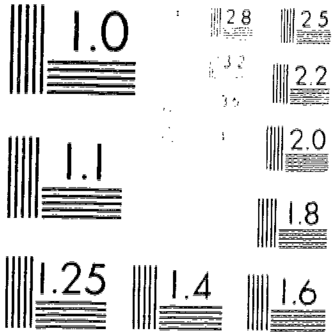
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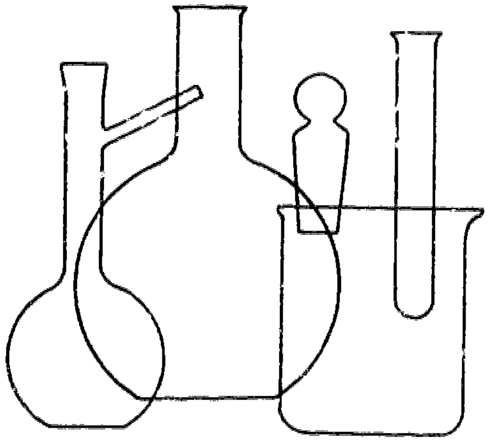
ABSTRACT

This publication, issued twice per year, includes proceedings from Two-Year College Chemistry Conferences and papers of special interest to the two-year college chemistry teacher. Course content is discussed for first-year, second-year, and other introductory chemistry courses, as well as for chemical technology courses. Instructional methods in chemistry are discussed, including audio-tutorial approaches and the use of films and mini-computers. Special topics in the chemistry of water and the environment are presented. The content of a short thermodynamics course for teachers is described. (MH)



CHEMISTRY
IN THE
TWO-YEAR COLLEGE

1972 NO.1

COMMITTEE ON CHEMISTRY IN THE TWO-YEAR COLLEGE
DIVISION OF CHEMICAL EDUCATION • AMERICAN CHEMICAL SOCIETY

FOREWORD

This issue of *Chemistry in the Two-Year College* is the first of two which report on the 12th year of activity of the Division of Chemical Education, Inc. of the American Chemical Society in the two-year college field. This activity is presently being directed by the Committee on Chemistry in the Two-Year College.

The Division of Chemical Education is involved in improving chemistry teaching, with respect to both content the communication of this information to students. To this end, it serves as a common meeting ground for teachers of chemistry and their students, as well as others who are also interested in the larger aspects of chemical education. In addition, the Division includes within its purview those who are preparing for careers in fields related to chemistry, as well as those who study chemistry for its broad educational and cultural values.

These interests are served, notably, by the official publication of the Division, the *Journal of Chemical Educati* but other activities also serve: Summer conferences, summer institutes, the visiting scientists program, the consultants service, the small grants program, the two-year college program, participation in regional ACS meetings, special regional conferences, cooperation with similar groups overseas and in other countries of North America, cooperation with the Division of Science Teaching of UNESCO, sponsorship of comprehensive conferences and symposia dealing with broad aspects of chemical education, continuous on-going re-examination of curricular pro and problems, continuous attention to the teacher and his work, and notably, the Divisional meetings which are part of the semi-annual national ACS meetings.

In no less a manner, the Division is a liaison agent between high school and college teachers, integrating and extending their individual and collective efforts. With equal emphasis, the Division is concerned about the impro of the professional dignity and responsibilities of teaching, in general.

The individuals who carry out these activities are recognized by the Division through the sponsorship, or co-sponsorship, of awards for outstanding contributions. Professional status is also encouraged by emphasis on resea and other scholarly activities, and by the purposive development of a public attitude which leads to a better understanding and appreciation of the contributions of the teacher to our society.

Members are invited to participate in the standing committees of the Division. It is by this voluntary work that chemical education has been able to show a steady growth in the past, and by such future participation that it will continue to grow. Generally the committees of the Division each meet separately twice a year during and preceding the national meetings of the American Chemical Society. Visitors are always welcome at these working sessions. Almost any new idea or valid criticism of chemical education can be carefully considered at one or the other of these committee meetings. They are indeed a forum for chemical education.

Two-year college chemists are encouraged to join the Division of Chemical Education and participate in its programs and work on its committees.

During 1972 the Committee sponsored four Two-Year College Chemistry Conferences, the 29th through the 32nd, published four Newsletters and two issues of *Chemistry in the Two-Year College*, and studied the problems and programs of the chemistry departments of the two-year colleges through several subcommittees.

The 1972 Conference schedule included the 29th Conference at Franklin Institute of Boston in Massachusetts, April; the 30th Conference at Oregon State University in Corvallis, Oregon, June; the 31st Conference at New York City Community College in Brooklyn, New York, August; and the 32nd Conference at Laney College in Oakland, California, October. These Conferences all were favored with outstanding programs.

The Boston program featured three symposia: the Future Trends in Chemistry For the Non-Science Major, Innovations in Teaching Chemistry, and Environmental Education. The Corvallis Symposia were devoted to Environmental Chemistry and Innovations Involving Chemistry Teaching and the Environment. At Brooklyn a symposium on the Chemistry Needs of the Biological and Health Science Majors was followed by one on Innovati in Teaching Chemistry Related to the Health and Biological Sciences. The Oakland Conference also included a Chemistry Needs of the Biological and Health Science Majors Symposia but followed it with a symposium on Computers and Chemistry.

Each 1972 Conference included keynote presentations and discussion sessions related to the first year general chemistry course for science and engineering majors; to the second-year chemistry courses; and to chemical and other laboratory technology programs. Similar programming was included for the non-science majors course at three conferences and for the allied health chemistry courses at two conferences.

Each conference concluded on Saturday afternoon with different arrangements: Timely Topic Discussions in Boston and Corvallis; Special Topic Section Meetings in New York and General Session on Science and Society at Laney.

Additional features of each of the Conferences included open subcommittee meetings, a Committee on Chemistry in the Two-Year College meeting, exhibits by the industrial-commercial sponsors and the informal conversations and exchange of ideas.

Chemistry in the Two-Year Colleges features papers and discussion summaries from the Two-Year College Chemistry Conferences and other conferences of interest to the two-year college chemistry faculty member. We also include other papers, submitted and invited, which we believe will serve the interests of improving chemical education in the community colleges, junior colleges, technical institutes, and university branch campuses which we serve.

The papers in this issue deal with the content and curriculum for the first year chemistry course for science majors, the second year chemistry course for science majors, other introductory chemistry courses, and for chemical technology programs. Sections are also devoted to Instructional Methods in Chemistry and the Administration of Chemistry Programs. Two special topics sections have been included and are concerned with the Chemistry of Water and Environmental Topics in Chemistry Courses. The volume is concluded with a short course for teachers by Professor J. Arthur Campbell of Harvey Mudd College.

During 1972 we continued cooperation with the Manufacturing Chemists Association through the Recognition and Awards Subcommittee, chaired by Cecil Hammonds, Penn Valley Community College, which reviews all nominations for the Annual MCA Two-Year College Chemistry Teaching Award and recommends several finalists to the MCA. On behalf of the two-year college chemistry community, I should like to publicly acknowledge our gratitude to Dr. Robert Varnerin, Manager of Education, and to the Committee on Educational Activities of the MCA for the support and recognition of our programs and work through their College Chemistry Teaching Award Program.

Fred Schmitz of New York City Community College is the MCA Two-Year College Chemistry Teaching Award recipient for 1972. Fred has had a distinguished career in Brooklyn and is one of the leaders in chemical technology education in the country.

Two men who have long been leaders in the two-year college chemistry field left our ranks in 1972. One, Dr. Milton Cooper of Wright College, Chicago City College and an active member of the Committee since its inception, passed away suddenly in April. We were all saddened by Milt Cooper's passing and will miss him and his contributions in the future. Milt was one of the 35 in attendance at the 1st Conference in Chciago in 1961 and since then has been a steady participant and contributor to the conferences and the committee.

Mr. Kenneth Chapman, editor for the Committee, left the American Chemical Society staff to go into the publishing and printing business as an executive. Ken's contributions to our efforts started in 1964 when he hosted the 4th Conference at the Technical Institute of Temple University and increased during his tenure in the ACS Education Office where he was in charge of the Two-Year College program and continued at a high level, both quantitatively and qualitatively, during his service as Associate Director of the ACS-NSF Chemical Technology Curriculum Project at the Lawrence Hall of Science in Berkeley. We all extend our thanks to Ken for many jobs well done on our behalf and wish him well in his new position with CBIS.

The work of the subcommittees during 1972 will be mentioned in the 1972 volume 2 issue.

All two-year college chemists are invited to attend and participate in our conferences.

William T. Mooney, Jr.

Chairman

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FUTURE TRENDS IN GENERAL CHEMISTRY

David W. Brooks
First Year Chemistry Program Director
Texas A & M University, College Station, Texas

Keynote Address presented at 2YC3 Conference
Saturday, December 4, 1971, San Antonio, Texas

Predictions concerning the future of general chemistry are difficult, and my crystal ball is not superior to yours. I would like to divide into two groups my remarks. I shall first discuss trends in the area of environmental chemistry, and then teaching methods.

