation of the cell processes show the nature of the electrode reactions, the motion of the electron and ion currents, and the relationship between concentrations and cell voltage. Extreme close-ups of a hydrogen electrode illustrate its operation and lead to a discussion of the table of E^0 values.

#4133 22 min. In color $165

NITRIC ACID

Collaborator: Professor Harry H. Sisler, University of Florida, Gainesville. Produced in cooperation with the Manufacturing Chemists' Association.

Nitric acid acts as an acid in the manufacture of chemical fertilizers; it acts as a base in the manufacture of nitro compounds; it acts as an oxidizing agent in many systems. In making the fertilizer, ammonium nitrate, from nitric acid, it is necessary to neutralize the acidity of HNO_3. This is accomplished by addition of NH_3. In nitration reactions, such as the making of nitrobenzene, nitric acid is made to act as a base in the presence of sulfuric acid and forms nitronium ion which is the reactive intermediate in the nitration reaction. As an oxidizing agent, nitric acid can be reduced to a number of different products. The temperature of the system helps to determine which reaction predominates. The manufacture of nitric acid is a process which starts with the oxidation of ammonia, and includes several steps. Le Chatelier's principle is applied in achieving a maximum yield of the acid.

#4136 18 min. In color $135

CRYSTALS AND THEIR STRUCTURES

Collaborator: Professor J. Arthur Campbell, Harvey Mudd College, Claremont, California.

Crystals have plane faces, sharp edges, sharp melting points, and may cleave easily to give new plane surfaces. Crystals also interact with x-rays to produce well-defined diffraction patterns. Such properties lead us to believe that crystals are composed of regular, repeating arrangements of atoms. The film raises the question of how we actually discover these arrangements. Experiments are then performed in a ripple tank on an unknown crystalline array so that the student sees the principles and measurements by which actual crystal structures are determined.

#4139 22 min. Black & white $120

MOLECULAR SPECTROSCOPY

Collaborators: Professor Bryce Crawford, Jr., and Dr. John Overend, University of Minnesota, Minneapolis.

The film uses laboratory experiments,

molecular models, and animation to show details of the infrared light absorption process and its relation to molecular properties. The film stresses the concept of natural vibrational frequencies in molecules. Further, it demonstrates the use of the infrared spectrum in identifying molecules and determining their molecular structure.

#4142 23 min. In color $165

THE HYDROGEN ATOM—As Viewed by Quantum Mechanics (standard version)

Collaborator: Prof. George C. Pimentel, University of California, Berkeley.

This film presents a description of the atom that is in accord with quantum mechanics. This description explains the energy levels and line spectrum of the hydrogen atom and furnishes the basis of contemporary theory of chemical bonding. The electron position in the atom is considered in terms of probability, and the meaning of a 1s orbital is clarified with a digital computer plot, two analogies, and animation.

#4148 13 min. In color $105

THE HYDROGEN ATOM—As Viewed by Quantum Mechanics (advanced version)

Collaborator: Prof. George C. Pimentel, University of California, Berkeley.

A 20 minute advanced version includes the complete content of No. 4148 plus a final section which contrasts the electron distributions of 1s, 2s and 2p orbitals. The principal quantum number, n, is introduced together with its relation to energy levels, number of orbitals and the number of nodal surfaces.

#4149 20 min. In color $150

PIMENTEL DISCUSSES THE HYDROGEN ATOM

This film was not made to be shown to students. It is a lecture by Prof. George C. Pimentel designed for teachers to reinforce background materials related to films #4148 and #4149 in the Film and Course Teachers Guides.

#4191 32 min. Black & white $150

IONIZATION ENERGY

Collaborator: Professor Bruce H. Mahan, University of California, Berkeley.

This film presents two methods of measuring ionization energy: photo-ionization, and electron bombardment. A high vacuum system is used with a simple conductivity cell. The photo-ionization of sodium by the use of a mercury light source and monochromator is carried out. The electron bombardment method is then demonstrated with gaseous sodium, and helium, argon and xenon. Animation shows what occurs on the atomic level during the ionization process. Relation of ionization energy to chemical reactivity is explained.

#4151 22 min. In color $165

SHAPES & POLARITIES OF MOLECULES

Collaborator: Professor David Dows, University of Southern California, Los Angeles.

Observations are made of electric effects, including deflections of streams of liquids by a charged rod, and changes in charging time of a capacitor. There is evidence that different molecules give two types of results: Some give very marked interactions with electric charges, while others give little effect. To explain these different results, a conceptual model is developed based on two types of molecules: Polar and non-polar. Consideration of bond polarity and molecular shape allows prediction of molecular polarity. The molecular dipole model is used to explain differences in solubility, conductivity, and chemical reactivity.

#4154 18 min. In color $135

CHEMICAL BONDING

Collaborator: Prof. George C. Pimentel, University of California, Berkeley.

This film explains chemical bonding in terms of the electric interactions that cause the bonding in the hydrogen molecule. The release of energy when H atoms combine to form H_2 on a platinum surface is shown. This energy change is related to the simultaneous attraction of electrons by two or more nuclei, opposed by electron-electron and nucleus-nucleus repulsions. Through animation, the quantum mechanical view of electron distribution is portrayed. The bonding interaction between two hydrogen atoms is contrasted to the very weak, non-bonding interaction between two helium atoms.

#4157 16 min. In color $120

PIMENTEL DISCUSSES CHEMICAL BONDING

This film was not made to be shown to students. It is a lecture by Prof. George C. Pimentel designed for teachers to reinforce background materials related to film #4157, in the Film and Course Teachers Guides.

#4192 27 min. Black & white $150

A RESEARCH PROBLEM: INERT (?) GAS COMPOUNDS

Collaborators: Prof. George C. Pimentel, University of California, Berkeley, California, and Dr. J. J. Turner, Cambridge University, Cambridge, England.

This film conveys the intense excitement and deep personal involvement of research in the stimulating context of the first synthesis of one of the inert gas compounds. An actual research problem, the first synthesis of krypton difluoride, is traced from its inspiration to the first tentative success. A train for the pyrolytic preparation of XeF_4 is shown. In extreme closeup, the colorful reaction of XeF_4 with water is displayed and a crystal of XeO_3 is detonated by tickling with a piece of tissue. Krypton difluoride is prepared by photolysis of fluorine in solid krypton at the temperature of liquid hydrogen and identified by its infrared spectrum.

#4160 19 min. In color $150

SYNTHESIS OF AN ORGANIC COMPOUND

Collaborator: Professor T. A. Geissman, University of California, Los Angeles.

The film shows the synthesis of 2-butanone, a ketone, from 2-butanol, an alcohol, as an example of a common type of organic synthesis. It discusses three basic steps: synthesis, purification, identification. In the synthesis, 2-butanol is oxidized by sodium dichromate and sulfuric acid to yield 2-butanone. Purification is accomplished by solvent extraction, followed by distillation of the 2-butanone. The identity of the product is established by forming a solid derivative of the 2-butanone and determining its melting point, and is confirmed by infrared spectroscopy.

#4163 22 min. In color $165

MECHANISM OF AN ORGANIC REACTION

Collaborators: Professor Henry Rapoport, University of California, Berkeley, and Dr. Philip Eaton, Department of Chemistry, University of Chicago.

A study of the hydrolysis of an ester, methyl benzoate, shows that the discovery of a reaction mechanism includes a determination of the chemical equation, the structures of the reactants and products, the fate of each atom of the reactants, and the structures of the intermediate molecules. The concepts of bond polarity and the effect of varying the structure of the ester also provide valuable hints. The use of oxygen-18 and its detection on a mass spectrometer provide critical experimental data for the mechanism of the hydroxide-catalyzed hydrolysis of methyl benzoate.

#4166 20 min. In color $150

BROMINE—ELEMENT FROM THE SEA

Collaborators: Prof. J. Leland Hollenberg, University of Redlands, Redlands, California, and James E. Magner, Dow Chemical Company.

The high chemical reactivity of bromine plus the high solubilities of bromine compounds result in most of the world's bromine being in the oceans. For this reason the chemistry of an aqueous solution of bromine is explored. The process for recovering elemental bromine from sea water is then developed on a laboratory scale. The essential steps are 1) oxidation of bromide ion with chlorine, 2) concentration by reduction with sulfur dioxide to hydrogen bromide, and 3) reoxidation followed by separation of the bromine by steam distillation. The same steps are then shown in an industrial bromine plant.

#4169 22 min. In color $165

VANADIUM—A TRANSITION ELEMENT

Collaborator: Professor Robert Brasted, University of Minnesota, Minneapolis.

Vanadium is studied as a typical transition element. The different oxidation states of vanadium and the corresponding colors are observed and then identified by means of a quantitative titration of vanadium (II) solution with cerium (IV) solution. The oxidation states and the observed colors are correlated with the electronic structures using an orbital board. The reaction with hydroxide ion and the formation of complex ions containing vanadium in different oxidation states are demonstrated. The variations in chemical properties are discussed in terms of ion size and charge density.

#4172 22 min. In color $165

HIGH TEMPERATURE RESEARCH

Collaborator: Prof. Paul W. Gilles, University of Kansas, Lawrence.

Why do we know more today than we did yesterday? One reason is that scientists engage in research. The excitement of discovering new knowledge through research is illustrated by studying the bond strength of gaseous titanium monosulfide. Its gaseous molecules as well as gaseous titanium and sulfur atoms are produced by the vaporization of the high melting crystalline titanium monosulfide at temperatures near 2000°K. The procedures for producing and measuring temperatures in this region are shown. A mass spectrometer identifies the gaseous species. Analysis of the mass spectrum gives the relative concentrations of atomic Ti and S, and of TiS molecules. A torsion effusion apparatus gives data on the total gas pressure at a series of temperatures. The partial pressure of each gaseous species is then calculated. Through LeChatelier's Principle, measurements at different temperatures give the bond strength of gaseous TiS. But at least as many new questions are raised as are answered. We don't run out of questions in research.

#4175 19 min. In color $150

TRANSURANIUM ELEMENTS

Collaborator: Prof. Glenn T. Seaborg.

This film, produced in the Lawrence Radiation Laboratory of the University of California, Berkeley, features four scientists who were principals in the discovery and identification of several of the transuranium elements. Glenn Seaborg reviews the historical problem of the placement of the transuranium elements in the periodic table. Burris Cunningham performs experiments showing that neptunium, plutonium, and americium have chemical properties similar to those of uranium, but that under the same experimental conditions curium behaves like its rare-earth homolog, gadolinium. Stanley Thompson demonstrates how the ion-exchange separation technique is used in identification, using actual solutions of curium, berkelium, californium and einsteinium. Albert Ghiorso discusses the methods used in the synthesis of elements 102 and 103, and proposes a similar type of reaction which may lead to the discovery of element 104.

#4178 23 min. In color $180

BIOCHEMISTRY AND MOLECULAR STRUCTURE

Collaborator: Dr. Donald E. Rounds, Pasadena Foundation for Medical Research, Pasadena, California.

The film demonstrates the role of molecular structure in determining biological activity. Correlation of the structure and biological activity of sulfanilamide with a vitamin essential for bacterial growth leads to a more general investigation of the biochemical nature of growth. Paper chromatography is used to separate some of the compounds which make up human cells. It is proposed that compounds similar to those found in cell chromosomes may stop cell growth and thus be useful in controlling cancer. The technique of time-lapse micro-photography is used to demonstrate the effect of one such compound, 5-FU (5-fluorouracil), on cancer cells.

#4181 22 min. In color $165

MLA FILMS ARE AVAILABLE IN THESE THREE WAYS

SUBSCRIPTION: A series subscription plan by which these films may be ordered for either a 3-school-day period or an 8-school-day period. Rates are based on the number of films ordered for the above periods. Rates are indicated in detail on the order form.

PURCHASE: These films are available for purchase as a complete series or by individual titles. Preview prints are available without charge to those contemplating purchase. Prices are indicated below each film description, quantity discounts are shown on the order form. NDEA funds may be used.

LEASE-TO-BUY: This film series, or titles of your selection, are available for purchase on a 3-payment plan. You pay $35\frac{1}{3}\%$ of purchase price for use of print for one year without obligation to renew. When you make two more payments of the same amount during the next two years, the prints become your property.

C-4

TEACHER TRAINING FILM PROGRAM

Purpose

To aid teachers teaching CHEM Study for the first time. . . . To provide helpful background for the experienced teacher.

To provide an opportunity to see and hear directly some of those distinguished chemists most influential in providing the spirit, philosophy and experience which have made it possible for CHEM Study to achieve its preeminent position in high school chemistry teaching.

Created to Meet a Teacher Training Need

This series of programs grew out of a need that developed in the City and County of Los Angeles when CHEM Study was adopted for the 1965–66 year. Many of the teachers had been unable to attend CHEM Study institutes and yet they were called upon to teach the CHEM Study program.

The series was televised so that all chemistry teachers in the city and county were able to participate. The success of the series was so great that the series has been made available as films which can be projected on any 16mm sound projector or can be televised on either open or closed circuit. (Special arrangements must be made with CHEM Study for open circuit televising.)

A summer or in-service institute devoted to intensive study of the CHEM Study materials is the ideal preparation for teaching the course. Where this is not possible, this series of films will be especially helpful, since they were prepared by those who have directed or participated in an official capacity in such institutes.

Related Reading Lists

Reading lists which provide references to the Text, Teacher's Guide and Film Teacher's Guide are provided. It is recommended that each lesson be used at weekly intervals. Teachers who do the recommended reading before each lesson can obtain a background of understanding which should prove valuable in the teaching of CHEM Study.

Program Content and Use

Each of the filmed lessons calls for approximately thirty minutes of viewing time. Thirteen of the programs introduce CHEM Study films, providing background and indicating how the films are integrated into the course. Since the total viewing time of each of these lessons is 29 minutes, a seven minute introduction indicates that the CHEM Study film to be introduced is 22 minutes in length. The price of each teacher training segment depends upon the length of the introduction. If you already have access to a print of the CHEM Study film which is introduced, that print may be used to accompany the introduction.

In some cases, in addition to the introduction, there is a conclusion which follows the CHEM Study film.