It is clear that environmental chemistry will play a small but meaningful role in general chemistry courses. However, the long-term future of lower chemistry courses devoted either entirely or in part to environmental chemistry is not good. The turmoil in academic chemistry concerning environmental subjects derives as much from adverse psychology as sincere interest. For many years research chemists spent large sums of federal money while offering only modest justification for these sums. Chemists did not do a good job of public education. Therefore, when the spending crunch came, chemists' pleas for sustained support fell upon less than sympathetic ears. As a very young boy growing up in Brooklyn, New York, I can remember inhaling the most awful smelling air that I've ever inhaled. I remember beaches in which one couldn't swim because of incredible amounts of floating debris. Many years later I discovered discarded beer cans in Alaska, far from the beaten paths, clearly dated to indicate that they had been tossed away at the time that I was very young. Pollution is new neither to me nor to you. However, at the time when chemists were depressed about their funds, the environmental issue became a dominant one. Someone cleverly pointed out that pollutants were made up of atoms, which in turn were the chemists' business, which in turn made pollution the chemists' fault. This is pure bunk. That such logic can be perpetuated into lasting viable courses seems as unlikely to me as it does unwholesome.

Environmental chemistry will become a small topic in our courses, much as nuclear chemistry, organic chemistry and biochemistry have. (Also, marine chemistry and geochemistry are likely to become important, as all of us begin to re-explore our world.) We will have considerable support from publishers, providing us with general texts and particularly with paperbacks. For example, I recommend to you *Energy and Environment*, by T. L. Brown (Merrill). This book talks about environmental problems in terms of molecules! As usual, the burden of coping with the information explosion in this area will fall upon you, the teacher. Your choice of examples and experiments for lab will determine how effectively your students relate environmental chemistry to the larger body of chemical concepts.

As teachers, our problems still reside in choosing the most effective teaching methods. The poor interactions of chemists with their society is a direct or indirect result of poor teaching. Although some universities have made excellent attempts at improving techniques (for example, I strongly praise the University of Texas at Austin group for their fine contributions in CAI), most senior institutions have maintained traditional lecture systems, traditional labs, and traditional grading. In the future, all of these traditions may be eroded.

We will all judge student performance in relationship to educational objectives and not course curves. (One problem with attendees at 2YC3 meetings is that even though one speaker always talks about objectives, too few go home to practice writing them. Try them! They're not so trivial to write as they seem. May I recommend *Taxonomy of Educational Objectives, I. Cognitive Domain*, Bloom et al, eds., David McKay, Inc., New York, as a basic reference.)

We shall eliminate F grades (for the most part), and use the grade of "In Progress" to carry students who start slowly. Please note that we should not eliminate grades, since as alumni our students are graded. In chemistry, those of our alumni who received low grades by their erstwhile employers are now seeking work!

Tutorial self-paced teaching methods of all kinds are prominent on the wave of the future. Some self-paced programs will enjoy lots of hardware support—computers, fancy visuals, audio tapes—while others will be based almost exclusively on written materials. The success of such projects has been overwhelming.

As new methods become more accepted, the two-year college chemistry teacher will play what is a new role for him—a role of leadership. For years, the effective methods of teaching (note that I have not said anything about the most learned teachers) have been more widely and effectively employed at the 2YC level than they have at senior institutions. The junior college teacher, therefore, is most likely to be able to assume leadership in this area of teaching methods in chemistry. He should do this; otherwise, the senior colleges learn more slowly than they need to, and then think that implementation of these methods was their doing in the first place. If you've got it, flaunt it. Many of you have already got it.

The Use of Experimental Data and Performance Objectives in General Chemistry

George M. Fleck
Department of Chemistry, Smith College, Northampton, Massachusetts

How can experimental data from laboratories be interpreted to yield insight into the chemical nature of matter?

This paper presents some specific ways to get students actively and deeply involved with the interrelationships between experiment and theory in chemistry. Central to this discussion is the concept of chemical and mathematical *models*. The presentation, both in this paper and in actual chemistry courses, involves extensive use of explicit performance or instructional *objectives*. The overall teaching strategy focuses on the *confrontation* of experimental data and the predictions of theory. The methods described were developed in a freshman course for students with strong background in chemistry, and in two other courses that have a semester of general chemistry as prerequisite.

On the Nature of Chemical Models. Chemistry is a science that leans heavily on the results of experiments. The conceptual models of chemistry cannot be fleshed out with unaided fundamental theory. But neither are these models the direct, unambiguous consequences of uninterpreted experimental chemical data. Most chemical models are semi-empirical models, models that have been formulated and elaborated by continuing interactions between chemical and physical theory, and the results of laboratory experimentation. Models should be faithful to the data. Models should be simple, elegant, and beautiful. Models may also be true, in some sense. But models must be useful, or appear to be useful, or they will be discarded. Chemical models are constructed by imaginative people who need ways to interpret data. Without models, most chemical data would have no obvious meaning. The actual process—choosing a chemical model, designing appropriate experiments to yield data that can be interpreted in terms of the model, and confronting model and data—is a process in which both exactness and artistry play substantial roles.

Associated with some chemical models are explicit mathematical models. The predictions of such mathematical models can often be made quite precise. Simulations of an experiment can then be compared with the experiment itself, in quantitative terms. The theory becomes vulnerable to the carefully executed experiment. The model becomes accessible to a student with only a limited amount of chemical experience, because the mathematical model exposes the essence of the model in numerical terms. If appropriate experiments can be designed, then model and experiment can be compared in comparable numerical terms. This is a confrontation.

It is the thesis of this paper that the interaction of experiment and theory can and should be an integral part of chemistry courses, that laboratory and lecture should actually and obviously be integrated in the minds of the course teachers and the course takers, and that evaluation of student performance can be based largely on the extent to which they can perform as integrators of chemical data and chemical theory.

Demonstrating Attainment of Instructional Objectives by the Confrontation of Theory and Experimental Data. Certain chemical topics are especially well suited for involving students in the interaction of theory and experiment. By confining the subject-matter coverage to a single well-defined area for a substantial block of time, students can attain a sufficient level of understanding to enable them to appreciate the power, scope, limitations, and significance of the relevant theory. They can work with, interact with, and manipulate the important concepts. They can have first-hand experience with the interaction between theory and experiment in an important area of chemistry. Three such topics where in-depth instruction is appropriate for a college course in general chemistry are *acid-base equilibria, complex-formation equilibria,* and *reaction mechanisms.* Each topic involves integration of laboratory and classroom, making modest use of a computer. In each case, each student demonstrates achievement of the instructional objectives by confronting experiment and theory. The confrontation is arranged to produce a clear-cut challenge to the validity of the theory and to the reliability of the data.

A student is expected to attain a level of competence that involves integration of the various aspects of the topic, a level that permits the student to design a meaningful confrontation between his own experimental data and the predictions of a chemical model that he has formulated. A student demonstrates that he has attained the required level of understanding by carrying out such a confrontation and writing a formal report that includes a discussion of the results of the confrontation. This achievement level represents a broad, stable learning plateau. Virtually all students achieve this plateau, some at considerably more effort and with more frustration However, it is a rewarding experience to achieve this degree of mastery over subject matter, whether mastery comes easily or with difficulty It seems likely that a student who has achieved this level will retain much of the insight gained. Our approach involves a sacrifice of breadth of coverage in order to achieve substantial depth of treatment. It represents a marked departure from the chemistry instruction familiar to the students from their secondary school courses.

General Objectives, Specific Objectives, and a Pathway for Achieving these Goals. General objectives are stated for the students, who are to demonstrate the attainment of these objectives by confronting their own experimental data and the predictions of their own chemical model. General instructions are given for the laboratory experiments, although there is considerable freedom in experimental design.

The general objectives are attainable in a stepwise fashion via the attainment of each one of a group of specific objectives. The specific objectives are listed in a logical order, but a student may choose to master them in whatever order seems to be appropriate to him at the moment. Helps for achieving the specific objectives include textbook discussions, references to the chemical literature, class discussions, and individual conferences. Most students are able to use the set of objectives to pinpoint their questions and thus get the information they want and need. Copies of these objectives for acid-base equilibria, complex-formation equilibria, and reaction mechanisms can be obtained by writing to the author.

Confrontation of a mathematical model with numerical data requires some form of calculation equipment. At Smith College, we have made extensive use of an IBM 1130 computer. We have also begun an evaluation of the Wang and the Olivetti programmable calculators for these purposes. Freed from repetitive manual computations, most of our students at the freshman level are stimulated by the calculation and confrontation procedure.

This method does not remove the teacher from the teaching process. Rather, in the author's experience, the teacher spends more time talking with students about chemistry, but less time in trying to orient students who are having trouble articulating their questions. This method provides a direction and focus for a great deal of laboratory and classroom instruction. It is ideally suited to open-ended laboratory teaching.

CHEMISTRY – A POINT OF VIEW

Leonard Fine
Housatonic Community College
Ave., Bridgeport, Ct

Presented at the 29th Two-Year College Chemistry Conference
The Franklin Institute of Boston, Boston, Mass.
Concurrent Section, Saturday afternoon, April 8, 1972

Today we experience almost for the first time a sense of urgency in doing more than just teach chemistry. The reasons are all too evident. Somewhere along the way, the bubble burst. Rampant science and technology have caused a sudden shedding of a 300 year cocoon and the shock of the experience has been upsetting. We are no longer innocents loose in paradise. But we still cling to comfortable old ways; we still communicate too much of the old chemical message to new generations in the classroom. As chemists, we can ill afford to ignore the signs of these changing times lest we be suicidal. To teach atoms, molecules, and energy is not enough. Students must be allowed to develop a broader point of view.

Method in Science

The eighteenth and nineteenth century gradually nurtured a view of Bacon as the prophet of a strict empiricism. Scientists were hardly more than accountants of facts in a manner of speaking. But a reading of Bacon's *Novum Organum* shows this not to be the case at all. As Harvey Brooks has noted in his comments on this very subject in a recent issue of *Science*, Bacon . . . .

> "understood the importance of hypothesis, theory, and understanding, but above all he described accurately the cumulative and cooperative nature of the scientific enterprise and the fact that *it was a social system for understanding nature which transcended the capability of individual men, or even one generation.*"

In developing a point of view toward method in science, a second critical aspect is differentiation between scientific method as a code or guideline for the production of science – it's most salient feature – and scientific method as dogma, a face that much of science wore after Newton in the eighteenth and nineteenth century. It is immoral in today's scientifically revolutionized world to palm off a few rules for inductive reasoning as constituting method in science when everyone who has ever practiced science in any real sense knows that it is rarely the real route to discovery. Further, it is an injustice to impugn by such a stand that science and scientists are as blind and unthinking as such a method would pretend.

Objectivity in Science

Knowledge gained objectively according to the method of science is hardly objective at all. True, there is an objectivity of knowledge. But the social sense of science requires the deeper consideration of objectivity in terms of involvement. There are two separate but interwoven threads that make up the fabric referred to here as objectivity. First there is the objectivity of nature that is the systematic interplay between logic and experience – the stuff of true knowledge. The objectivity of involvement is the stuff of value judgements, something over which science and scientists can exercise control, a control the authority for which we have abrogated for a variety of reasons and in a number of ways. For example, consider how a scientific activity is related to attainment of social goals; steel processing has markedly contributed to the pollution of Lake Erie, creating a sense of national shame. Social merit raises some terrible and perplexing questions for science and the scientist. For example, should one refrain from objectively attempting to obtain knowledge on subjects such as the relationship (if any) between race and native intelligence, or mechanisms of genetic manipulation of inherited traits. If there are answers to such questions, they clearly transcent the boundaries of science.

Ethics in Science

The problem here is deeper than one would guess at first glance. It is not satisfactory to take comfort in one's research being free of social malaise. Because your research hasn't killed anything or anyone or added more pollutants to the environment does not establish one's innocence anymore. Every member of the scientific community is party to all of the implications and manifestations of science. Disavowing responsibility because one does not personally do research under contract to the Department of Defense is a foolish and dangerous illusion.

A Point of View in the Classroom

The science of chemistry is hardly a benign subject and should not be sold as such. Each of us has his own point of view and one can do a great service to science and to society by helping the student to realize his personal involvement in this scientifically revolutionized society.

Laboratory sessions offer an untapped opportunity. Set aside a corner of the lab where some reading can be done and where there is access to audio-visual aids. These can be used by the student whenever he had an opportunity during an experiment. Available study units can be designed to tremendously broaden and develop a point of view, well beyond what might otherwise be possible in the normally allotted time slot. With a pair of earphones and a disc tape recorder, a student can listen to a lecture by Ritchie Calder on the social implications of population and pollution, or he can view a series of slides on the atom bomb from Manhattan to Trinity to "the gadget" (as the bomb was called). He can look at a number of reproduction of authentic documents in support of the slides, such as the Einstein–Roosevelt letters or the Arthur Compton-Farrington Daniels poll of the atomic scientists, or Robert Lifton's eye-witness accounts from the survivors of Hiroshima. There are readings on chemistry in war, ranging from the acoount of the first gas attack at Ypres to Defoliation in Vietnam. There are slides to see on the subject as well. The student is exposed to a tremendous amount of material, painlessly and interestingly, in a time slot that isn't an added burden, in a way that more fully submerges a student in chemistry. To mention a few other units . . . .

Chemists in cartoon and caricature.
Chemists when they were young.
The Connecticut Wetlands. A local ecological tragedy.
Ernest Rutherford 1871–1937

The program in the laboratory is of course first experimental. We've tried to make something more of it and in so doing give further recognition and reinforcement to the place where chemistry ought to be—in the lab. In short, teach the stuff of chemistry—but with a point of view.

FUTURE TRENDS IN ORGANIC CHEMISTRY MULTI MEDIA AND RELEVANT PROBLEMS

David N. Harpp
Chemistry Department, McGill University
Montreal 110, Canada

Presented at the 29th Two-Year College Chemistry Conference
The Franklin Institute of Boston, Boston, Mass.
General Session, Saturday morning, April 8, 1972

In spite of a present job shortage in many areas of chemistry, enrollments in introductory chemistry courses have significantly increased in the past year or two (*Chemical and Engineering News,* March 13, 1972, p. 23). Environmental issues and an increased understanding of the chemistry of life processes are among the areas which have clarified to many the importance of the study of chemistry. These factors place increased pressure on the teacher not only to convey basic concepts, but to relate these concepts to the areas of more direct concern to an expanding student audience.

Various classroom techniques (such as overhead projectors, TV, super 8mm films, slides and audio tapes) have been increasingly used to assist in this endeavor. Our* experience with the overlap-dissolve slide projection method (lap dissolve) has shown it to have unique advantages for a variety of pedagogical situations.

Contemporary trends in the teaching of chemistry often require the student to analyze complex three dimensional systems which frequently involve moving components. Concepts derived from stereochemistry, conformational analysis and reaction mechanisms are found in this category. Such topics as cyclohexane

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*Prof. J. S. Daniel, Ecole Polytechnique, Montreal; Prof. J. P. Snyder, Yeshiva University and the University of Copenhagen.

dynamics, ammonia inversion, the importance of steric effects, nucleophilic substitution, optical isomerism and crystal structure can be usefully portrayed. In addition, complex line diagrams can be rendered more comprehensible and lab demonstrations made clearly visible for everyone in the classroom. An important asset of the lap dissolve method is the facile display of a wide variety of relationships and dynamic events at a controlled pace with no dark interval when slides are exchanged. The resultant ability to manipulate information flow can help provide a novel learning experience for the student. Unlike film, which runs until it is stopped, dissolve projection is static until it is run so that the instructor is in command of the lesson in a way that he cannot be during the projection of a film.

Another useful visual device which we feel will have increasing use, is the single frame advance, super 8mm projector. The Kodak model MFS-8 (super 8mm) unit allows the entire visual components of a course (including single frames, coordinated dissolve sequences and conventional film reels) to be conveniently shown by means of one super 8mm strip. The main advantage of this technique involves instantaneous change from frame to frame or motion by remote control. In addition, screen light levels are at a high level during all operations. This system might be particularly effective as the central device in modular course instruction. In this format the student studies independently in a carrel arrangement with appropriate audio-visual aids and works his way through the material by mastering a package or module before advancing to the next stage. We feel the MFS-8 technique is complementary to dissolve projection and has high potential for classroom as well as carrel use. Information relating to details of lap dissolve projection and the preparation of materials are attached.