The segments may be spliced together (there are never more than three segments) or one may use two projectors—one projector showing the introduction and conclusion, if there is one, and the other projector showing the CHEM Study film. When two projectors are used, the necessity for splicing is obviated.

The remaining four films are complete lessons, and are not coupled with regular CHEM Study films. Two of the films consist of lectures by Professor George Pimentel developed especially to provide teachers with a background of understanding in principles—one relative to chemical bonding; the other to the quantum mechanical view of the hydrogen atom. These filmed lectures, lessons 8 and 12, run 32 and 29 minutes respectively, and there is no projection problem.

Two of the films are "feedback" or interview sessions. In these, high school chemistry teachers meet with and question in "Meet the Press" style, those scientists and teachers who were instrumental in developing CHEM Study. Each of the two "feedback" films has a running time of 29 minutes.

Those Who Appear in the Films

Professor George C. Pimentel—Editor of the CHEM Study Text, Chairman of the Chemistry Department, University of California, Berkeley.

Professor J. Arthur Campbell—Director of CHEM Study during its development, Chairman of the Chemistry Department, Harvey Mudd College, Claremont, California.

Dr. Aubrey L. McClellan—Editor of the Teachers Guide, Research Chemist, Chevron Research Corporation, Richmond, California.

Professor Henry Rapoport—Collaborator on the film "Mechanism of an Organic Reaction," Professor of Chemistry, University of California.

Dr. Richard J. Merrill—Former CHEM Study teacher and former Executive Director of CHEM Study; Curriculum Consultant, Mount Diablo Unified School District, Concord, California.

High School Personnel in the Panel Sessions

Mr. Gerald Garner
Los Angeles Secondary Science Center
Miss Margaret Henley
James Monroe High School—Los Angeles
Mr. Henry Kumada
Los Angeles High School
Mr. Lawrence Lynch
Beverly Hills High School
Mr. Orlando Powers—John Fremont High School—Los Angeles

David W. Ridgway—Producer

Lesson Descriptions

Lesson 1—TEACHER TRAINING INTRODUCTION to "Gases and How They Combine"

Professor Campbell briefly outlines the history of CHEM Study and emphasizes that the course is based on experimental evidence.

Professor Pimentel discusses why the concept of combining volumes of gases is used as the principal evidence for the atomic theory when it is first introduced. He explains CHEM Study's somewhat unusual approach to quantitative problems and suggests methods of teaching chemical symbols and equations.

#4003 12 min. (2 sections)
Black and white $65.00

Lesson 2—TEACHER TRAINING INTRODUCTION to "Chemical Families"

Professor Campbell discusses the background of the development of the periodic table pointing out that its correlations and regularities, while useful, are not perfect. He then illustrates the kinds of trends and relationships that are evident in periods and families, and among the elements surrounding any given element.

#4012 7 min. Black and white $40.00

Lesson 3—TEACHER TRAINING INTRODUCTION to "Reaction Kinetics"

Professor Campbell shows some chemical reactions and discusses them in terms of the concepts presented in the CHEM Study film. These concepts include collisions, orientation of the colliding molecules, and activation energy. The effect of concentration on reaction rate and the idea of the rate-determining step are demonstrated using the oxygen-dextrose-methylene blue system. The role of activation energy in breaking or weakening bonds of the reacting molecules is related to the reaction $2H_2 + O_2 \rightarrow 2H_2O$.

#4021 16 min. Black and white $90.00

Lesson 4—TEACHER TRAINING INTRODUCTION to "Catalysis"

Professor Pimentel emphasizes the importance of reaction rate in determining the utility of chemical reactions. The reaction $H_2 + I_2 \rightarrow 2HI$ is discussed in terms of activation energy and collision geometry. The reaction $4HBr + O_2 \rightarrow 2H_2O + 2Br_2$ is shown to proceed by a series of two-particle collisions. The reaction $2I \rightarrow I_2$ is used as an example of a reaction in which a third particle must be involved in the collision to carry off the energy, or an alternate reaction path must be provided. The role of I_2 in catalyzing this reaction is explained.

#4027 13 min. Black and white $70.00

Lesson 5—TEACHER TRAINING INTRODUCTION to "Equilibrium"

The treatment of equilibrium in CHEM Study is characterized by emphasis on the quantitative aspects and on the dynamic microscopic processes involved. Professor Pimentel demonstrates that in order to explain equilibrium, one needs not only the idea of a tendency toward minimum potential energy, but also the idea of a tendency, implemented by temperature, toward greater randomness.

#4024 7 min. (2 sections)
Black and white $40.00

Lesson 6—TEACHER TRAINING INTRODUCTION to "Electrochemical Cells"

Dr. Merrill discusses the structure of Chapters 7–12 of the CHEM Study text in which reaction energies, reaction rates, and equilibrium are introduced and then applied to systems of solubility, acid-base, and oxidation-reduction.

#4033 8 min. Black and white $45.00

Lesson 7—TEACHER TRAINING INTRODUCTION to "The Hydrogen Atom—As Viewed by Quantum Mechanics"

Professor Pimentel emphasizes the advantages of the quantum mechanical model of the atom, as presented in the classroom film, over the planetary model. He discusses the relationship of quantum number to the spatial distribution of the electron in the one-electron atom. He then considers the screening effect of electrons at lower energy levels upon those at higher energy levels, and the relationship of the quantum states of the electrons to the periodic table.

#4049 9 min. (2 sections)
Black and white $50.00

Lesson 8—PIMENTEL DISCUSSES THE HYDROGEN ATOM

This lecture was especially prepared because CHEM Study's treatment of this subject differs substantially from that of many "conventional" high school courses. Professor Pimentel discusses the shortcomings of the planetary model in terms of its inconsistency with experiment and with quantum mechanics. He then gives a basis for understanding the significance of the Schroedinger equation. The film emphasizes the desirability of teaching an up-to-date, useful model of atomic structure rather than an easy, incorrect model which students find hard to unlearn.

#4191 32 min. Black and white $150.00

Lesson 9—A PANEL FEEDBACK SESSION (Midway in Course)

A panel of CHEM Study staff members and high school teachers discuss questions raised by teachers who were using the CHEM Study materials and participating in the in-service training program. The topics include difficulties in teaching the concepts of uncertainty and measurement, teacher preparation and institutes, further applications of the concept of randomness, the use of models, some specific laboratory techniques, an evaluation of student achievement, the use and grading of laboratory reports and standardized texts.

#4050 29 min. Black and white $150.00

Lesson 10—TEACHER TRAINING INTRODUCTION to "Ionization Energy"

Professor Campbell demonstrates the usefulness of the electron energy level chart and points out that ionization energy data provide some of the important evidence upon which the chart is based. In a novel way he shows the familiar flame test for sodium and uses the energy level chart to identify the energy change responsible for the yellow color.

#4051 8 min. Black and white $45.00

Lesson 11—TEACHER TRAINING INTRODUCTION to "Chemical Bonding"

Professor Pimentel emphasizes the general application of the explanation for bonding as developed in the course and as presented in the CHEM Study film. He uses the virial theorem to explain why the change in potential energy rather than in kinetic energy must be the dominant factor accounting for bonding. Using the molecule H_2^+ he explains why "exchange forces," magnetic interactions due to spin, and other electron-electron interactions cannot account for bonding. He discusses the use and misuse of the term "overlap" in discussing bonding, and touches upon a few of the ideas associated with molecular orbital theory.

#4057 14 min. (2 sections)
Black and white $75.00

Lesson 12—PIMENTEL DISCUSSES CHEMICAL BONDING

Professor Pimentel amplifies the idea that attraction of one or more electrons for two or more nuclei accounts for bond formation. The virial theorem is presented and used to show that the lowering of the electron's total energy in bond formation can only occur through a lowering of its potential energy by being simultaneously near two or more nuclei. This principle is shown to apply equally well to covalent, ionic, and other types of bonding.

#4192 27 min. Black and white $150.00

Lesson 13—TEACHER TRAINING INTRODUCTION to "Crystals and Their Structures"

Professor Campbell demonstrates the uses and limitations of some styrofoam models. He uses models representing solid krypton, silver, gold, iron, ice, sulfur (S_8), solid carbon dioxide, diamond, and graphite. He relates some of the properties of these substances to their structures as illustrated by the models. The CHEM Study film then goes on to show some of the experimental evidence upon which such models are based.

#4039 7 min. Black and white $40.00

Lesson 14—TEACHER TRAINING INTRODUCTION to "Vanadium—A Transition Element"

Using chromium as an example, Professor Campbell shows that the transition metals are characterized by valence electrons in closely spaced energy levels. He then comments upon the difference in color between aqueous chromium nitrate solution and aqueous chromium chloride solution. The color difference and the incomplete precipitation of chloride from the latter solution is related to the formation of complex ions.

#4072 7 min. Black and white $40.00

Lesson 15—TEACHER TRAINING INTRODUCTION to "Mechanism of an Organic Reaction"

Professor Rapoport discusses the importance to the organic chemist of general principles which apply to chemistry as a whole. He stresses the importance of understanding the relationship between structure and properties and of understanding reaction mechanisms. He reviews some of the means that have been used by organic chemists to determine mechanisms, such as substitution of tracer isotopes and the modification of molecular shapes. These techniques are utilized in the classroom film.

#4066 9 min. Black and white $50.00

Lesson 16—TEACHER TRAINING INTRODUCTION to "Biochemistry and Molecular Structure"

Professor Campbell explores relationships between structure and properties found in biochemical systems. He relates the stiffness of plant tissue, which is primarily carbohydrate, to the abundance of hydrogen bonds between molecules. He contrasts this with the suppleness and relative scarcity of hydrogen bonds between the protein molecules of which animal tissue is largely composed.

#4081 7 min. Black and white $40.00

Lesson 17—A DISCUSSION AMONG TEACHERS AND THE CHEM STUDY STAFF—Concluding Panel Session

Topics discussed in this panel session include the ability range of students for whom the CHEM Study materials are designed; problems some students have with quantitative concepts and manipulation of numbers; performance of CHEM Study students in freshman college courses; the rationale for presenting atomic theory and bonding late in the course; the possible effects of a detailed teacher's guide on teachers' creativity and initiative; the minimum content of the course that should be taught in a year's time; security of the testing materials; ideas for central distribution of the laboratory material; and the desirability of teachers getting together several times during the year to compare problems and share ideas.

#4082 29 min. Black and white $150.00

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COLLATERAL READING LIST FOR TEACHER TRAINING PROGRAM

Reading assignments from the CHEM Study text, Teachers Guide, Laboratory Manual, and the Teacher's Guide to the CHEM Study Films correlate with each program. The teacher who reads the assigned materials, as the series progresses should be greatly aided in teaching the course. The CHEM Study Staff recommends that participants in the Teacher Training Program complete the following collateral reading assignments before each viewing session. The article "CHEM Study—Implications for the School Counselor" (CHEM Study Newsletter, May, 1964*) will also provide useful information about problems frequently encountered in teaching the course, as will a nineteen minute, color film "CHEM Study: Information for Educators." This 16mm sound film may be borrowed, without charge, from MLA.

Key to References: Text—Chemistry—An Experimental Science, CHEM Study, 1963
TG—Chemistry—An Experimental Science Teacher's Guide, CHEM Study, 1963
TGF—Teachers Guide to the CHEM Study Chemistry Films, CHEM Study, 1964

Lesson	*Title*	*Reading*
1	Gases and How They Combine	Text: pp. vii–ix (Foreword) and 1–61 (Ch. 1–4) TG: pp. 1–13, 39–49, 55–61, 75–84, 96–99, 109–110, 119–123, 135–138 TGF: #4103, 4106
2	Chemical Families	Text: pp. 65–104 (Ch. 5–6) TG: pp. 149–154, 167–176, 187–199 TGF: #4109, 4112
3	Reaction Kinetics	Text: pp. 108–139 (Ch. 7–8) TG: pp. 209–214, 225–230, 239–245, 255–264 TGF: #4115, 4121
4	Catalysis	Text: pp. 179–230 (Ch. 11–13) TG: pp. 335–340, 353–362, 371–377, 387–393, 407–409, 419–421 TGF: #4130, 4133, 4136
5	Equilibrium	TGF: #4127
6	Electrochemical Cells	Text: pp. 142–176 (Ch. 9–10) TG: pp. 273–279, 289–296, 309–313, 319–323 TGF: #4124
7	Hydrogen Atom as Viewed by Quantum Mechanics (Advanced)	Text: pp. 233–272 (Ch. 14–15) TG: pp. 435–439, 451–461, 475–486 TGF: #4142, 4149
8	Pimentel Discusses the Hydrogen Atom	Text: Review pp. 252–267 (Ch. 15) TG: pp. 487–500
9	A Panel Feedback Session (Midway in Course)	No collateral reading

* A copy of the Newsletter or additional copies of this reading list may be obtained from Modern Learning Aids, 1212 Avenue of the Americas, New York, N. Y. 10036.

Lesson	*Title*	*Reading*
10	Ionization Energy	Text: Review pp. 267–272 TG: Review pp. 499–500 TGF: #4151
11	Chemical Bonding	Text: pp. 274–297 (Ch. 16) TG: pp. 511–518, 523–538 TGF: #4157
12	Pimentel Discusses Chemical Bonding	Text: Review pp. 274–297 (Ch. 16) read pp. 300–317 (Ch. 17) TG: Review pp. 525–538 read pp. 549–555, 563–574
13	Crystals and Their Structures	Text: Review pp. 248, 300–317 (Ch. 17) TG: Review pp. 565–572 TGF: #4139, 4160
14	Vanadium—A Transition Element	Text: pp. 387–409 (Ch. 22) TG: pp. 633, 697–703, 723–727 TGF: #4172, 4178
15	Mechanism of an Organic Reaction	Text: pp. 321–349 (Ch. 18) TG: pp. 587–595, 613–621 TGF: #4163, 4166
16	Biochemistry and Molecular Structure	Text: pp. 421–435 (Ch. 24) TG: pp. 745–751 TGF: #4181
17	A Discussion Among Teachers and the CHEM Study Staff (Concluding Feedback Session)	No collateral reading

D

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E

American Chemical Society Ad Hoc Committee (1959) on Possible Organization of a High School Chemistry Course (excerpts from report)

Chairman: Alfred B. Garrett, Professor of Chemistry, The Ohio State University
Bryce Crawford, Jr., Chairman, Department of Chemistry, University of Minnesota
Farrington Daniels, Chairman, Department of Chemistry, University of Wisconsin
Edward C. Fuller, Chairman, Department of Chemistry, Beloit College
Leonard K. Nash, Professor of Chemistry, Harvard University
Robert L. Silber, American Chemical Society

PART I—SOME GUIDELINES

1. We desire a searching reexamination of the purposes and content of the present chemistry course from which reexamination a drastically improved course might emerge.

2. Ideally, we wish some plan of action that will make possible better correlation of high school and introductory college chemistry courses.

3. Ideally, we want some plan of action that will benefit all high school students of chemistry regardless of their previous preparation, ultimate destination, and innate capacity.

4. Ideally, we conceive action in terms of some program of maximum flexibility —one that permits experimentation; one that allows for local variations depending on local facilities and on the interests and capacities of the high school teacher and his students.

5. Ideally, a plan of action will include attention to such considerations as the in-service training of high school teachers, improved laboratory programs, improved demonstrations, such as the exploration of new teaching tools, the motion picture and film strip, the development of new testing instruments, and so on.

6. We realize that the desires for flexibility and for better coordination pull in opposite directions; for with maximal variation in high school courses, the problem of coordination is impossible of solution; while determined action to improve coordination is bound to restrict the possibility of local variation. Ideally, we

must find some reconciliation between the desires for flexibility and for coordination.

7. We recognize that the content of the high school course tends to grow by accretion. New topics are introduced to ensure "modernity" and to enlist the students' interest. But older topics are seldom dropped; their place is secured by a conservative tradition enforced by the College Entrance Examination Board and the state boards of education. A major improvement in the high school chemistry course might then be expected to result from identification *not* alone of topics newly to be *added* to it but, perhaps, more importantly of presently treated topics that might be *dropped* from it. Were this the finding of a group backed by the prestige of a national professional organization, a successful approach to the CEEB and to state boards of education might then be possible. Such success would make possible more extensive experimentation on improved curricula.

8. A reduction in the total number of topics covered would make possible a deeper penetration on narrower fronts. As a result the students' grasp of chemistry and of the nature of scientific reasoning and experimentation might be vastly improved.

9. A reconstruction of the high school curriculum *by reduction* demands the greatest imagination: imagination to see the dispensability of topics that have long enjoyed a secure place in that curriculum. Yet it is only with recognition of the dispensability of such topics that any new topics can be added successfully or deeper penetration and understanding achieved on narrow fronts. Recall Livingstone's dictum that "the good schoolmaster is known by the number of valuable subjects that he declines to teach."

10. The committee does not assume itself competent to do this job alone. It needs the suggestions and help of other chemists and teachers.

PART II—THE PROPOSAL

We conceive the possibility of a high school course in chemistry with a solid core that would require $\frac{1}{2}$ to $\frac{2}{3}$ of the time in the present average high school chemistry course. We conceive that this core could be developed in various ways, at local option. To vary the metaphor, we conceive of a skeleton course that could be fleshed out in various ways. Imagine a course that develops fully and carefully the central principles of chemistry. Conceive a basic textbook that meets the needs of such a course. And consider the possibility that for such a text there would be provided a variety of paper-bound addenda—keyed to the textbook—that carry on from the solid core either by additional topics and principles, or by going still more deeply into one or more of the principles that form the solid core.

The high school teacher could then guide his selection of one or more of the addenda according to the availability of facilities and according to his own and his students' interests and capacities. For a group of poor students he might elect simply to teach the solid core itself; he would then teach relatively little, but there would be time to teach the central principles thoroughly. With more gifted students, addenda might be selected according to the previous preparation, ultimate destinations, and innate capacity of the class as a whole. But note that with the availability of the multiple addenda individual students might to some degree be treated individually. Individual variation would be possible; local variation certain.

Yet each classroom group would share the same solid core of material across each state and across the nation. The college instructor could then be certain, as he cannot be at present, that certain topics have been treated very carefully at the high school level. Testing instruments of the CEEB and of state education departments could then also be devised with the solid core of essential principles as the focus of primary concern.

We do not envisage the preparation of a single authoritative text and set of addenda, though the preparation of one sample of such an assembly might well be a project worthy of an interested group. There could be many texts and addenda if all shared the same conception of the solid core. The text(s) would have to be revised less frequently than at present, treating as they would, only of the secure foundations of modern chemistry. The addenda would no doubt need more frequent revision to keep pace with recent advances. At present one can easily conceive addenda treating such topics as the following:

Atomic structure and orbitals
Bonding and molecular stability
Industrial chemistry and its economic connotations
The chemistry of everyday life
Biochemistry, etc., etc.

F

Steering Committee Agenda, January 9, 1960

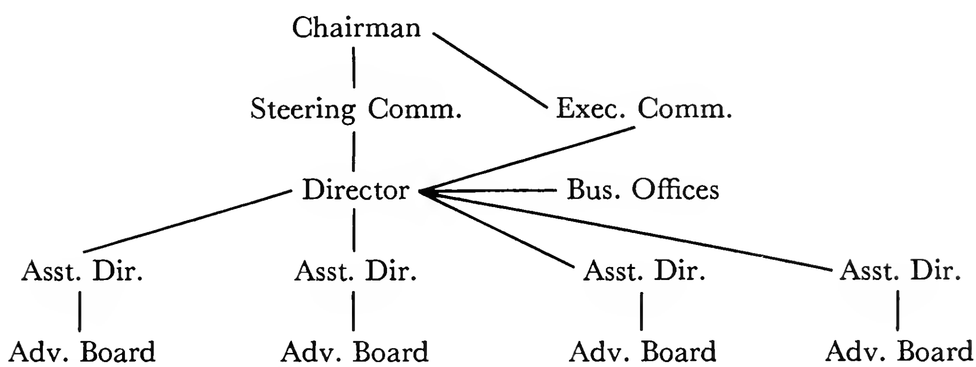
January 9:	9:00 A.M.	Convene at University House
	12:30	Lunch
	1:30 P.M.	Reconvene
	5:30	Adjourn

AGENDA ITEMS (*Asterisked items seem to need most discussion.*)

A. Introduction and History
   1. Other current projects of similar nature
   2. Present proposal to NSF by CHEM Study*

B. Objectives*
   1. Elementary, secondary, higher, and graduate schools
   2. Average and gifted students
   3. Terminal and professional students

C. Organization



D. Liaison with schools*
   1. Administrative-national, state, local, school
   2. Teacher-professional organizations, individual
      a. NSTA
      b. Summer and academic year Institute Directors
      c. Metropolitan school districts
      d. Private schools
      e. Council of Chief State School Officers
      f. Division of Chem. Educ., ACS
      g. College admission offices
      h. Visiting scientist program
      i. Local sections, ACS
   3. Geographical distribution

E. Teacher preparation
   1. Summer conferences
   2. Academic year contacts—staff, local individual
   3. Teachers of teachers

F. Textual material
   1. Preparation—number of writers, composition of groups*
   2. Media and format
   3. Copyrights
   4. Recompense of authors
   5. Organization and coverage*

6. Commercial publications—editorial services
7. Addenda—optional material
8. Experimental emphasis
9. Chemical systems
   a. Atomics, molecules, structure
   b. Dynamics
   c. Systematics
   d. One element of family thoroughly treated

G. Monographs
1. Organization and coverage
2. Integration with textual material
3. Copyrights
4. Recompense for authors

H. Films
1. to 4. As under monographs
5. Animation, lecture, experiments, industrial

I. Experiments—lecture and laboratory*
1. Extent of directions
2. Time requirement (length of laboratory period)
3. Equipment requirement (purchase and storage)
4. Safety
5. Lab design
6. Pre-packaged chemicals, "pills"

J. Teaching machines
1. Projectors
2. Television
3. Learning machines

K. Testing and Evaluation*
1. National examinations
2. Feedback
3. Design of experimental approach

L. Distribution of information
1. Newsletter
2. Trial material
3. Extent

M. Calendar of operations

January 9—Steering committee

March—International Conference on Chemical Education, Ireland, two weeks

April 3—Steering committee, one day—First conference of contributors

June–July—Second conference of contributors, six weeks

August—First conference of participating teachers, four weeks

Academic year, 1960–61—First trial in secondary schools; Feedback, preparation of further materials; Attempt to have project in full swing in two years, tapering somewhat after three years.

N. Budget*
 1. Current proposal
 2. Proposal for 1960–61 (April meeting)

G

Organization and Content

G-1

A POSSIBLE ORGANIZATION FOR A HIGH SCHOOL CHEMISTRY COURSE

By J. Arthur Campbell, Director, Chemical Education Material Study

January 22, 1960. The initial assumption is that the course is *designed for the same general level of students now taking high school chemistry.* That is, it will be given students who are largely in the upper half of the intelligence and ability group in this country. We should remember that this may be the last science course for a large segment of the group, that it should build toward a college science course in another segment, and that it should serve as a reasonable presentation of science for those who should seriously consider a professional future in any scientific field. The exceptionally gifted student will be taken care of by the basic material in the course plus a considerable amount of addenda such as monographs and special experiments.

The course should have a *strong experimental basis* even though this may involve a fair degree of change in present scheduling practices in the high schools and in the emphasis used in the regular class period. It is difficult to perform real experiments in 40 minutes of laboratory, or to set up lecture experiments with current teaching loads.

The experimental approach seems highly desirable since chemistry is a science which deals with things as well as with ideas, and it has been rather well established that students remember much longer what they see and physically manipulate than they do those things concerning which they have only discussions. I would also suggest that the experiments be *real experiments rather than demonstrations.* The student should not, in general, know the answer to the experiment before it is begun, but should be able to make discoveries during the performance of the experiment. The experiment should be simple and each experiment preferably should lead to a clear understanding of one or a few points rather than involving several ideas simultaneously. This would be particularly true at the beginning.

The design of these experiments both for the laboratory and the lecture part of the course is not the subject of the present discussion, but well may constitute a most important part of the overall program.

The following organization of the course into six basic sections is based partly on present educational practice of having "units" in high school courses, partly on the fact that I do not conceive of the possibility of a course covering all of chemistry intensively, partly because I believe that most present high school courses are much too extensive in nature but would profit from a deeper coverage of fewer topics, and partly from the desirability of being able to break up the writing of the material among several groups of contributors.

The six parts are labeled, (1) Introduction, (2) an introduction to *Structural Chemistry*, including atomic, molecular, and macromolecular structures, (3) an introduction of *Chemical Dynamics*, (4) an introduction to *Systematic Chemistry*, (5) a rather intensive study of the chemistry of a single element, or family of elements, and (6) a review paper of some area of current chemical interest. The subjects are deliberately broad and vague at this point and will probably remain so in spite of the following discussion. The only realistic step, I believe, which can be taken at this time is to *suggest an organization to the contributors and then let the actual writers work out that organization* which best fits into their own capabilities and enthusiasms. I would not want to defend vigorously the distribution of the six parts nor the actual six areas which are discussed below.

Part I. *An Introduction to Chemistry*

Many students are introduced to chemistry by definition of the subject and by a theoretical or trivial approach which sometimes represents a "Gee Whiz" school of chemistry. If *an actual chemical system*, such as Faraday's candle or a simple gas flame, or a corroding piece of iron or some other system which is already *known to the student, but not understood by him to be used*, so that he gets an experimental as well as a theoretical overview of what he is going to study in the rest of the course, the balance of the course should fall into place better. I would suggest that this section might be one or two chapters long and that it be primarily designed to give a realistic view of the fields of interest to the chemist, as well as to raise in the student's mind the questions which the rest of the course will partially answer, but also questions to which current answers are unknown. The *main goal* might well be *not so much to introduce a student to chemistry but to give him a feeling for the types of problems which are of scientific interest* and which can be handled in scientific ways, *and*, preferably, a feeling for *the general methods which are useful in attempting solutions* to problems discovered in this way.

Part II. *Structural Chemistry, Including the Structure of Atoms, Molecules, and Macromolecular Substances*

No contemporary approach to chemistry can neglect, without serious hindrance, *the advantages of a structural interpretation of chemical properties and chemical reactions.* Having discussed a chemical system in a general way in Section I, this section, I believe, should introduce the main structural ideas. The emphasis ought to be on an experimental approach to the subject and might begin, for example, with Brownian motion, the electron microscope, the electron emission "microscope," and the heterogeneity shown by X-ray diffraction. I do not believe that an introduction by way of weight relations is the best approach to atomic and molecular theory. I would rather approach it by what I think is a more straightforward system in light of current experimentation, i.e., through microscopy of one sort or another.

The experimental distinction between elementary substances and compounds might then be followed by a discussion of the packing of atoms in a cubic structure such as a metal and the interpretation of the bulk properties of metals in terms of the packed atoms and the way they can move and react under stress. From this and electrical properties the constitution of elementary substances might be developed together with nuclear ideas. Isotopes could be introduced. All these atomic structural ideas should be tied in to direct experimental evidence at a level which the student is capable of comprehending. The polyatomic and macromolecular nature of other of the elementary substances would then follow in a straightforward fashion. This might lead to a discussion of the crystalline, liquid, and gaseous states. The particularly simple relationships in gases between the variables—pressure, volume, temperature, and number of molecules—would serve as an introduction to the quantitative measurements and calculations possible in a scientific subject.

We might then return *from* our *macroscopic investigation of structure and states* of matter and behavior of the gaseous state *to a microscopic investigation of the forces acting* between atoms and molecules. The continuous gradation in so-called "bond types" throughout all chemical substances would be emphasized and the experimental distinctions used as a basis for showing the desirability of having some general classification. These classifications might well be based on the electrical properties of matter, the mechanical properties of matter, their behavior on boiling and melting, and the experimental internuclear distances found in the various states of the substances.