1. *Camera* – Pentax Spotmatic (macrolens 50 mm) and Nikkormat (microlens 50 mm), both 35 mm SLR models with through the lens light metering, provide good to excellent results. Recent preliminary experiments with a Leica instrument suggest this to be the camera of choice. It appears to deliver each frame in precisely the same relationship to the film ratchet holes a very high percentage of the time. (cf. slide mounts below) However, the latter camera is considerably more expensive ($600–$700).
2. *Projectors* – Kodak Carousel Ektagraphic (the Ektagraphic line is crucial). There are three models; auto focussing, etc. Model AF appears to give the best results, but model B is suitable.
3. *Tripod* – good, firm.
4. *Copy stand* – most professional models will do; e.g., Leitz Repro (ca. $100).
5. *Dissolve Unit* – Kodak has one called the "Dissolve Control" (ca. $260). In addition, The MacKenzie Company, 10355 Vacco Street, So. El Monte, California 91733, Tel: (213) 579-0440, puts out a very fine unit (ca. $300). It has the great advantage of variable lenth dissolve time (0–10 sec.) which maximizes motion effects and covers small errors in photography. Neither of the above units will go backwards but will operatie by remote control. Another model is put out by Spindler and Sauppee, 1329 Grand Central Avenue, Glendale, California 91201. This instrument allows you to go backwards as well as dim the projectors (by remote control), but costs ca. $600. For more information on mechanical, less expensive dissolve units you can obtain Bulletin S-15-30 from Eastman Kodak Co.–Customer Services, Motion Picture and Educational Markets Division, Rochester, New York 14650.
6. *Slide Mounts* – **crucial** – must have mounts which are available from Sickles, Inc., P.O. Box 3396, Scottsdale, Arizona 85257, Tel: (602) 966-6256 designated as #6406 35mm Circle S Pin Registered Plastic Slide Mounts. These cost ~$10 per 500 if purchased by the 1000. They have registration pins so each slide may be perfectly mounted relative to its predecessor (via the film perforation holes. Ultimately the quality of registration relates to the ability of the transport mechanism of the camera to uniformly deliver the same amount of film for each picture. Slides are usually very well registered with these, but if not, shaving the bottom or right edge of the mount as it is picked out of the carousel tray *or* afixing a piece of scotch tape on the same edges (Scotch Magic transparent tape is best) will allow minor adjustments.
7. *Slide Mounter* – a press called the Kaiser Mounter is very handy for the above described mounts. The press is available for ca. $30 from Kaiser Products Co., Colorado Springs, Colorado, Tel: (303) 495–2444. If necessary, the slides can be attached to the mount with Avery Self-Adhesive Correction Tape (secretarial equipment).

8. *Negative Slides* – for the Sequential Coordinated Information Display Sequences (SCIDS!) – Kodalith film (ortho type 3) is used; it is a high contrast copy film. Your audiovisual people would know about this. One useful tip: for best registration it is useful to make the master drawings with as thick lines as possible. In general, the master is photographed the required number of times and then the slides selectively masked out with Craftint negative opaque (kind of a red mud) and a sable hair brush (Windsor and Newton works well). A variety of brush sizes will be useful to have. Thus, by this technique the information can be selectively displayed. It might be mentioned that press-on (letraset etc.) type symbols provide very professional looking results at low cost. In addition, curves of all shapes may be easily formed by the use of ACS Flex tape. It should be available from any well-stocked store which sells artist's and draftsman's supplies. This tape is really quite remarkable for rapid construction, clean straight lines, etc. The coloring of the slides is accomplished with overhead projector pens – Maruzen Wonder Markers work well – yellow, pink, pink + yellow = orange, brown + yellow = gold, are effective clean colors (blue and green less so). Even better (smoother, cleaner etc.) for coloring slides is a water color system called Dr. P.H. Martin's Synchromatic. These bottles cost ~ $.80. Particularly effective colors are yellow, blue and green. It is interesting that excess paint can be wiped from the frame with no danger of smearing onto unwanted parts.

9. *Light Box* – Essential for preparing and viewing large numbers of slides. A convenient portable model (20 x 24") can be had for ca. $80 (4 lamps) from Porta-Trace, Gagne Associates, Inc., 50 Wall St., Binghamton ,N.Y. 13901, Tel: (607) 723–9556.

BIOCHEMISTRY IN THE ORGANIC COURSE

Eugene H. Cordes

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I. Rationale for inclusion of biologically-oriented material in the early years of the studyof chemistry.
  A. Molecules of biological origin form an important part of the basic fabric of organic chemistry and there is every reason to include them in a discussion of this area of chemistry. Most distinctions between organic chemistry and biochemistry are artificial.
  B. The audience for organic (and general chemistry) courses is frequently strongly biologically oriented. Usually a minority of such students are authentic chemistry majors (and some of these will develop into biochemists at any event) and a majority are either in biology, are pre-meds, or are included in the paramedical group.
  C. Relegating biologically-pertinent material to the third and fourth years of study creates a number of problems. These include (i) a return to rather trivial types of chemistry in biochemistry courses at a time when the student is prepared for advanced and sophisticated work; (ii) there is a consequent time problem in the biochemistry course; and (iii) no chemical basis is provided for concomitant courses in the biological sciences.

Limitations on the introduction of biochemical material into the organic course.
  A. The course must serve the needs of those who intend to be professional chemists, in whatever subdiscipline.
  B. The trend in the biological sciences is strongly in the direction of a more mechanistic view of the life process. Support and reinforcement of this trend requires that students receive a sophisticated introduction to organic chemistry, not the minimal treatment required to begin a discussion of biochemistry.
  C. The understanding of biological matters changes exceedingly rapidly with time as do experimental approaches employed in investigations in this area. The student must be equipped to meet and understand (and hopefully to cause to happen) these changes. This fact, too, requires increasing emphasis on mechanistic (asking why, not what) material in comparison to descriptive recitation of the current state of understanding of chemistry or biology.

III. We have a problem: excellent rationale can be developed for including more biological material in early courses but good arguments are also present suggesting increased emphasis on the most basic aspects of chemistry. What do we do now? At least three reasonable avenues are open to us.

IV. It is essential to make adequate use of the general chemistry course.
  A. We need to remember that general chemistry includes those aspects of the subject matter that are germane to all chemists. This includes molecular structure, electronic structure and chemical bonding, thermodynamics, and reaction mechanisms. All of these areas turn out to be crucial for the understanding

of biochemistry.

B. Biochemically pertinent material enters naturally into a general chemistry course.
  i) polymer chemistry can focus on nucleic acids, proteins, polysaccharides.
  ii) stereochemistry (molecular geometry) can be beautifully illustrated by biologically important examples. These include enzyme specificity, pheromone properties, drug activities, anti-metabolities, the sense of smell and taste, and so forth.
  iii) photochemistry can be usefully extended to include both photosynthesis and the visual process.
  iv) redox reactions can be developed in terms of the associated free energy changes and how these are used for metabolic processes; one can include the electron transport chain, synthesis of ATP, utilization of ATP as the metabolic currency.
  v) thermodynamics is everywhere important; can illustrate using ATP reactions, protein synthesis, nucleic acid synthesis, life and entropy, and so forth.
  vi) reaction mechanisms can be chosen to include those associated with enzymes, building at the same time on the structural information developed earlier.
  vii) acid-base equilibria can include consideration of the function of hemoglobin and blood chemistry generally.

The point is that the introduction of the biological examples is easy, natural, and important. But a proper paving of the way is essential: first structures, then thermodynamics and mechanism, then everything else. This type of organization leads to continual reinforcement of material learned earlier. The biological examples reemphasize simpler non-biological ones.

V. The organic course itself can directly serve biochemical purposes in at least two ways.

A. Emphasis may be placed on those aspects of organic chemistry which are most important to biochemistry. These include:
  i) everything that has to do with the disposition of atoms in space: isomerism, optical activity, conformational analysis. These considerations underlie almost all of biochemistry and include the structure and function of nucleic acids and proteins, the specificity and regulation of metabolic pathways, the action of drugs and hormones, and the biosynthesis of macromolecules.
  ii) reaction mechanisms: here again, a good understanding of an essential area of biochemistry, intermediary metabolism, depends on understanding a diversity of chemical reactions, not just memorizing them. Moreover, the essential problems of processes as diverse as oxidative phosphorylation requires a good mechanistic understanding of organic chemistry. But it is true that some mechanisms are more important for biological purposes than are others. The free radical chlorination of hydrocarbons is less important than nucleophilic displacement reactions or carbonyl addition reactions.
  iii) the techniques of organic chemistry: particularly nmr, epr, ord and mass spectrometry are of great importance in biochemistry and their importance will increase.
  iv) perhaps less crucial than the areas mentioned above but important nontheless are specific areas of learning: polymer chemistry, and carbohydrate chemistry are the two most important.
  v) there are lots of areas in organic chemistry that impinge on biochemistry rather strongly but are, in fact, not very important at this level. These include amino acid chemistry, heterocyclic chemistry, and the chemistry of most natural products. Synthetic and degradative methods are peripherally important.

Biochemically-relevant examples can be chosen for the purpose of illustrating organochemical concepts.
  i) why not illustrate the uses of mass spectrometry using fortuitine or peptide sequencing? Or illustrate nmr by talking about ribonuclease? Such examples are the best way to indicate the power of these, and other, experimental techniques.
  ii) the principles of stereochemistry are perhaps best developed in terms of carbohydrates. The importance of stereochemistry can be illustrated in the terms developed above.
  iii) illustrations of synthetic methods can be done in terms of biologically important molecules: steroids, pheromones, etc.

VI. Some advantage can be taken of current basic biology course material. Increasingly, these courses are taking on chemical aspects; enough organic chemistry is developed to permit a basic discussion of proteins and nucleic acids. Possibly, this background will permit the saving of time in later chemistry courses.

A MODEL FOR THE ONE-YEAR ORGANIC CHEMISTRY COURSE IN A TWO-YEAR COLLEGE

Bobby Walters
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The Twenty-Eighth Two-Year College Chemistry Conference
December 4, 1971, San Antonio College, San Antonio, Texas

This study is an attempt to describe the two-semester Organic Course in the junior colleges in Texas state schools. It seemed appropriate to secure facts related to curriculum, use of texts, level of training of instructors, course load, and type of laboratory, etc.; thus, a questionnaire was developed for this purpose.