From the development of the general types of bond classifications based on experimental observations one could go to the truly microscopic level of interpretation of these bond types in terms of electron structures. Various alternative depths of penetration into bond theory are possible at this point. I would personally argue, though not strongly, for the use of a rule of two in the formation of chemical compounds, that is for pairing of electrons. I would feel that we could easily introduce, from the experimental point of view on ionization energies the concept of sub-levels to the extent of s, p, d, f, and so on, orbitals. I do not believe that we should at this level go into molecular orbital rotation, but do feel that one should point out atomic orbitals apply strictly only to isolated atoms and that one can expect some complications arising when two atoms are very close to one another as they are in a molecule or in a condensed phase.

This section might close with the investigation of the chemistry of some common substances, and the interpretation of chemical formulas, obtained on a weight basis, in terms of electron structures. The interpretation of their chemical and mechanical properties in terms of packing and the nature of the forces between the entities present in the substance would serve as a means of tying together the material at this point.

I am suggesting, therefore, that weight relations be introduced as an experimental method of determining composition using the ideas of atoms rather than that weight relations be used to indicate the existence of atoms as was historically done. I do not see any great merit in discussing percentage composition and would suggest that almost all weight relations be based on experimental weight data and calculations which can be done with these experimental data.

Part III. *Dynamics of Chemical Systems*

I believe the biggest lack in contemporary high school chemistry is a discussion of the dynamics of chemical systems. Because of this lack, it is very difficult to study actual chemical reactions in a realistic fashion and I feel that we could make a major contribution by *studying chemical systems from a dynamic point of view rather than in terms solely of the over-all reaction.*

Two central ideas that would seem profitably presented in this section *are the kinetic mechanism of the chemical reaction, and the drive toward more and more stable systems in chemical reactions.* By the first, I mean that reactions can occur only upon collisions of molecules and that the actual mechanism may involve a very complicated series of steps in order to accomplish the overall change. By the second I mean that each of these steps occurs because a more stable system is formed than was initially present.

I would present the second phase in terms of competitive reactions which would lead to a consideration of the equilibrium state. The importance of energy in chemical reactions would be stressed throughout, and as many reaction energies as possible would be included in the equations for the reactions.

I hold no brief at this time as to whether the dynamics should be approached through a kinetic and mechanistic emphasis initially, leading to equilibrium, or whether the ideas of competitive reactions in the equilibrium state would lead backwards to a study of the kinetics and mechanisms. I am not sure whether it is more important for the student at this stage to be able to balance an over-all chemical equation initially and then go on to mechanisms and equilibrium or whether he might be introduced to dynamics on an atomistic and molecular level and then be lead to balancing over-all chemical reactions. It might even be worth while putting off any discussion of weight relations until this section of the course, so that weight relations would be tied in with the idea of an over-all reaction and it would be clearly indicated that the weight of material one got starting with any particular set of initial weights depended on equilibrium conditions as well as the equation for the net reaction.

Part IV. *Systematic Chemistry*

This section might be most quickly characterized as a *tour of the periodic table with emphasis placed on stops at the scenic spots.*

One might present the periodic table as based on the structural ideas developed in Part II, and show how the discovery of the elements historically fits in with the structural interpretations. The inert elements in the central portion of the periodic table were known in ancient times because they occurred free in nature. Inert gases were not discovered until rather late in the game because of their lack of compound formation, and the radioactive elements even more recently because of their scarcity in natural materials. Relations both in the rows and columns of the periodic table would be discovered experimentally by the students and would be discussed in terms of their structural interpretation. The limitations of the periodic table as a means of correlating chemical knowledge would be pointed out as well as its strengths.

An *introduction to acid-base theory and to oxidation-reduction* might well come at this point. *The similarity between these two ways of looking at chemistry* could be developed.

The main emphasis, however, would be to show *the value of* a device such as the *periodic table in reducing a very large amount of information to a small compass.* A considerable number of examples of trends in properties with changing atomic number would be used, and the student would be encouraged to predict the properties of elements with which he was completely unfamiliar using the periodic table as a correlating device.

Part V. *An Intensive Study of the Chemistry of a Single Element or a Family of Elements*

I would not argue strongly for any particular element or family at this point. I think that there is considerable merit in not labeling the section organic chemistry, nor labeling it chemistry of carbon. My initial suggestion would be to talk about nitrogen and the nitrogen family, and in the process to develop most of the ideas which are useful in organic chemistry including the chemistry of many compounds which have a carbon skeleton and nitrogen functional groups. I think that concentrating on a few functional groups such as this might greatly enhance the material at this time and still allow one to show the complexity which comes in to a subject such as organic chemistry without specifically calling it that.

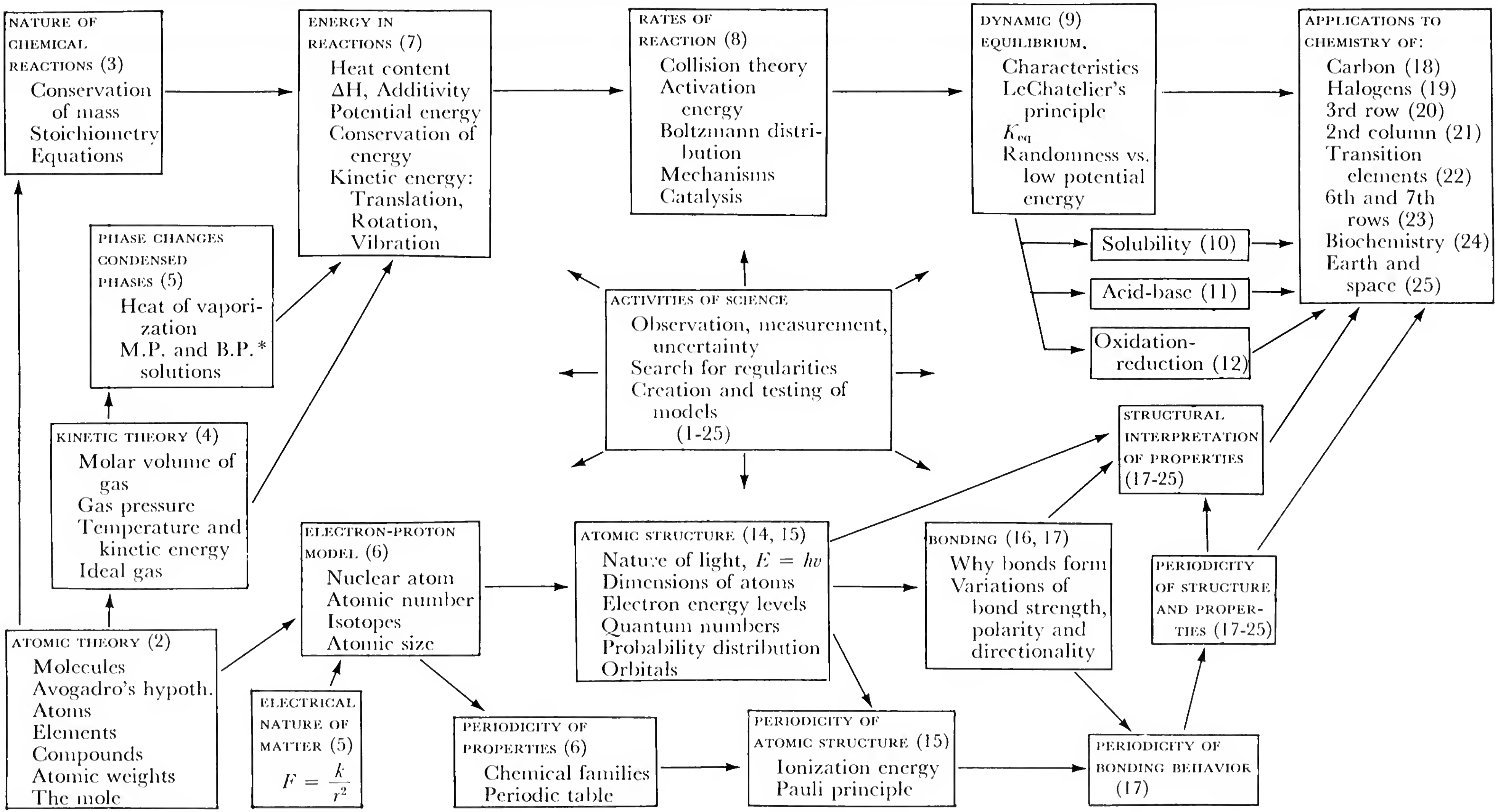
I would suggest, as a general aim for this section, *a rather intensive development of the chemistry of the element*, for example, nitrogen, *terminating in the field of biochemistry.* It has been my experience that students are as interested in biochemical ideas as in any field of chemistry.

The field of biochemistry offers the great advantage of tying together essentially all of the ideas which have been presented in the course so far, and of doing it in systems which are of "vital" interest to beginning students. Structural ideas, the dynamics of chemical systems, the generalizations based on the periodic table, and the specifics as brought out in this last section on the chemistry of a single element or its family, all can be combined in a biochemical discussion.

Part VI

This section might not be numbered formally, but I believe the book ought to close with a discussion of what has been attempted over-all, and this discussion should not really be formal, but that *some idea or set of ideas should be presented drawing on the materials* which have been covered in the other five sections. This would allow the student to look back over the course and see it as an entity rather than as a set of isolated sections or units. He would have a feel for some particular problem presented from this point of view. I have no strong suggestion at this point as to what might be included in Part VI, but it occurs to me that it might be a review article by some outstanding scientist of a field of relatively current research on the general level of an article in the Scientific American. It would require the background presented in the first part of the book for its comprehension. It might, for example, be an article on the history of the universe and the world and its bearing on the origins of life, all presented from the standpoint of chemistry. It should emphasize not only what is based on strong evidence in current terms, but also on what is uncertainly known and on what the basic assumptions are in making the deductions used in arriving at the over-all picture.

I would hope to *leave the student at the end of the course with a feeling for both the power and limitations of science, with a feeling for what current ideas and methods are accomplishing; but even more, with an understanding of the inevitability of change in scientific thinking and a realization that it is possible even for a non-scientist to keep abreast, in a general way, of these changes if he has a feeling for the basic methods, ideas, and facts used by scientists.*



(*melting point and boiling point)

Appendix G-2

FLOW CHART OF CHEM STUDY CONTENT

H

Letter from Glenn T. Seaborg to Proposed Contributors, February 1960

Dear _______________:

As you may have heard, the University of California under my Chairmanship is undertaking a Chemical Education Material Study primarily concerned with the organization of a high school chemistry course. It is our plan to investigate the production of textual material, laboratory material, monographs, and films, and to investigate any other areas which we feel have a direct connection with the effectiveness of chemistry in the high school curriculum.

This is a major project on which we have embarked with a very ambitious time schedule. The general calendar of operations envisages a meeting on April 2nd, 3rd, 4th, and 5th in Claremont, California, of a group of potential contributors to the project. This meeting would allow these men to get acquainted with one another, to discuss the mutual problems, to divide it among themselves so that the area to be discussed and time required by each person can be well defined and kept in manageable proportions. This group would then return to Claremont for six weeks, June 18th to July 30th, to produce the written materials and laboratory experiments which would be used in a set of high schools for testing during academic year 1960–61.

There will be a meeting in August in Claremont of high school teachers who will be using this material. During the academic year, the teachers will be in contact, at least once a week, with a staff member of the project to discuss problems and provide feedback into the project so that the following summer materials with higher order of worth may be produced.

We are quite agreed, even at this stage, that it may be impossible this summer to produce material of sufficiently high standard to satisfy the contributors. If this should be so, and the contributors are unsatisfied with the results, we shall not have any trial in the high schools during the coming year. On the other hand, there is evidence from the progress other studies have made and from our own planning that we can indeed produce material of high quality for trial during this coming year. If so, we gain a whole year of evaluation and information that will be invaluable in preparing better material for the following year.

This rapid time schedule and the scope of the project will require changes in the personal plans of many of the top flight chemists in this country if it is to succeed. I think you would be interested to know that every member who was invited to join the Steering Committee of the project (except one person who will be out of the country) was able to accept, has given generously of his time to it, and plans to continue. I am enclosing a list of the Steering Committee members so that you can see the type of professional advice which the project will have.

Many of these men know you personally, and it was the unanimous agreement that we would like to have you as one of the contributors meeting in Claremont in April and again for six weeks in the summer. We quite appreciate that this may indeed involve a major change in your plans for either of these periods, but we are convinced that the worth of the project, its potential in the high schools, and, indeed, in science and chemical education in general in this country, is so great as to merit serious consideration of really large changes in personal plans for the future, changes which I trust that it will be possible for you and your family to make in light of the circumstances.

The general plan of organization is to have writing teams of two or three people composed of, for example, a professional chemist and a first-rate high school teacher. These two will act as checks on one another and will select a particular area for their own writing. Top-flight editorial assistance will be available, as well as a full corps of stenographic and other help, to minimize the chore part of the writing. We are choosing as contributors men noted for the lucidity of their writing, for the clarity of their ideas, for the originality of their presentation, and for their insight into chemical problems. We would guess that each person might produce about 100 pages of material in the six-weeks session.

Should you not now be convinced that you can spend the six weeks in the summer on the project, may I still extend a special invitation to come to the April meeting. I have two reasons for this. One is that you could provide the ideas which are so essential in the early stages, and, secondly, I think you might be caught up in the spirit which all who have so far had contact with the project have felt, and find that you could indeed arrange your six weeks actively contributing to the project during the summer months.

We will be able to pay a $50 per day consultation fee for the April meeting plus $15 per diem. For the summer session we plan to offer each contributor a salary at a rate of pay equal to approximately 110% of his regular rate. Two-room suites of bedroom, private bath, and study will be available at Claremont during both sessions. The summer price for board (six days of lunch and dinner) and room will be about $42 per week. Wives are welcome in the dormitories (all bedrooms contain two single beds), and even families can be accommodated.

I hope to hear from you soon that it has been possible to make these changes in your professional plans and so to participate in what we are undertaking. I am enclosing the names of the other chemists that we are approaching at this time to participate so that you can get some idea of the colleagues with whom you might be working on the project.

Sincerely yours,

Glenn T. Seaborg

GTS:db
Encl.