Procedure

The questionnaire was sent to all junior colleges listed by the Coordinating Board, Texas Colleges and Universities, in September, 1971. Forty-seven questionnaires were mailed, addressed to the Chairman of the Chemistry Department.

Results

The material was sent out in October, 1971. Returns drifted in over a two-week period, and a second mailing was made in the middle of November to those colleges who had not returned the material. The data were then tabulated. Of the 47 questionnaires mailed, 43 were returned, a percentage of ninety-two. A summary of the results follows.

Full-time Staff Members Teaching Organic Chemistry

All the schools reporting, except three, had one full-time staff member. There seems to be a trend indicating that the larger the school, the more staff members it will have.

Number of Staff Members Teaching Lab

There were only five schools having staff members teaching lab, if different from lecture, indicating that the larger the school, the more assistance needed.

Level of Academic Training

There was only one school having a staff member with a bachelor's degree only. Nine schools had persons with the Master's degree plus. Fourteen schools employed persons having the Ph.D. This is more than the total number reported because some schools have more than one staff member teaching Organic Chemistry.

Use of Student Assistants

14 schools used student paper graders.
6 schools used student lab instructors.
31 schools used student stock-room help.*
2 schools used student proctors.
19 schools used student secretaries.

Teaching Load—2-semester Organic Course

The *total* load was from 12 to 25 semester hours, with an average of 17 semester hours. Lecture hours per week were from three to twelve hours, an average of eight hours. Laboratory hours per week ranged from zero to twenty, with an average of ten hours of laboratory per week.

Schools Offering 2-semester Organic Course

Of the 43 schools reporting, 39 offered the two-semester course, and four schools offered both the one- and two-semester courses in Organic Chemistry.

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*There was a definite indication that most schools use students for stock-room help, especially for organic chemistry.

Most Widely Used Texts for Organic Course

30 schools used *Organic Chemistry* by Morrison and Boyd (80%)
2 schools used *Organic Chemistry* by Brewster and McEwin.
3 schools used *Modern Organic Chemistry* by Roberts and Caserio.
1 school used *Organic Chemistry* by Rakoff and Rose.
1 school used *Organic Chemistry* by Shirley.
1 school used *Elements of Organic Chemistry* by Richards, Crom, and Hammond.

Annual Enrollment

The range was from 5–125, with an average class size of 19 or 20.

Semester Hours' Credit Given

The annual credit in all cases was eight hours. Twenty-six of the schools felt the credit should be eight hours, and eleven schools felt that the credit should be ten hours. All of these included laboratory.

Laboratory

About 15 different laboratory manuals were listed. Some schools used their own manuals, and some used the following:

6 used Brewster, Vanderwerf, McEwin.
5 used Adams, Wilcox and Johnson.
4 used Helmkamp and Johnson.
3 used Roberts, Gilbert, Rodewold and Wingione.

As to laboratory fees, the range was from \$2.00–\$10.00, with an average of \$5.00.

The number of hours per week each student meets laboratory varied from three to six hours per week with an average of four hours per week.

The next question dealt with the use of the lab partner system. Reporting schools indicated the following:

13 used the system sometimes.
14 never used the system.
11 answered yes.

The average laboratory class size ranged from 4–26 with an average of 14.

Schools which included Organic Qualitative Analysis as part of the laboratory numbered twenty-five. Ten schools did not combine the two, and four schools did not report. The number of weeks Organic Qualitative Analysis was taught ranged from one week to thirty-six weeks, with an average of five weeks.

Instrumentation

The number of schools who have instruments for their students are as follows:

20 Visible spectra
23 Gas chromatograph
18 Infrared
8 Ultraviolet
1 NMR
7 Refractometer
6 Polarameter
1 Molecular App.
1 Digital MP

Interpretation of Spectra

15 use actual instruments.
11 use films.
5 use film strips.
8 use 2 x 2 slides.
23 use workbooks.
2 use texts.
2 use spectra collection.
1 uses overhead transparancies.

Laboratory Evaluation

The number of schools using laboratory examinations was twenty-five. Twenty-four of the twenty-five use written examinations. Fourteen did not use laboratory examinations for evaluation. Some schools use pop quizzes before the lab periods. One school uses lab practicals, and one school uses practicals (unknowns) and written questions on lecture tests.

Twenty-nine of the schools use formal laboratory reports, and 35 of the schools have discussion groups either before or after the laboratory. One school uses prep tests at the beginning of lab. The other schools use this system when they feel the discussions are necessary.

Evaluation of laboratory counted an average of 25% toward a student's grade.

Weaknesses of the Students

15 – Reading
9 – Mathematics
7 – Chemical background
4 – Poor study habits

Student Interest

4 – Excellent
31 – Good
3 – Fair
1 – Poor

Discussion

Based on these data, broad, descriptive statements can be made, many of which are directly ascertainable from inspection of the results and need little further elaboration. There are, however, some trends which appear to be supported by the data:

1. The smaller the college, the greater the teaching load of the instructor.
2. The course is mechanically-oriented from the type of books used.
3. The instruction of spectra determination is practiced in most colleges.
4. Increasingly more schools are using instruments in their laboratory instruction.
5. A large number of the students are pre-professional majors and not chemistry majors.

Conclusion

This study could not have been made without the cooperation of the schools participating. My thanks to each school and the persons completing the survey.

Concurrent Section Meetings

The discussion was concerned with the results from the *Model for the One-Year Organic Chemistry Course.* Dr. Billy J. Yager from Southwest Texas State University and Dr. J. C. Stallings from Sam Houston State University conducted the morning discussion.

Most of the discussion was concerned with the transfer problem from two-year colleges to four-year colleges and universities. It was concluded that most students have little or no difficulty in transferring.

The next discussion session was made up of a panel of Drs. T. J. Cogdell, University of Texas at Arlington; Royston Roberts, University of Texas at Austin; and Raymon Seymour, University of Houston. Dr. Seymour presented a very provocative opinion on what the one-year Organic Course should be, and this stimulated a great deal of discussion. Discussion was also presented on the use of instruments with the conclusion that the actual instrument stimulated the student to learn and on the undertaking of laboratory procedures with the students and trying experiments that were not in the manual.

TRENDS IN THE SHORT ORGANIC COURSE

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Presented to the Second–Year Chemistry Courses Section,
29th Two–Year College Chemistry Conference,
Boston, Massachusetts, April 8, 1972

Nearly twenty years have passed between the publication of the first and fourth editions of our textbook "A Short Course in Organic Chemistry." During that time many changes have occurred in the actual course content, as well as in the way the material is presented to the student. Perhaps one can use the experience of the past to extrapolate to the future, dangerous as that may be.

I. Attitude Toward the Student

The 'short course' is generally taken by students who have no strong interest in organic chemistry *per se,* but who need the course material as a background for other studies, be they nursing, veterinary medicine, agriculture or whatever. The course may be followed by an equally brief introduction to biochemistry. Often the student does not really understand why the course is a requirement for his curriculum, and it is helpful if the relevance of organic chemistry to biochemistry and biology is pointed out by the instructor at every appropriate opportunity. For example, the phenomenon of cis-trans isomerism may seem rather theoretical to this group of students, but it can be made very practical by a brief discussion of the mechanism of vision, or the difference in toxicities of maleic and fumaric acids, or the effect of double bonds in lowering the melting points of fats.

It is my view that students who take the short organic course are as intellectually capable as chemistry majors, but have other interests It is important to engage their intellect with subject matter that is, whenever possible, relevant to those interests. The concept of knowledge for its own sake is not appealing to today's student, and is likely to be even less so in the future. It is important to treat these students with respect, and to not consider the course a "watered-down" version of the full year course. It should be just as challenging and intellectually stimulating as the course for majors, and explanations should avoid superficiality and be just as intellectually satisfying. The subject matter must, however, be selected with care to avoid material which is only really of interest to chemists.

II. Organization of the Course

Two major approaches have been used by textbook authors, and I presume by teachers who use those texts. The subject matter can be classified according to functional groups or according to reaction mechanistic types, or to some modification of these extremes as a compromise. There is no question that the trend has been from a funtional group classification toward a mechanistic type classification, since this is the way the field of organic chemistry has developed during the past thirty years. I am not sure that this is necessarily the best trend for the short course, however, though I think it is a good way of teaching organic chemistry majors (with some limitations).

The functional group organization has the advantage that it minimizes the new language presented to the student at any one time. I believe that it is important for the student to know some thing about functional group nomenclature, structure and reactivity patterns before he can appreciate the subtleties of mechanistic discussions. Later, one can use mechanistic similarities as a review device – forexample, to point out the similarities and differences in the carbonyl reactivity of esters or other acid derivatives with those of aldehydes and ketones. Repetition of this type is an aid to the learning process. If the mechanistic approach is used in the extreme, the student may find himself talking about the reactions of compounds he cannot name.

Mechanistic discussions are important, even in the short course, because they can provide the student with some framework for facing new, previously unencountered chemistry. But special care should be taken to ensure that the mechanisms do not become an added memory burden, but actually do enhance the student's understanding of the chemical reactions.

III. Role of the Laboratory

There is a growing tendency to economize on laboratory in the short course, the argument being that students who take this course may never have to synthesize a compound, or recrystallize, or distil, etc. I agree that the emphasis in laboratory for these students should not be on learning techniques, or on obtaining high yields, etc. (unless, perhaps, they are students who will end up in a laboratory job, such as clinical chemists or medical technicians.) But the laboratory can lend reality to the subject for the student; he can see, handle, smell some of the compounds which may seem from his lecture or text to be only intellectual constructs. Hopefully a good laboratory manual will contain enough discussion material to clearly relate the purpose of the experiment to the text or lecture.

IV. Study Guides or Answer Booklets

I think that as the number of students taking the short organic course continues to increase, and funds for new faculty become increasingly tight, there will be a growing trend to make greater use of self-study aids. The student learns organic chemistry best if he has an opportunity to work as many problems as he can, and they should be assigned in an amount which is consistent with a reasonable homework assignment. An answer booklet can relieve the faculty of some of the burden of grading homework problems, indeed the problems need not be graded, and one can use as an incentive for doing them a promise to use some of the same problems on quizzes or exams. A good study guide should not only give answers to problems, but should explain how to obtain the answers, and should cross reference answers to sections of the text which may require further study.

V. Specific Subject Matter Trends

In the last section of this paper, I will consider very briefly some of the major trends with regard to specific subject matter in the short organic course.

a. How much biochemistry? The trend toward including more biochemistry and less industrial organic chemistry in the short organic course is clear. In the 1953, 1959, 1966 and 1972 editions of our own text, for example, we devoted 0, 1, 4 and 10 pages respectively to the nucleic acids. Many texts include sections on metabolism though in my opinion this subject should be left primarily to the biochemists to teach, with just enough examples in the short course to show that the metabolic reactions are often simply examples of well-known organic reactions – hydrolysis, oxidations and reductions, aldol and other condensations, decarboxylations, etc. But to discuss, for example, the Krebs cycle in this course is just to add another series of reactions for the student to memorize without really understanding them.

I predict that in the future greater attention will be paid to hydrolytic chemistry, to phosphate and thio esters, to the chemistry of amines and heterocyclic compounds; less time will be spent on petroleum chemistry, acetylenes and certain hydrocarbon reactions, organic halides, and other classes of compounds or reactions which are of lesser importance in the reactions of living systems. It makes good sense to spend more time on reactions which will interest the clientele of the course.

b. What about the relevance of organic chemistry to societal problems? Student interest picks up when one discusses drugs, birth control compounds, the biodegradability of detergents, pollution by halogenated insecticides, etc. One can take advantage of this interest to teach organic chemistry which is just as sound as the reaction of Gringnard reagents with carbonyl compounds, and surely of much greater relevance to the nonmajor who takes the short course. Students also get interested when I discuss the Miller and Urey experiment, and others like it on chemical evolution, and I predict that this topic may be expanded in the future.

c. Where should stereochemistry come in? The concept of three-dimensionality in organic structures should of course be discussed from the word 'go'. Geometric isomerism is also easily introduced at an early stage, perhaps with cycloalkanes and surely with the carbon-carbon double bond: The concept of optical isomerism tends to come earlier and earlier as the years go by, though I think the discussion of optical activity, polarized light, etc. can disrupt in the sense that it focuses attention on an unfamiliar subject and unfortunately connects structure with some phenomenon regarding light rather than chemical behavior. One can easily use geometric isomers to illustrate reaction mechanisms and defer optical isomerism until the student is familiar with the functional groups present in lactic acid, glyceraldehyde, tartaric acid, etc. In short, the subject can be deferred until it is really needed to discuss amino acids, carbohydrates and other natural products. However this is admittedly a matter of personal taste and my own may run counter to current trends.

d. What about other new topics? The contributions of spectroscopy to structure determination may interest some students and the trend is for more material in this area–though I am not convinced that it means a great deal to the clientele of the short course. Molecular orbital theory comes in the same category, though pictures of orbitals do help the student to conceptualize structures and I think they will be increasingly used. Energy diagrams are rather abstract and not too helpful for students in the short course.

VI. Conclusions

The point which has to constantly be kept in mind by those teaching the short organic course is that the students are there for a purpose different from that of chemistry majors. The problems of selection of material and of motivation are exceedingly important. Hopefully the future will bring an even greater regard for the student's interests than has been seen in the past. If sight of this goal is not lost, the course will continue to serve a useful function.

QUANT, THE REAL THING

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Some institutions have saved quantitative analysis as an independent entity through restorative pedagogy (1,2). Some have deemphasized quant by fusing it with allied lower division chemistries to create unique combinational offerings (3). Still others have dropped the course completely or predicted its imminent demise, not atypically because they have judged analytical chemistry superannuated by comparison to purer disciplines which by definition are less applied (4). It is the feeling of this author that quantitative analysis is a workable discipline and that both its undergraduate and graduate programs should be sustained and strengthened. At Los Angeles Valley College we have modernized and invigorated the course through reevaluation of the goals and objectives of training in chemical analysis.

Philosophy and Reorganization

The main thrust of reality is analysis of "the real sample." As indicated in the lab outline below we use mostly real samples, some furnished by the student himself. Utilizing "what chemists do" provides fertile ground for making valuable correlations while holding student interest and scientific significance (5). The intriguing complexity of practical analyses presented as case histories with exhibits gives glimpses of other sciences and technologies and leads into wide ranging discussions of current analytical problems and the analyst's attack on them. We picture the analyst as a scientist who does both basic and applied work and one who knows how to (a) evaluate a problem as a whole and interpret a sample's origin and chemistry in order to select the appropriate analytical method, (b) devise a method if a new one is desirable, (c) gather a representative sample, isolate the analyate and determine it, and (d) properly express the result, knowing the limitations the procedure has imposed.

We began serious redirection of quant in the early 1960's when first noting a general shift of student interest from engineering to biology. Since then we have altered the classical quantitative curriculum by shifting the emphasis toward life science and environmental chemistry while generally updating the content. Previously, for example, we analyzed alloys, minerals and salts using such techniques as furnace combustion and electrolytic separation. Now we are examining foods, natural products and the structure of organic molecules using spectrometers and chromatography. As developments dictate we will continue to change the material somewhat each year.

Our two freshman semesters have been divided into three approximately equally weighted units of work: (a) general chemistry, (b) chemical equilibria, descriptive chemistry of the elements and qualitative analysis, and (c) introduction to quantitative-physical measurements. Experiments preserve certain analytical fundamentals (gravimetry, and titrations involving acid-base, precipitation and redox). To them are added studies that employ simple instruments such as the pH meter and conductance bridge.

Lecture Material

The following outline summarizes the formal principles presented in lectures with the aid of the textbook (6) and library assignments. In one way or another all prime topics are interpreted in lab except NMR, which is introduced through examples of actual spectra. By using laboratory hours for all other activity (giving exams, film viewing) we average 29 lectures per semester.

1. Overview of analytical chemistry and its importance today; sampling; errors; statistical handling of data.
2. Review of stoichiometry; gravimetry; solubility equilibria; activity coefficients.
3. Acid-base chemistry; normality; polyprotic acids; amino acid systems; nonaqueous methods.
4. Extraction; distribution coefficient.
5. Redox chemistry; iodine methods; potentiometry; ion-selective electrodes.
6. Spectrometry-I; nature of electromagnetic radiation; general instrumentation for measuring radiation absorption; absorption of visible light; photometry laws; absorption of ultraviolet; structure correlations and quantitative methodology.
7. Spectrometry-II; absorption of infrared; structure correlations and quantitative methodology.
8. Spectrometry-III; flame emission and atomic absorption.
9. Chromatography; principles; brief survey of types; gas chromatography.
10. Nuclear magnetic resonance spectroscopy.

Lab Demonstrations and Experiments

Demonstrations focus on new lab procedures and usually include analysis of one or more samples which are not duplicates of other lab work. During each demonstration the student takes notes in his notebook and processes the analytical results as if he had been the analyst.

Student experiments have been chosen to illustrate lecture principles and give experience in both classical and modern methods. Experiments that employ single, major instruments (Experiments 6, 7, 8) are assigned on a rotation basis for teams of two or three students at a time. Each person gets hands-on experience with every instrument.

For analytical procedures we use adaptations of journal articles and standard methods published by such organizations as the American Society for Testing Materials. In common with much commercial lab work in which slide rule accuracy (or less) is adequate, we regard our methods for real sample analysis as semiquantitative. Student answers are evaluated by comparing them to last semester's analytical results, and the understanding the student shows both in his notebook and during in-person discussions. A few synthetic unknowns (example: Experiment 3b–1) are included specifically to check on the accuracy of the student's work.