I

CHEM Study Contributors Meeting, April 2–5, 1960

All contributors and staff attending.

The contributors agreed, at long last, upon a working outline which permitted a division of topics as follows.

I. *Introduction: Microscopic Description of Matter: The Particulate Nature of Matter.*
Steiner, R. Campbell, MacNab.

II. *Atomic Structure and the Periodic Table.*
Mahan, Davis, Geffner.

III. *Molecules, Chemical Bonds.*
Geissman, Rapoport, Nicholson, Parrish.

IV. *Reactions; Stoichiometry Equilibrium, Energetics, Rates.*
Haenisch, Hurley, Greenstadt, Tellefsen.

V. *Systematic Descriptive Chemistry.*
Katz, Sienko, Menesini, Silber.

A tentative outline of content, the combination of the divisional reports, is appended.

The divisional reports were presented to the entire group of contributors. After the detailed critique and commentary, the following conclusions emerged.

1. The high quality of the material proposed by the divisional groups leaves no doubt that the competence and originality needed for this strenuous task are richly present and widely dispersed among the contributors.
2. Each group, in its zeal to produce a novel, stimulating and smoothly connected section, overshot the quantity of material which could reasonably be presented in a high school course.

3. The high school teachers are uniformly in agreement that far too much material was included in this first outline. Their further response varied from alarm that we might not be able to bring the material within the grasp of the average sixteen-year-old student to confidence that paring is possible since we recognize the need for it.
4. The morale of the group is high and everyone seemed to be convinced that the initial goal set for the six-week writing session will be reached. The university and high school groups are thoroughly integrated and the team spirit essential to this operation has been established.

The staff plans to meet on April 28 to reappraise both the order of presentation and quantity of material. Suggestions by the Steering Committee are solicited prior, if possible, to this meeting.

PROPOSED AGENDA
CHEM STUDY MEETING
APRIL 2–5, 1960

SATURDAY, APRIL 2:

2–5 P.M.	Faculty House—Where are we now? High school teachers evaluation.

SUNDAY, APRIL 3:

9–11:30 A.M.	Informal "pooling" of knowledge at the Harvey Mudd College Pool
2–5 P.M.	Goals of a high school chemistry course—Faculty House

MONDAY, APRIL 4:

9–12 noon.	Development of a (coarse) course outline—Faculty House
2–5 P.M.	Division of material—Faculty House

TUESDAY, APRIL 5:

9–12 noon.	Divisional discussions of text and lab content—Faculty House
2–5 P.M.	Divisional discussions of text and lab content—Faculty House
	General assembly—resumé of progress

TENTATIVE DETAILED OUTLINE OF TEXTBOOK
AS PROPOSED APRIL 5, 1960

I. *Introduction* (about five weeks)

States of matter: macroscopic and microscopic point of view

Crystalline and glassy solids

Liquids and gases

Phase changes; energies, fixed points, reversibility and equilibrium from macroscopic and microscopic points of view

Substances: Atoms, molecules, symbols, formulas

Pure materials

Mixtures and solutions

Conservation laws

Solids

Metallic solids

Organic solids

Ionic solids

Insulating solids

Gases

Molar concept

Extensive properties (on a molar basis)

Kinetic theory

Solutions

II. *Atomic Structure and the Periodic Table* (about four weeks)

Why do we believe in atoms?

Electrical nature of matter: electrolysis

Nuclear atom

Rutherford expt.

Charge

Nuclear mass

Protons and neutrons

Isotopes

Structure of atoms

Moseley expt.: an ordering property

Electron bombardment: energy levels, ionization potential, a periodic property

Photoelectric threshold with gaseous atoms

Orbitals and quantum numbers

Periodicity

Physical properties

Some descriptive chemistry

III. *Molecules and Chemical Bonds* (about seven weeks)

Formation of bonds: overlap of atomic orbitals

Bond length and direction; 1st row of periodic table

Why formed: observational evidence

M.O.'s from A.O.'s: hybridization

H_2

sp: $BeCl_2$

sp^2: BCl_3

sp^3: CCl_4

Concept of bond energies: qualitative basis for use of orbitals in bonding

Bond angles

Dihydrides: H_2Se, H_2Te, H_2S, H_2O

BCl_3

CCl_4

Bond distance

Dihydrides; other simple molecules

Ionic compounds

Electron transfer

Absence of directionality

Integrity and stability of ionic crystal lattice

Stereochemical consequences of the tetrahedral angle

Incorrect implications of other structures (e.g., planar structure)

Distortion of regular tetrahedron (e.g., $CHCl_3$)

Multiple bonds

Acetylene

Ethylene (sp^3, possibly also π model of overlap)

Rigidity of double bond: geometrical isomerism

Optical isomerism

IV. *Reactions* (about seven weeks)

Types of reactions

Acid-base reactions

Oxidation-reduction reactions; balancing

Ionic reactions; *net* ionic reactions

Electrolysis

Stoichiometry

Wt.-mole relations (*no* percent composition)

Gas volume-mole relations

Concentrations, titrimetry (*no* equivalent wts.)

Energetics

Hess' law

LeChatelier's principle and temperature

E°s

(Entropy and free energy in monograph only)

Kinetics

Energy barriers in rates of reactions

Temperature effect

Catalysis

Mechanism

V. *Systematic Descriptive Chemistry* (about 13 weeks)

Geochemistry

Abundancies

Distributions O^{16}, O^{18}, C^{14}

Congruent groups in the periodic table

Alkalis

Metals: preparation, properties and reactions

Ions: ionic radii (trend) from crystal data, from diffusion data

Emphasis on similarity and gradations

Halogens (where gradations are more marked)

F_2 to I_2: properties, preparation, reactions, peculiarities of F_2 (large emphasis)

Interhalogens

Hydrogen halides

Acidity functions, HF anhydrous

Oxy compounds

Horizontal gradation

Second short period: sodium to argon

Branch-off to near neighboring elements

Heavy play to silicon chemistry

Transition elements

Consequences of incomplete shells

Color, magnetic properties, coordination complexes, hemoglobin, chloroplasts

Crystal field theory

Multiple oxidation states

Lanthanides and actinides

Ions in solution

Equilibrium

Species present in aqueous solution: hydrolysis, complex formation, oxidation-reduction: Cr or Mn

Non-stoichiometric aspects of chemistry

Important technical chemicals and reactions

Tonnage chemicals: H_2SO_4, NH_3, phosphates, HNO_3, etc.

J

Reactions to Proposed Course Outline

This is a letter from Professor Kenneth S. Pitzer, a member of the Steering Committee, to Professor J. Arthur Campbell, dated April 21, 1960, concerning his reaction to the tentative detailed outline of April 5, 1960.

I was very much interested to see the tentative detailed outline for the high school course as prepared at the preliminary contributors meeting April 2–5, 1960. While I noted many interesting and good individual ideas and realize that many other features might well be improved upon more thorough consideration, nevertheless I find myself so seriously in disagreement with the general philosophy which seems to underlie part of the outline that I want to indicate this difference in opinion very clearly at this time.

Possibly I can best illustrate my point by first stating some general philosophy. I believe very strongly that chemistry is an experimental science and should be so presented to the student. At the same time, chemistry is not merely an accumulation of experimental facts but has a very general and beautiful structure which also should be presented as soon as possible even if all of the experimental basis is not yet available to the student. Some compromise is required between one policy in which one would accumulate the complete experimental basis for a given generalization before presenting the theory, and the other extreme in which the theory is presented first as authority "from on high" and the experimental basis is later provided to whatever extent is feasible.

Even in the area of experiment one must distinguish between those experiments which are accessible to the student at this stage of his work and experiments which are so complex or whose interpretation involves such advanced theory that they are not accessible to the student at this stage. The student will readily accept the idea that many other experiments, similar to the ones he does in the laboratory, have been performed and that the results are as stated. If he doubts any of these results, it is possible for him to go into the laboratory and repeat the experiment itself. Thus it is by no means necessary to develop a full array of experimental basis in the laboratory, but it is desirable to clearly distinguish between the sorts of experiments the student could do in his laboratory and those which are possible only at a much more sophisticated level. Again a compromise is needed since some of these inaccessible experiments are nevertheless so dramatically important in establishing atomic theory, molecular structure, etc., that they should be included even though not in the accessible category.

Theories are likewise subject to some classification of this same type. There are those theories which may be developed rigorously in terms of mathematics available to the high school student, and there are also theories which can only be developed and understood at a much more sophisticated mathematical level and therefore can be presented to the high school student only by authority.

I believe that the Chemical Bond Approach outline is subject to criticism for its heavy emphasis on material which is not experimentally accessible to the student at the high school level and more severely because of a high emphasis upon material which is neither experimentally nor theoretically accessible to the student and which is therefore merely given by authority. There are, doubtless, arguments pro and con in this area, but I feel very strongly that if we are to have a second project in the high school chemistry field, it should differ drastically in this particular respect.

Our tentative outline as proposed April 5, 1960, contains in the first semester's work three general sections. The first one, "Introduction," seems to me quite satisfactory. The next two sections, "Atomic Structure and the Periodic Table" and "Molecules and Chemical Bonds," are based almost entirely upon this type of experimentally inaccessible material and also to a very large degree upon theoretically inaccessible material. I fail to see any significant number of high school chemistry experiments which can be directly tied to this material, and I would be very reluctant to see practically the entire first semester pass before a chemical reaction is related to the main thread of classroom instruction. Note that the first section which does associate experiments quite satisfactorily does not primarily involve chemical changes.

I would recommend that the outline be altered by moving into position 2 some real experimental chemical reactions and the study of this basic chemical reaction information for a somewhat larger variety of the most common elements and compounds. This should include the elements of quantitative stoichiometry, atomic weights, etc.

I can then imagine two alternative sections for the remainder of the first semester: (a) a preliminary discussion of the periodic table somewhat along the lines of present II or (b) a further study of the types of chemical reactions, acid-base, oxidation-reduction, etc.

The second semester would then include the other of the (a, b) alternates above and a reduced amount of present section III. I would put more emphasis on experimental molecular architecture and probably omit reference to spectroscopic orbital notation (s, p, d, π, etc.).

I favor talking about atoms, molecules, and even electrons and nuclei right from the beginning. But these concepts should be admitted as postulates to be proven later. This avoids the need to discuss the inaccessible experiments before getting into the high school level experimental work.

I hope that revision in the direction I have indicated is still feasible. Even more, I hope that the importance being accorded to the experimental aspect is still so great that revision in this direction will be accepted as necessary.

I am sorry that a mix-up in dates prevents my attendance at the April 28 meeting and I have written these remarks at length in view of this absence.

Excerpts from a letter from Professor Bryce Crawford, Jr., a member of the Steering committee, to Professors Campbell and Pimentel, dated May 18, 1960, concerning his reaction to the tentative detailed outline of April 5, 1960.

Passing on to the tentative detailed outline, I rejoiced to see under I no discussion of liquids as such. This is very sensible, because we don't know much about liquids; I would suggest myself only that it be pointed out to the students that the structure of the liquid state does represent one of our frontiers.

Under II, I think that the discussion of the nuclear atom beginning from the Rutherford experiment is sound, and probably the best way to start this particular point.

Under III, I regretted to see that "M.O.'s" has reared its ugly head, and that further down there was some discussion of the pi model of overlap in multiple bonds. I would like to re-affirm my belief that this sort of discussion is all right for us advanced theoretical chemists who have far too much experience and judgment to believe in all this quantum mechanical speculation, but that it is very bad to plant these slightly metaphysical concepts in the young and innocent mind.

Under "Kinetics" I think that the recently available ACS film on kinetics might be referred to and made use of, for I think it would be valuable.

Still further down, under V, it seems to me that the last five headings, from "Transition elements" on,* might well represent items which could be used for "enrichment" and which really need not be included in the course, or at least should not be included in the "core" (if I might use that word).

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* Transition elements
Lanthanides and actinides
Ions in solution
Non-stoichrometrical aspects of chemistry
Important technical chemicals and reactions

Excerpts from a letter from Professor Bryce Crawford, Jr., to Professors Campbell and Pimentel, dated June 9, 1960, concerning Professor Crawford's reaction to the April 28 outline.

Let me react to the new outline, officially designated the April 28 outline.

In page 2 of your covering letter, you indicate a good deal of deletion of material, most of which caused me to rejoice. I note however in the outline itself that the Moseley experiment and some interhalogen still remain. I have no strong feelings. I have a little stronger feelings regarding the deletion of the stereochemical consequences of the tetrahedral angle; I think it is unfortunate that this is left out, because I think that some substantial introduction to the geometry of molecules would be a good thing. It seems to me that the development of chemistry over the last decade or so (starting indeed further back) has shown increasingly that chemical properties and chemical reactions are very largely controlled, if not dominated, by the shapes of molecules and the geometrical relations which obtain when two or more molecules come into proximity. So important an idea—and its importance becomes even more apparent in biochemistry—might well be included even in a first high school course.

In the outline itself, under reactions, III-A, I find acid-base reactions included; this prompts me to ask if you intend to include only the old original proton definition of an acid and base. I trust that you are not planning to go any further than, possibly at an extreme or in "fine print," the Bronsted-Lowry viewpoint.

Further along in the same heading, III-C, I note that you are going to use electrode potentials, presumably quantitative—and I think that this is a very fine idea. Won't this require you to say something about galvanic cells? Again, I would thoroughly approve putting in something about galvanic cells, but I would suppose you would want to do this back under III-A.

Down under V-B I note that you are going only as far as s and p orbitals, and I suppose this is reasonable. However, you know as well as I do that the p^3 and p^2 pictures for NH_3 and H_2O are lies or at least pretty poor approximations. Wouldn't it be better to concentrate on the tetrahedral arrangement, which comes a lot closer to giving the actual shapes of most molecules? This is going to be a tricky subject to deal with, of course, and here more than in some of the other sections success will depend on inspired pedagogy in working out the exposition. Good luck on this!