The remaining time is used for a "research" project which the student selects individually. He has been anticipating this and done some reading and consulting with the instructor. He is expected to (a) propose his own problem and find adaptable directions in texts or the literature, or (b) select an experiment from a list furnished him for which a procedure is available but which is to be modified in some novel way. Projects are graded for originality, completeness of planning and writing, and results.

Ideally, two laboratory assistants should work with the class throughout the semester. We have one knowledgeable upperclassman whose job includes getting demonstrations ready. He is indispensable the last three weeks of the semester which are unusually busy.

The present schedule of demonstrations and experiments follows.

Demonstration A. *Lab measurements.*
  a) One-pan balance.
  b) Gravimetric techniques.
Experiment 1. *Calibration of a buret.*
Experiment 2. *Gravimetric phosphorus in detergents.*
Demonstration B. *Acid-base titrations.*
  a) Volumetric techniques.
  b) Conductometric titration of HCl–HOAc mixture with KOH (7).
  c) Saponification number of a fat (8).
Experiment 3a. *Potentiometric titration for total acid in powdered gelatin dessert.*
Experiment 3b. *Nonaqueous titrations.*
  1) Pure amine titrated for equivalent weight.
  2) Total alkaloids extracted from tobacco (9), titrated with the $HClO_4$.
Demonstration C. *Iodine methods.*
  a) Analysis of a copper ore.
  b) Titration of I_3^- with $S_2O_3^{2-}$, biamperometric end point system (10).
Experiment 4a. *Fat in prepared meat and its (Hanus) iodine number (11).*
Experiment 4b. *Ascorbic acid in citrus juice (12).*
Demonstration D. *Visible spectrometry.*
  a) Spectral curves of Ni^{2+} and Ni–EDTA complex; finding wavelengths of maximum absorbance.
  b) Finding the reacting ratio of the complex (Job's method) and the instability constant (13).
  c) Analysis of Ni^{2+} plating bath solution after establishing a calibration curve.
Experiment 5a. *Fluoride in water by visual colorimetry (14).*
Experiment 5b. *Spectrophotometric determination of* Cr^{VI} *in waste water (15).*
Demonstration E. *Ultraviolet spectrometry.*
  a) Absorption spectrum of benzene vapor.
Experiment 6. *Ultraviolet spectra of selected compounds.*
Demonstration F. *Infrared spectrometry.*
  a) Spectra of thin polymer films (16).
  b) Cell thickness from interference fringes (17).

Experiment 7. *Infrared spectra of a solvent, solute and solution.*

Demonstration G. *Chelometric titrations (18).*

- a) Total hardness of tap water.
- b) Ca^{2+} in tap water.

Demonstration H. *Atomic absorption spectrometry.*

- a) Establishing instrumental parameters: sensitivity at different wavelengths, effect of spectral slit width, effect of fuel/oxidizer flow rates, flame background absorption.

Experiment 8. *Analysis of natural waters for Ca^{2+} and Mg^{2+} by atomic absorption.*

Demonstration I. *Gas Chromatography.*

- a) Establishing instrumental parameters: flow rate, temperature, column selection.

Experiment 9a. *Gas chromatographic resolution of a mixture and determination of certain characteristics.* Instrument: Carle Basic Gas Chromatograph with recorder.

Experiment 9b. *Gas chromatographic quantitative analysis (19).*

Experiment 10. *Research.*

Some examples of recent student selection:

- a) Conductance studies of water pollution; student-made circuit.
- b) Blood analysis with a blood gas analyzer.
- c) Investigation of the quinhydrone electrode; student-made circuit.
- d) Cholesterol by colorimetry; isolation from gallstones.
- e) Performance of an Oldershaw perforated-plate column by refractometry.
- f) Chloride in desert plants; comparison of methods.
- g) Sodium in diet-controlled urine specimens by flame photometry.
- h) Nickel in meteorite fragments; synthesis of α-benzildioxime for gravimetry.
- i) Total atmospheric oxidants by spectrophotometry.
- j) Photometric titrations; tannin in tea, etc.

Summary

Response to the program described has been gratifying. We believe the results are due partly to a humanistic teaching philosophy which recognizes that socially directed idealism, a desire to understand the physical world and a need to become useful (and therefore acknowledged) are powerful wellsprings of student self-motivation. Chemical analysis serves admirably to tap these sources because it demonstrates with convincing directness how quantitative answers can be obtained from nature. As the student examines genuine bits of his environment from a foundation of theoretical principles he comes to realize that analytical chemistry is one of the most powerful problem-solving tools we have. And as he finds how chemists are applying it to questions everywhere in the service of man we think on balance he sees a need for more science—not less—and therein opportunities for his own career. So far, nobody has finished the course saying quant is not the real thing.

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Future Trends in Chemistry for the Non-Science Major

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Introduction

Who can predict the future? I surely cannot! But I can see some of the future needs of the human race, and they are all related, in some measure at least, to chemistry. From the urgent need for a balanced diet by much of the human race to the dedication of a wondrous work of art or a religious sacrifice, it all has to do with matter and the value we place on material things. Even the poet is inarticulate except in his comparisons to material things. A chemical Garden of Eden or a chemical doom are the extremes at either hand for the human race. In the near future we will likely not go to either extreme; but in the long term, either is conceivable for a human family such as ours. We will move! To say the obvious, we will progress or regress; but the important point is: *our motion will, in a way, be chosen*—either by default, or by intelligence, or some combination of the two. How we handle liberal arts chemistry can surely be a significant point in the determination of our chemical future. So this makes our meeting today and our discussions important, as I am sure you are well aware.

It is apparent that the speakers for this symposium were chosen because of the chemistry books we have written for the non-science major. Let's be honest about it—we would like to sell books! We are somewhat like the six Democrats who appeared with Frank McGee last Tuesday morning before the Wisconsin voting; we would like to create the best possible impression in order to achieve our goals! And I, for one, admit it is sometimes difficult to distinguish between personal greed and human need. I hope that in this talk and in my writings with Jones, Johnston, and Wood, I can, and have, avoided the error of observing the motion of the crowd, racing to its front and shouting, "I am your leader!" I further hope that this talk will adequately represent the writings of our group, which are intended to help meet individual and social needs relative to chemistry.

We are indebted to the W. B. Saunders Company for publishing our work and making this presentation possible.

But, we are here to discuss trends.

> *Trend Number One: There will be a growing awareness of the vital self-interest involved for the individual and the society in chemical understandings, chemical control, and chemical transformations.*

A good many years ago, when I was teaching the seventh grade in Ketchikan, Alaska, the principal of the school, Walter Savikko, and I were dealing with a truant. The lad insisted at first that he had the right to remain ignorant. He argued that he would hurt no one but himself, and he was not at all sure that he was even going to do that. After much talk, the point that seemed to score best with the boy was, and is, the most basic reason for compulsory education in the United States—our system of government cannot survive an uneducated electorate. He came along and was an acceptable student after that.

Now, I know it may be somewhat premature for me to draw a strong analogy between the Alaskan truant and the non-science major who says "so what?" to the physical sciences. But in my judgment, my only error is in the degree of prematurity. When I think of population trends along with the consequent need for food, clothing, and shelter and the attendant pollution problems, I wonder just how much chemical ignorance we can stand.

There was a time when an education in the liberal arts was a luxurious thing. If one had a patron, or an endowment, he could in his ivory tower "do his thing" with no real concern for the practical consequences. "Intrinsically interesting matters!" "Learning is important!" "The scholar cannot be concerned with the results of his newfound knowledge, not the effect that it has on things or even its effect on people, for that matter." Chemistry was born, and it flourished in such a climate.

But the consequences of chemical knowledge were small, and are even yet. Thus far, chemistry has claimed much that technology has wrought. However, it is changing fast! The "golden age" of chemistry is at hand. It will change our environment if not life itself. We are fast approaching the point where we cannot do without the common sense of the common man in the chemical affairs of this world.

Now the common man, more than the scholar, does much of his learning for extrinsic reasons. If convinced that a chemical solution is available to answer his need for a paper mill in his community and his desire to maintain a good environment, and if he believes that such chemical matters are scrutable for ordinary folk, he will proceed to acquire the needed understandings. And this we believe to be a wholesome thing, for in keeping with our approach to government, all who are affected should participate to some degree at least in the group decision. The question will be just as important in the chemical revolution as it was in the American revolution: can the masses trust the elite? And the masses will surely answer, "No!"

More and more, the enlightened individual will demand more chemical information and the understanding to use it to solve his immediate problems. The liberal arts chemistry course cannot provide all that is needed, but it can show the ready accessibility of the information and understandings. In my area of Tennessee, my dairy-farmer friends constantly talk about the chemistry of feed stock nutrients, and of the soil, and why some fertilizers are easily leeched from the soil while others are not. Some even subscribe to the research publications on these matters from the University of Tennessee.