I note that the descriptive chemistry is heavily emphasized on the top and sides of the periodic table—the alkali metals, the halogens, and the first row. I thoroughly approve of this, for in my ignorance I have always felt this is the best way to introduce students to chemistry. I would suppose that, if necessary, your section IV could go even a little lighter on the transition elements, though I gather you do not plan heavy emphasis here. Perhaps indeed this section VI is a place where the individual high school teacher could exercise his own judgment and preferences to a great extent.

If you do find yourself pinched for time, I would suggest that the section on kinetics (III-D) could perhaps be slighted or even deleted; this might be a little drastic, but I fear something might have to give.

. . . Perhaps I should just say in conclusion that, over-all, I think this April 28 outline is absolutely first-class. . . .

K

Evaluation Conference Notes, June 18–20, 1961

AGENDA
AGONIZING REAPPRAISAL SESSION
JUNE 18–JUNE 20, 1961
BERKELEY, CALIFORNIA

Saturday evening, June 17:	Accommodations available in Davidson Hall. Dormez bien.
Sunday, June 18:	Noon to 1:30 P.M.—Luncheon at the Claremont Hotel. (Transportation will be provided from Davidson Hall to the Claremont.)
	2:00 P.M. to 4:30 P.M.—*Summary reports*
	Analyses of tests
	Analyses of experiments
	Course timing
	Student reactions
Monday, June 19:	8:30 A.M. to 12:00 noon—Group meetings
	12:00 noon to 1:15 P.M. —Luncheon armistice
	1:15 P.M. to 5:00 P.M. —Group meetings
Tuesday, June 20:	8:30 A.M. to 12:00 noon—All together now: Group reports
	12:00 noon to 1:15 P.M. —Luncheon calm
	1:15 P.M. to 3:00 P.M. —General discussion, final appraisal

May 8, 1961

PROPOSED GOALS FOR THE CHEM STUDY COURSE

Understanding and use of:

Topic:

I. *Scientific Method:* think critically; know the relations between observation and interpretation, experiment, and explanation; become interested in the environment; experience discovery.

II. *The Mole Concept* to its fullest advantage: balance reactions; use Avogadro's law; stoichiometry.

III. *The Periodic Table:* Column similarities and trends; row trends; metals *vs* non-metals; bonding; ionization potentials.

IV. *Principles Governing Reactions:* Energy, rate, equilibrium.

V. *Descriptive Chemistry:* Inorganic, organic, and biochemistry.

VI. *Types of Reactions:* Net reactions, ionic species in aqueous solutions; acids and bases, oxidation-reduction; complex formation.

VII. *Chemical Bonds:* Electron dot formulas, electronic structures and bonding capacity; covalent *vs* ionic bonding; bonding in solids.

VIII. *Structure of Matter:* Nuclear atom, electron structure, molecular structure; solids, liquids, gases; phase changes.

IX. *Behavior of Gases:* Avogadro's principle, absolute temperature, PVT relations.

GROUPS

A: Topics I and VI.
B: Topics II and VII.
C: Topics III and VIII.
D: Topics IV and IX.
E: Topic V.

June 19, 1961

TYPICAL EXCERPT FROM SUMMARY OF GROUP MEETING DISCUSSIONS

CHAPTER 9

This chapter will be deleted entirely as a chapter. Part of its content will be condensed and used as an introduction to Chapter 10. Part of the content will be placed in the introduction of old Experiment 14.

CHAPTER 10

The section on nuclear reactions caused some difficulty, mainly because it was a temptation for the teachers to treat it too thoroughly. It is recommended that this material be left in Chapter 10 for the purpose of comparing magnitudes of energies. The students are not expected to master this in great detail. Eventually a monograph would be written covering this area.

CHAPTER 11

No recommendation.

CHAPTER 12

No recommendation.

CHAPTER 13

Much confusion in students minds re ions:
(a) how they get a charge;
(b) their source.

The third paragraph of page 15-26 should be placed up ahead of the topic "predominant reacting species" page 13-3.

A contradiction exists between page 12-16 and 13-6 re the omitting of AgI in an equilibrium expression since its concentration is constant.

It is recognized that Chapter 13 was shifted in its original placement. It should be rewritten for clarity with this in mind.

Since the concept of ions is difficult to understand without the benefit of a background in atomic structure, the *possibility* was suggested of changing the position of Chapters 17, 18, and 19 (?) to precede Chapter 13.

The concept of ions must be made more real to the students. The solubility product material will be put into fine print. Another example of a complex ion will be chosen to replace the $HgI_4^{=}$. Be sure that the concept of aquated ions is clarified prior to Chapter 13.

CHAPTER 14

Many high school people reported that this chapter was confusing to the students. The committee could come to no essential agreement on which acid-base theory should be emphasized. The emphasis on the Brönsted theory was questioned since there is no firm evidence for the existence of the hydronium ion. The only agreement was that:
(1) it is a very controversial chapter;
(2) it should be rewritten for clarity;
(3) the acid-base table should be retained for predicting reactions;
(4) work on this chapter should be an early piece of business so that it will reach the institutes early.

CHAPTER 15: OXIDATION AND REDUCTION

This chapter will be left largely as it is, except that it is pointed out that oxidation-reduction systems exist where electron transfer cannot be demonstrated. The definition of oxidation-reduction on page 15-3 is modified. The discussion at the end of the chapter is expanded. The new chapter will give a more broad and historical approach to oxidation and reduction, including systems involving changes in oxidation state. Illustrations of the e.m.f. page 15-7 should be changed since these examples will be used in the new Experiment #25.

L

Sample Open-Book Achievement Tests

FROM EXAM 63–64—1, CHAPTERS 1–4.

Questions 1 and 2 relate to the following data obtained by a group of students who weighed the same beaker empty and also when it contained a precipitate. Different balances were used to make the various weighings.

The best value, with the uncertainty of measurement included, appears at the bottom of each column so you do not have to calculate this.

Weight of Beaker	Weight of Beaker + Precipitate
102.44 grams (g)	105.27 g
102.45 g	105.29 g
102.41 g	105.25 g
102.43 g	105.26 g
102.42 g	105.26 g
102.43 g	105.25 g
102.43 ± 0.02 g	105.27 ± 0.02 g

Average values including uncertainty.

1. Which of the expressions best represents the uncertainty of measurement in the calculated weight of the precipitate?

   (1) 2.84 ± 0.01 g
   (2) 2.84 ± 0.02 g
   (3) 2.84 ± 0.03 g
   (4) 2.84 ± 0.04 g
   (5) 2.84 ± 0.05 g

2. The molecular weight of the precipitate is given as 143.4 g/mole. Using the weight of the precipitate obtained in Question 1, the best value for the number of moles of precipitate is

   (1) 1.98×10^{-2} mole
   (2) 1.980×10^{-2} mole
   (3) 2.0×10^{-2} mole
   (4) 1.9805×10^{-2} mole
   (5) 2×10^{-2} mole

FROM EXAM 63–64—2, CHAPTERS 5–7.

Questions 3–5 relate to the use of the periodic table which is found inside the front cover of the text.

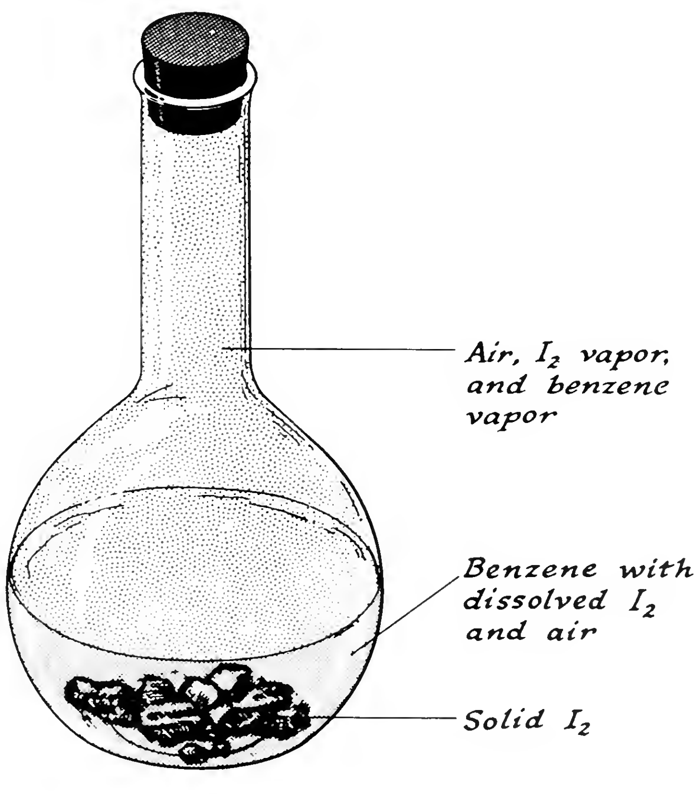
3. At room temperature the elemental form of barium (Ba atomic number 56) would likely be an example of
   (1) an ionic solid
   (2) a molecular solid
   (3) a metallic solid
   (4) a network solid
   (5) a gaseous substance

4. The formula for magnesium oxide is MgO and for magnesium chloride is $MgCl_2$. From this information and the periodic table it can be concluded that magnesium IONS have the same number of electrons as each of the following EXCEPT
   (1) neon atoms, Ne
   (2) sodium ions, Na^+
   (3) fluoride ions, F^-
   (4) oxide ions, O^{-2}
   (5) calcium ions, Ca^{+2}

5. Which of the following formulas represents a substance which you would NOT expect to exist under normal conditions in the laboratory?
   (1) KCl (s)
   (2) HCl (g)
   (3) SiO_2 (s)
   (4) Ba_2O (s)
   (5) Ne (g)

FROM EXAM 63–64—3, CHAPTERS 8–10.

Questions 26–28 relate to the system illustrated. The stoppered flask contains benzene, iodine, and air, and has reached equilibrium at 25° C.



26. Which one of the following statements concerning this system at equilibrium is FALSE?
    (1) There is no change in the pressure of the vapor phase.
    (2) There is no further evaporation of the liquid occurring.
    (3) There is no change in the color of the liquid phase.
    (4) The amount of solid iodine remains constant.
    (5) The temperature of the system is not changing.

27. Which of the following statements concerning this system at equilibrium is FALSE?
    (1) The various equilibria in the system represent a balance between the opposing tendencies toward greater randomness and toward lower potential energy.
    (2) The iodine molecules in the vapor phase are more random than those in the solid phase.
    (3) A tendency toward low potential energy accounts for the fact that the liquid does not evaporate to dryness.
    (4) A tendency toward greater randomness accounts for the fact that some benzene vapor continues to condense.
    (5) A tendency toward greater randomness accounts for the fact that some iodine molecules continue to break away from the crystals and go into solution.

28. Increasing the temperature of the closed system to 35° C would be expected to produce all of the changes listed below EXCEPT one. Identify the EXCEPTION.
    (1) An increase in the overall randomness of the system
    (2) An increase in the potential energy of the system
    (3) An increase in the pressure of the vapor phase
    (4) An increase in the average kinetic energy of the system
    (5) An increase in the amount of air dissolved in the liquid phase

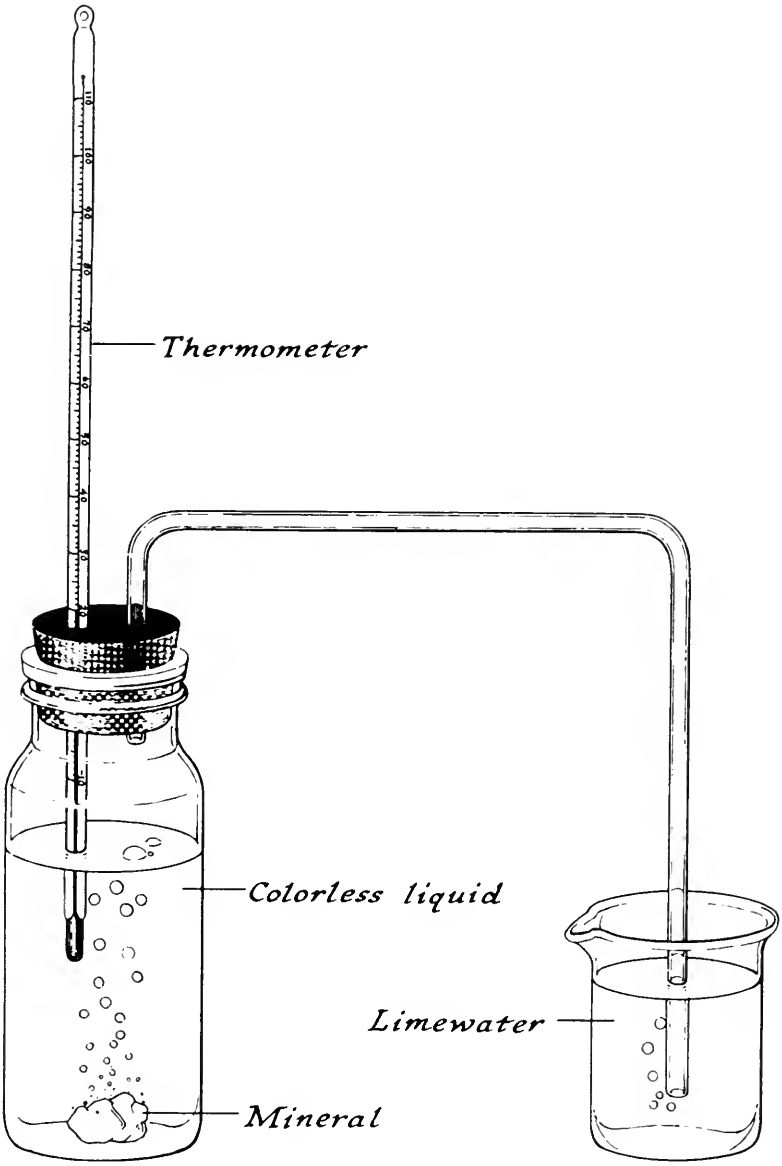
From exam 63–64—4(1), semester exam, part 1.

Questions 1–5 relate to the following situation.

A piece of mineral is placed in a bottle half-filled with a colorless liquid. A two-holed rubber stopper is then placed in the bottle. The system is then sealed by inserting a thermometer and connecting a glass tube to the stoppered bottle and a beaker of limewater as shown in the diagram at the top of the facing page.

The following series of observations is recorded.

I. *Observations during the first few minutes:*
   1. Bubbles of a colorless gas rise to the top of the stoppered bottle from the mineral.
   2. Bubbles of colorless gas begin to come out of the glass tube and rise to the surface of the limewater.
   3. The limewater remains colorless throughout this period of time.
   4. The thermometer reads 20° C, which is also the temperature of the room.



II. *Observations at the end of thirty minutes:*

1. Bubbles of colorless gas continue to rise in the stoppered bottle.
2. The piece of mineral has become noticeably smaller.
3. There is no apparent change in the level of the colorless liquid in the bottle.
4. The colorless liquid in the bottle remains colorless.
5. The thermometer reads 24° C.
6. The limewater is cloudy.

1. Based on all the observations above, which of the following hypotheses is most reasonable?

(1) The mineral is undergoing a phase change in which energy is released.
(2) The mineral is readily soluble in water.
(3) The mineral is undergoing a chemical reaction with the colorless liquid.
(4) The gas dissolves readily in the colorless liquid.

(5) The mineral is not composed of any of the elements contained in limewater.

2. What is the most probable explanation of the fact that the limewater remained colorless throughout the first few minutes?
   (1) The composition of the gas given off by the mineral changed as the experiment progressed.
   (2) The bubbles of gas coming from the tube during the first few minutes were air bubbles.
   (3) The gas produced by the mineral does not react with the limewater.
   (4) The composition of the colorless liquid changed as the experiment progressed.
   (5) The temperature of the limewater was too low during the first few minutes.

3. Which of the following statements concerning the above experiment involves an *interpretation* of the data rather than an observed fact?
   (1) No liquid was transferred from the reaction bottle to the beaker.
   (2) The quantity of solid mineral decreased.
   (3) The cloudiness in the beaker was caused by the product of the reaction of the colorless gas and limewater.
   (4) The bubbles of gas rising from the mineral remained colorless throughout the experiment.
   (5) There was a four degree rise in temperature at the end of thirty minutes.

4. Which one of the following is the best explanation for the appearance of gas bubbles at the end of the tube in the beaker of limewater?
   (1) The pressure exerted by the colorless liquid is greater than that exerted by the limewater.
   (2) The glass tube serves as a siphon for the flow of gas from the bottle to the beaker.
   (3) The temperature increase at the end of thirty minutes causes an expansion of gas in the stoppered bottle.
   (4) The bubbles coming from the mineral cause an increased gas pressure in the stoppered bottle.
   (5) The level of the glass tube in the bottle is above the level of the tube in the beaker.

5. The temperature increase observed at the end of thirty minutes can most reasonably be attributed to energy resulting from the
   (1) reaction between the mineral and the colorless liquid
   (2) heat of vaporization of the mineral
   (3) heat of fusion of the mineral
   (4) warming of the liquid by air in the room
   (5) reaction between the limewater and the gas bubbles

From exam 63–64—4(2), semester exam, part 2.

Questions 22–23 relate to the following equilibrium situation.

Hydrogen, $H_2(g)$, reacts with carbon dioxide, $CO_2(g)$, to produce gaseous water, $H_2O(g)$, and carbon monoxide, $CO(g)$, according to the following equations:

$$H_2(g) + CO_2(g) + 10 \text{ kcal} \rightarrow H_2O(g) + CO(g)$$

22. 3.0 moles of $H_2(g)$, and 4.5 moles of $CO_2(g)$ are placed in an empty reaction vessel and the temperature is maintained at 1000° C as the reaction is allowed to come to equilibrium. After equilibrium has been established, an analysis of the equilibrium mixture indicates that 2.0 moles of $CO(g)$ and 2.0 moles of $H_2O(g)$ are present. How much hydrogen, $H_2(g)$, is present at equilibrium?

(1) 1.0 mole
(2) 1.5 moles
(3) 2.0 moles
(4) 2.5 moles
(5) 3.0 moles

23. In another experiment involving the above reaction at 1000° C, the equilibrium concentrations were found to be:

$[H_2(g)]$ = 2.0 moles per liter
$[CO_2(g)]$ = 5.0 moles per liter
$[H_2O(g)]$ = 4.0 moles per liter
$[CO(g)]$ = 4.0 moles per liter

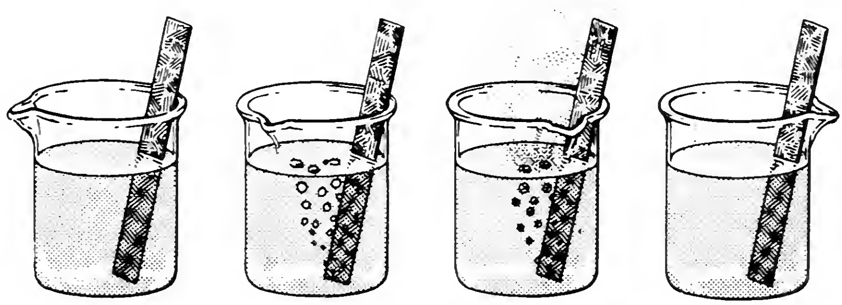
What is the equilibrium constant, K, for this reaction?

(1) 0.40
(2) 0.63
(3) 0.80
(4) 1.6
(5) 2.5

FROM EXAM 63–64—5, CHAPTERS 11–13.

Questions 25–28 relate to the following experimental observations.

Zinc strips are inserted into each of four beakers containing four different liquids, as shown below. (Each beaker and its contained liquid is identified by a single Roman numeral.)



I *II* *III* *IV*

Initial observations:

I	II	III	IV
no visible reaction	bubbles of a colorless gas form on zinc strip	a reddish-brown gas is evolved on zinc strip	no visible reaction

The conductivity of each liquid before the zinc strips are added:

I	II	III	IV
very poor	good	good	very poor

25. On the basis of the evidence given thus far, it is reasonable to conclude that

(1) beakers I and IV contain aqueous solutions of strong acids
(2) beaker II could contain an aqueous acid
(3) beaker III could not contain an aqueous acid
(4) beaker III must contain sulfuric acid, H_2SO_4
(5) beakers I and IV contain water

Some distilled water is added to each of the four liquids and is found to be miscible with all of them.

The conductivity of each solution after water is added:

I	II	III	IV
good	good	good	very poor

26. On the basis of this additional evidence, it can be correctly concluded that

(1) beaker I now contains a significant concentration of ions
(2) beaker IV now contains water only
(3) beakers II and III now contain more positive than negative ions
(4) beaker IV contains a strong acid
(5) this experiment does not provide information about the concentration of ions in solution

After one ml. of 0.1 *M* sodium hydroxide, NaOH, solution (base) has been added to each beaker, the contents of each beaker is stirred. The hydrogen ion concentration of each solution is determined by suitable indicators to be

I	II	III	IV
10^{-3} *M*	10^{-2} *M*	10^{-1} *M*	10^{-9} *M*

27. On the basis of all the information given thus far, it can be correctly concluded that *before* the addition of the NaOH solution

(1) beakers I, II, and III must have contained acids stronger than water
(2) all the beakers must have contained acids stronger than water
(3) beaker IV must have contained an acid stronger than water
(4) beaker IV must have contained a base stronger than water
(5) beaker IV must have contained water only

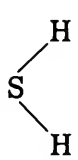
28. When a solution of silver nitrate, $AgNO_3$, is added to beaker II a white precipitate forms. On the basis of all the evidence now available, it can correctly be concluded that beaker II may originally have contained

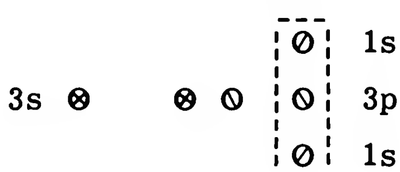
(1) NaCl solution
(2) Water only
(3) HNO_3 solution
(4) benzene, C_6H_6
(5) HCl solution

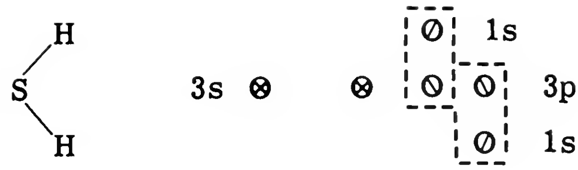
From exam 63–64—6, chapters 14–17.

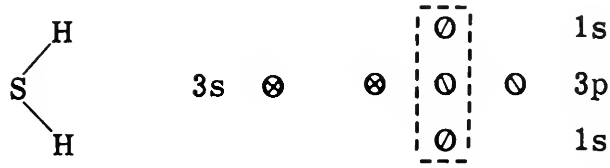
Questions 5–8 concern symbolic representations of molecules.

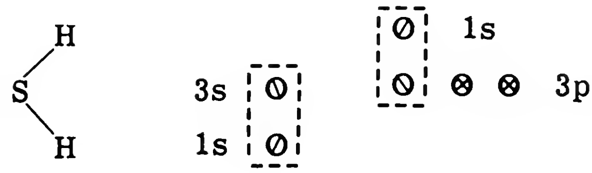
5. Which of the following is a correct orbital representation of hydrogen sulfide (H_2S)?

(1) 



(2) 

(3) 

(4) 

(5) 

6. Which of the following electron configurations would correctly be predicted for a phosphorus atom in its lowest energy state?

(1) ⊘ ⊘ ⊘ ⊘
3s 3p

(2) ⊗ ⊘ ⊘ ⊘
3s 3p

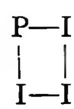
(3) ⊗ ⊘ O O
3s 3p

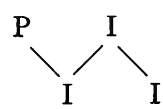
(4) ⊗ ⊗ ⊗ ⊗
3s 3p

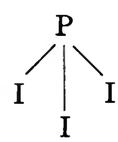
(5) ⊗ ⊗ ⊘ O
3s 3p

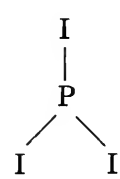
7. Which of the following is the BEST representation showing the shape of the gaseous PI_3 molecule?

(1) P—I—I—I (linear)

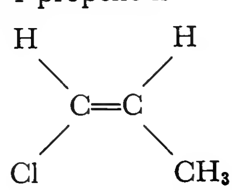
(2)  (square planar)

(3)  (angular)

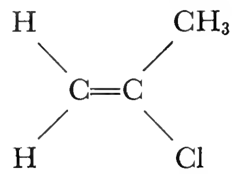
(4)  (pyramidal)

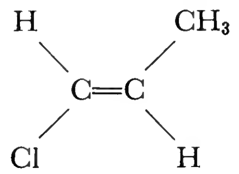
(5)  (planar triangular)

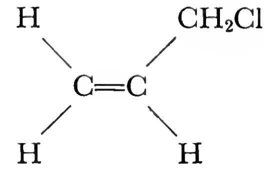
8. The structural formula for *cis*-chloro-1-propene is

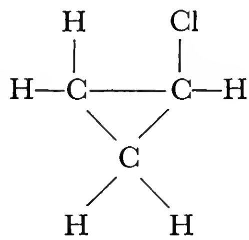


Which, if any, of the following is the correct structural formula for the *trans* isomer of this molecule?

(1) 

(2) 

(3) 

(4) 

(5) None of the above

From exam 63–64—7(1), final, part 1.

Questions 20–22 deal with the following experiment.

An unknown metal, X, is found to react spontaneously with a 1 *M* solution of $CuSO_4$, plating out Cu(s). X does not react with a 1 *M* solution of $Zn(NO_3)_2$. The half-reactions for each of these metals are listed below.

$$X(s) = 2\,e^- + X^{+2}\,(aq)$$
$$Cu(s) = 2\,e^- + Cu^{+2}\,(aq)$$
$$Zn(s) = 2\,e^- + Zn^{+2}\,(aq)$$

20. On the basis of the experiment described above, what is the correct order for listing the metals according to decreasing strength as reducing agents? (strongest reducing agent first)

 (1) X, Cu, Zn
 (2) Cu, Zn, X
 (3) Cu, X, Zn
 (4) Zn, Cu, X
 (5) Zn, X, Cu

Chromium metal, Cr(s), reacts spontaneously with a 1 *M* solution of X^{+2} (aq) to form Cr^{+3} (aq) and the solid metal, X(s).

$$\_\_\_Cr(s) + \_\_\_X^{+2}\,(aq) = \_\_\_Cr^{+3}\,(aq) + \_\_\_X(s)$$

Complete the equation for the net reaction, using the smallest possible whole numbers.

21. The coefficient for the Cr(s) in the net equation is

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

22. Another metal, which we shall call M, reacts with 1 *M* nitric acid according to the following equation:

$$\_\_\_M(s) + \_\_\_H^+\,(aq) + \_\_\_NO_3^-\,(aq) = \_\_\_M^+\,(aq) + \_\_\_NO(g) + \_\_\_H_2O$$

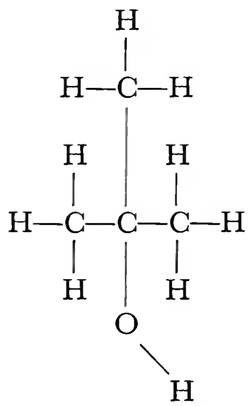
Complete the equation for the reaction using a piece of scratch paper. When *one* mole of nitrate ion, NO_3^- (aq) is reduced, the number of moles of M^+ (aq) ion produced is

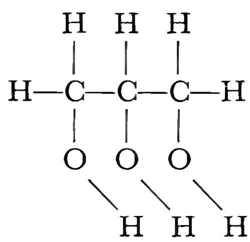
 (1) 1 mole
 (2) 2 moles
 (3) 3 moles
 (4) 4 moles
 (5) 5 moles

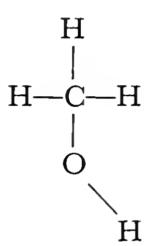
FROM EXAM 63–64—7(2), FINAL, PART 2.

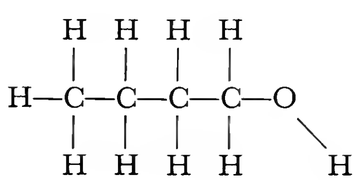
Questions 17–19 deal with intermolecular forces and their relation to molecular structure.

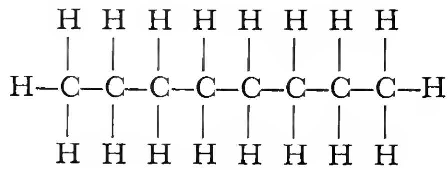
The questions relate to five compounds which have the following structural formulas.

I


II


III


IV


V


17. The occurrence of hydrogen bonding in certain compounds accounts for their abnormally high boiling points. Which one of the compounds would be predicted to have the highest boiling point due to this effect?

(1) I
(2) II
(3) III
(4) IV
(5) V

18. In which one of the compounds would the van der Waals forces be greatest? (Do NOT include hydrogen bonding.)

(1) I
(2) II
(3) III
(4) IV
(5) V

19. Which one of the compounds would be least soluble in water?

(1) I
(2) II
(3) III
(4) IV
(5) V

M

CHEM Study Appraisal Session, January 18–20, 1962

AGENDA

THURSDAY, JANUARY 18: *Gripes*

1:15–5:15 P.M.	This session is devoted to commentaries by the teachers on their classroom experience. The purpose is to identify topics and sections that are successful and to pinpoint problem areas. Criticisms should include positive responses if appropriate. Constructive suggestions accompanying complaints will be most welcome.
6:30–8:30 P.M.	Dinner, Kaiser Center Dining Room, 300 Lakeside Drive, Oakland. Several CHEM Study teachers from the San Francisco area will attend in addition to the appraisal session participants.

FRIDAY, JANUARY 19: *Grips*

8:45–12 noon	In this session we will come to grips with difficulties defined by the classroom experience.
12:20–1:30 P.M.	Luncheon, Faculty Club, U.C. campus.
1:45–5:15 P.M.	Continuation of morning discussions. Comments on effectiveness of teachers guide.
Evening	No planned activities. General carousing in San Francisco recommended.

SATURDAY, JANUARY 20: *Gropes*

8:30–12 noon	In this session we will grope for solutions.
12 noon	Meeting adjourned.

QUESTIONS WE MUST COME TO GRIPS WITH
BASED ON THURSDAY'S GRIPES SESSION

1. What is the proper role, emphasis, and time allotment for the introductory section, Chapters 1–6?
2. What is the optimum introduction to the atomic theory?
3. What ought to be included in the treatment on the electrostatics (presently in Chapter 2)? Like charges repel; unlike attract? Distance dependence?
4. What needs to be done about gas laws?
5. Can we retain the PV example in Chapter 1?
6. What experimental material accompanying Chapter 1 can be deleted or shortened? Expt. 4? Expt. 5?
7. Which experiment accompanying Chapter 3 could better be made optional—Expt. 7 or 9?
8. Can Expt. 11 be dealt with on basis of present gas law treatment?
9. What topics can be deleted or postponed in Chapters 1–6?
10. What do we do about formula writing and comprehension of formulas? Include organic formulas or not?
11. Should there be a summary section for each chapter?
12. Should solutions be treated with pure condensed phases?
13. How much emphasis on significant figures or uncertainty?
14. What is appropriate ratio of lab to class based on 5 sessions/wk.?
15. What balance between historical, experimental, and appeal to prior knowledge in atomic theory?
16. What about level of problems and graded problems?
17. What kind of data for discussion of uncertainty—PV, laboratory, personal?
18. Should amount of reference material, e.g., tabulations, definitions, rules, be changed?
19. Does "chatty" style of writing seem to student to be "writing down"?
20. Should development of charge interaction be changed and chemical applications included (e.g., include table of symbols and formula writing, explicit discussion of nature of ions)?
21. Would additional volume of drill, vocabulary, exercises, and problems be helpful?
22. Would "programmed material" on formula writing and other areas be useful?
23. How can we handle student absences and "catching up" problem?
24. Should there be more but shorter chapters?
25. Should TG make strong point that only some problems should be worked?
26. Should TG give more specific guidance for the overview aspect of the early chapters?

SUMMARY OF SUGGESTED GROPES

1. List of concepts at end (or beginning) of each chapter (index, glossary).
2. More figures and a few more tables.
3. Emphasize limitations of models and alternative models.
4. Work over questions—more easy ones, grouped by "hardness," more which allow student to use his knowledge on systems known to him.
5. Edit to simplify sentence structure, vocabulary (somewhat), word choice, section headings, level of writing.
6. Provide pre-lab discussion guidance in Teachers Guide, post-lab discussions.
7. Provide programs in (a) formula writing, (b) equation balancing, (c) chemical computations—gases, stoichiometry, equilibrium.
8. No longer divide book into units—smooth out flow.
9. Stress building on prior knowledge (atoms, static electricity).
10. Quickly review atomic theory and electrical laws emphasizing qualitative effects and immediate use. Also emphasize that model will grow but amplification not needed in early stages.
11. Introduce experiments with questions to give perspective.
12. Try to state assumptions explicitly—spherical atoms.
13. Structure of solids and atomic number in Chapter 6.
14. Ease into math. (PV example)
15. Emphasize uncertainty rather than significant figure.
16. Tone down "chatty" style. Maintain personal touch, e.g., "We."
17. Correct Expt. 4 to demonstration and one expt., make option between 7–9, delete most of (?) 12. Put 10 earlier to introduce mole. Do heat of fusion in test tube. Possibly defer 5 to Chap. 7. Try to obtain different candles.
18. Provide flow chart of development at beginning of Teachers Guide. Function of first 8–9 weeks—build on prior knowledge, establish scientific emphasis, introduce main ideas of chemistry (usually qualitatively but with experimental support), anticipate further growth of models as additional experiments are available.

Outline Commentary on Volume I

Ideas for overview needed in early and immediately subsequent chapters.

- Experimental approach and error.
- Model building—wondering why.
- Atomic-molecular theory.
- Nuclear atom.
- Molecular motion.
  - Maxwell-Boltzman dist.
  - °K

Mole.
Dynamic equilibrium.
Structure in gases, liquids, and solids.
Size and shape.
Periodic table.

Need continual "phrase referral" (like "cylindrical objects") to ideas already developed.

Need many more allusions to student's personal experiences.

Need segregation of questions: practical questions, thought questions.

Analogies are often still too long. Good analogy should be no longer than 1–2 pages at the most.

"Balanced equation" is redundant, use "equation."

CHAPTER 1

Let's stick to experiment in this chapter. Emphasize "wondering why" in 2.

CHAPTER 2

Let's begin Chapter 2 with a summary of some experimental data from 1. Then point out that students already have a model—the atomic theory and the nuclear atom to interpret this. State succinctly what model is (1 page), then apply it to experimental data—melting behavior, evaporation, gas behavior. Then on to potential-kinetic energy and Coulomb's Law as an extension of experimental "proofs" of the model.

Point out that here we use a model they have already learned; in future we will develop and extend models. This will greatly shorten chapter and sharpen its main point: the uses of a model to correlate experimental data.

Use this chapter to "review" what student should know about atoms from previous work. Explicitly say so.

Introduce ions and forces between them. Add conservation of charge law. Formulas by combining ions. Table of common ionic formulas (monatomic?).

Outline

(1) Summary of experimental facts on melting behavior and P − gm. relationship for Ne.
(2) Atomic-molecular model.
(3) Interparticle forces—attractive and repulsive.
(4) Nuclear atom—p, n, e, isotopes incidentally (come in 3.6)—main pt. pos. massive atom, negative outside.
(5) Electrical forces—Coulomb's Law.
(6) Attraction and repulsion between atoms; balance of elect. forces, nuclei and elect.
(7) Elect. motion—2 models (a) orbits (centrifugal and centripetal force); (b) in and out electrons (KE + PE = constant). Need no model of motion

for chemistry—thus dismiss question (besides, no one knows answer). Will treat atoms as spherical.

(8) Summary of model and applications to experiment. Drawing of fuzzy atom.

CHAPTER 3

We *must* have an experimental method of getting relative molecular weights. A combination of combining volumes and Avogadro seems best but we could settle for Avogadro. (Is it worth introducing mass spectrograph here (Coulomb forces again) and be done with it?) This method, whatever we choose, is needed in 3.2 before we discuss molecular formulas.

Let's leave chemical symbols unmentioned until after models, (based on 2) specifically, are thoroughly developed. Then introduce symbols as a simplifying system of representation.

Outline

(1) Elements and compounds (3.1).
(2) Molecules—combining volumes and Avogadro's Law (312 + new) Mass spectrograph? Expt. 10 here.
(3) Molecular models—space filling only (3.7).
(4) Mole—Atomic and molecular wts. (3.5 + 3.6). Spell out all names and use models.
(5) Chemical reactions.
  a. Between molecules (3.8, 3.9, 3.10). Use models only.
  b. Chemical symbols (3.3, 3.4).
  c. Empirical formulas—mole (3.11–3.14).
  d. Equations—conserve atoms + charge (as in Chap. 2).

CHAPTER 4

We must establish molar weight and experimental method of determining it before this chapter and refer to the experiments. Am more convinced than ever m. wt. experiment and discussion should come *early*. This chapter needs to be sharpened in aim and flow; more experimental references. Derive M.B. distribution here rather than in Chapter 7. Use in Chapter 5. Need more emphasis on *amount* of gas.

Outline

(1) P-wt. and vol.-mole relationship from 1 and 3. Avogadro's Law and m. wt. determination.
(2) T also affects wt. (moles) in a container. T-moles effect, T-P relationship.
(3) Absolute T and *translational* energy.
(4) Kinetic theory of P-V-T-n relationship.
(5) Perfect gas as an imperfect model.

CHAPTER 5

Outline

(1) Preparation of pure substances (or else at end of chapter).
(2) Pure substances.
(3) Phase changes—M.B. dist.
—dynamic equilibrium.
—energy.
(4) Types of substances—metallic. ionic. molecular. network. glassy } Mention behavior of g, l, and s. Tie in forces, bonding, energetics, dynamic equilibrium, M.B. dist.
(5) Solutions—s, l, g, molecular, and ionic.
Molarity.
Dynamic solub. equil.
Ionic reactions.

WHERE DO WE GO FROM HERE?— A CRITICAL EVALUATION OF VOLUME 1 OF CHEMISTRY—AN EXPERIMENTAL SCIENCE

Before attempting an evaluation of the text, some background discussion is essential. It is my contention that a textbook is not a self-teaching manual nor a series of programmed instructions. A text proclaims a philosophy of instruction and is predicated on the assumption that there will be an interested and capable teacher to develop the ideas therein. The text is invariably longer and more detailed than the course of study for which it was designed. The needs and abilities of the class will dictate the teacher's approach. Preparation, planning, and continued experience will enable the teacher to improve the presentation in the text. With a new text and a new approach, the teacher, initially at least, is a learner in the same sense as are his students. Some of the trial teachers, I feel, may have a mistaken notion about the role of the text. This has been a continued source of irritation.

Three other factors need to be considered before we get to the text:

1. The time element has been and will continue to be a source of frustration for both teacher and pupil. In our New York City high schools we are spending just a little more than half the time on this course compared to the majority of teachers throughout the country. We spend about 30 minutes per day for instruction, five times a week. The students and teachers donate their free time after school for

laboratory work. The total number of teaching days this semester has been about 70 days. The schedule for the spring semester is a little better, offering at most some 76 days. To what extent this factor has contributed to our difficulties is hard to say but this must be considered in the total evaluation.

2. The nature of the CHEM Study approach is quite unlike anything the student has had to contend with in his total program of studies. Traditional high school methodology emphasizes recall, recognition, and rote learning. The open-book examination is unheard of. These reactions have come from my own students in attempting to analyze their difficulties. The marked change in philosophy and direction posed by CHEM Study represents a major hurdle.

3. The nature of the overview approach is a source of much misunderstanding for our teachers. We need to instruct our teachers in the philosophy of the overview approach. In some ways the text has contributed to this difficulty. In other ways, the CHEM Study exams have raised the question "How far do we need to go?"

And now for my specific suggestions:

1. The overview is proper and necessary. To insure the proper depth of understanding, each of the chapters in the overview section requires a carefully prepared summary. The questions on the CHEM Study exams need similar redirection.
2. The students are not getting a sufficient exposure to formulas and equation writing. Some overview treatment of bonding might be in order at this point. Experiment 14 with its numerous reagents was a failure for my group for this reason.
3. The introduction of PV relationships in Chapter 1 before the study of gases is questionable. Data from the candle experiment might be used and would be much closer to the student's experience.
4. Kinetic and potential energy relationships were a major stumbling block for my group. This requires more time and perhaps more extended treatment.
5. The mole concept and Avogadro's law need greater clarification. The passing reference to Gay-Lussac is confusing.
6. Chapter 5 needs reorganization, especially the material on solutions and ions. Just why this material belongs to a chapter on condensed phases should be made clear.
7. I wonder to what extent emphasis on significant figures contributes to obscuring the real intent of a chapter.

I can only base my reactions on almost two years of trial experience with CHEM Study superimposed on a total experience of about twenty years in teaching high school chemistry. Never have I witnessed such sustained interest on the part of my students. Never have I observed on the part of my students a more sincere and serious desire to learn. These feelings are no mere accidents. Instead, they represent a tribute to CHEM Study—its philosophy, its approach, and its materials of instruction. CHEM Study has given me a tremendous lift and I, for one, look to the future with much hope and renewed interest.

Saul L. Geffner
Chairman, Department of Physical Science
Forest Hills High School
Forest Hills, New York

Time Use
1962–1963

Based on 17 northern California schools,
25 teachers, approximately 2,000 students.

Chapter	*Scheduled days*	*Average days needed*	*Approximate range*[1]	*Extra days needed*
1	9	11	9–12	2
2	5	6	5–8	1
3	9	13	8–15	4[3]
4	6	10	8–13	4[3]
5	9	11	8–13	2
6	5	7	5–12	2[3]
1–6	43	58	50–70[2]	15

[1] 15 of 17 schools included.
[2] 11 of 17 schools were between 50 and 57.
[3] Second-year users spent less time on Chapters 3 and 4, but more on Chapter 6 than the first-year users.

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