Consumer chemistry has been a matter for the curious, the choices involved giving way to the hard sell of Madison Avenue. But this will change! The demand for buying drugs by chemical names is a sign of the future. When food additives outnumber the foods, and when we admit to the public that we really don't know the consequences of some of the chemical things we are doing, they will demand a greater degree of chemical understanding and participation.

Chemistry for the immediate use of the non-chemist is here and will continue to grow. The college chemistry course for the non-science student cannot go on being oblivious to this.

In addition to the demands of society in general, and the individual in particular, for the desired chemical control to further man's interest, there is an increasing degree of chemical conscience showing. Dr. F. A. Long, Cornell University, and Chairman, ACS Committee on Chemistry and Public Affairs, said in the April 3 issue of *Chemical & Engineering News:*

> *In the face of these urgent problems (peace and war, elimination of poverty, a deteriorating quality of life) we as chemists cannot, in conscience, maintain a stand-offish position of dedication only to disinterested science, or act as spectators while technology develops under its own imperative. If we are aware of possible deleterious impacts of new science and technology, we have a responsibility to alert the Government and the public. We should foster and participate in technology assessment efforts, designed to maximize the benefits of technology and to minimize the deleterious effects. We should actively search for ways in which chemistry can contribute to desirable social goals. In a word, we should work toward a more perceptive and participatory social conscience to chemistry and chemists.*

Most of us, in fact, have commonly argued that the central characteristic of a profession, be it law, medicine, or the ministry, is a sense of responsibility for others. As we guide chemistry toward an increased professionalism, our standards surely should be no different.

This desire to use science to help people is at the highest level of human motivation—the human urge, yes, the human need to help humans.

Trend Number Two: There will be a clearer focus on the sensory world and the constantly changing theoretical world, the latter seeking to explain the former.

Inductive reasoning and circumstantial evidences concerning theoretical matters, by their very nature, can never be final and absolute proof for any assertion. The chemist will be forced, as his science becomes more and more public domain, to admit that much which he supposes and believes to be true is something less than fact. In talking with his peers, the chemist has a tacit understanding concerning what is real and what is theoretical, but this does not often come through in his conversations with the public. I suspect that the scientist himself often gets intoxicated with his theories and treats them as fact. John Dalton died before he gave up the argument. Consider this quote from J. J. Thompson:

> "This quantity can only be the charge on the central positive nucleus, *of the existence of which we already have definite proof.*"

We have a marvelous case for the nuclear atom; yes, even overwhelming evidence in the minds of most; however, let us admit it is not definite (in the sense of being final) proof. Dewey Larson, at least, would like for you to consider another possible explanation. History offers ample evidence that even though the scientific world generally agrees on a theoretical point, the point may soon fade in the light of new facts. It is too bad that elementary and high school science programs are so constructed that they make no distinction between fact and theory. It is no wonder that the students now coming to college think the science to be mysterious and "beyond them." It is not uncommon to hear them say that it takes a special kind of mind to understand chemistry. Some of what they learned had to be unlearned and little if any reason was given for either the new or old set of beliefs.

Now, lest I be misunderstood, I agree that there is a degree of subliminal understanding of fact and theory in the high school graduate's mind, but it is rarely in clear focus.

In my teaching experience, students seldom have trouble with facts unless you foolishly want them to remember all of them. They readily accept facts, especially if through demonstrations and experiments; they can experience them. It is hard to argue with laboratory facts, and hardly anyone does.

Theoretical ideas are quite another matter. They are harder to comprehend because they have already stretched the imagination of the conceiver. The ideas have to be conveyed to others. But, if you call a spade a spade and honestly admit that this imaginary idea is a plausible explanation for the accepted facts and nothing more, the whole thing goes rather well.

Until this fact-theory relationship is clearly developed in our liberal arts chemistry, our students will continue to leave even our college courses with a smattering of information and no coherency upon which to hang understanding.

I predict that society, as a whole, and our liberal arts students in particular, will increasingly suspect that we are not first-cousins to God. They will persist in "why" questions until we communicate as candidly with them as we do with each other.

The chemist will be forced in his exchanges with the public to be somewhat more conservative in his claims concerning his knowledge and understandings. We will learn to avoid such statements as: "all problems can ultimately be reduced to simple acts of the atoms and molecules." Or we imply that a molecular understanding of the most basic human problems is "just around the corner." It is possible that these statements are true, but it is nonsense to make them as fact. It is one thing to say that these assertions are possibly true, but it is quite another to challenge the will of the individual, religion, and ethical decisions made on personal values, by such molecular assertions. We will be far more believable, creditable, and understandable if we will insert a few "maybe's" and "possibly's" into our theoretical pronouncements.

Trend Number Three: Chemical laboratory experiences for non-science majors will be directed toward problem solving and the interpretation of individualized data, or they will cease.

A clear distinction should and will be made between demonstrations and experimentation. It is far too costly in trouble, time, and money for the same demonstration to be repeated 30 times for 30 students in a chemistry laboratory. Such a demonstration should be done by the teacher or a selected student for the benefit of all. Nothing is worse in the chemistry laboratory than the situation where the students can read the results of the lab work in the textbook and then dry lab the "experiment." This is not an experiment although it is an experience—an experience that is generally boring. An experiment involves a situation in which an observation is made and other observations were apparently possible. There is an inherent sense of excitement in a well-conceived experiment that is experienced by the liberal arts student as well as the research scientist. The level of sophistication of the experiment has little corrolation with the level of excitement; rather, it is related to the natural curiosity that is in us all.

Perhaps the greatest problem in understanding chemistry for most people is their lack of understanding of what chemists actually do as they "ply their trade." It is easy enough to allow the non-science major to do the things that chemists do, to gather data peculiar to each student, and then draw individual conclusions. Experiments in purification, identification, quantitative measurements, preparations and partial characterization of laboratory preps are easy enough to achieve in self-contained, three-hour experiments. If there is time and facility to move out into the community to experiment on pressing environmental problems, so much the better. But care will have to be taken here; nothing will substitute for experimentation.

In my experience, students with few exceptions state that the laboratory (as described above) is the most enjoyable and profitable part of the course. Perhaps it is only in the real laboratory with a real problem that students can get a realistic feeling for factual chemical information and its consequences.

To the largest extent possible, the experimental applications of the course should involve those things that have been encountered by the students. Experiments can and should be related to current problems such as pollution control.

If the lab is not relevant, it will be forced out.

Trend Number Four: The scientist will be downgraded and made to appear about as human as everybody else.

To say that science and technology have greatly improved the plight of the human race is to invite considerable debate. It may be a premature claim. It could be somewhat like the one-year-old who found the three-pound box of chocolates. It could have been a fine thing if used with discretion, but it wound up as a severe stomach disorder.

I am not at all sure how we have built up the notion that there is a typical scientist with all of the correct attitudes and qualities. We have led our students to believe that there is a scientific method, which, if properly applied, will finally solve all problems. Well, there is no typical scientist and there is no such thing as *the scientific* method. Our majors have known this for years because they get to know us; however, the masses, going by, have been fooled. As we affect their lives more and more in unpleasant ways, they will demand a better knowledge and see us for the humans we are. We cannot and should not hide our fumbling, groping, struggling efforts. To read one of our survey texts is to read one Nobel Prize winning story after another. As they watch us more closely, we all know they will see quite a few mistakes and abortive efforts between the prizes.

Now, I do not suggest that the scientist will not continue to be a respected person in the society. He will continue to have considerable power, but he will constantly be answering to the public who will be paying his bills. The awesome belief that science will surely make things better will be gone.

I think our public will come to the generalization that it takes no special kind of intelligence to be a chemist. In this area of human study, as in others, the smart ones make the most significant contributions, and it is harder to follow their thinking than that of the average fellow. I know that it is apparent that some human intelligence is more quantitative. But I am convinced that as the vital self-interest becomes more apparent relative to chemistry, people of all sorts will demand and obtain, to a measure, a greater degree of participation in the sciences. They will generally conclude, like the trial lawyer with a case in a new area, that an in-depth study will make them knowledgeable in the area. They, the people, will want and need the expert in chemistry, but they will not place their final chemical trust in him. Too much will be at stake!

The job of the liberal arts chemistry teacher will be twofold: (1) To set the chemical stage so that the student can operate with understanding and (2) to offer for study a wide variety of applications in current chemical problems, allowing the student to concentrate at his point of need and interest.

The particular facts and related theories that must be included are "up for grabs." We would never agree in mass. But some considerable effort has to be made here. Those who teach only chemical applications, without showing some of the "gut issues" in the inner workings of the science, will continue to mystify their students. A complete break with tradition wherein one looks only at current chemical problems will not satisfy; it will not work.

In summary, we will see these approaches:

1. Traditional (based on facts—this is fast dying out)
2. Traditional (based on concepts of theory)
   This will continue to have appeal for the true liberal arts student who loves learning.
3. A relevant approach (based only on current problems)
   This will have remarkable growth but it will not be satisfying and will not last.
4. A tandum approach (a combination of selected traditional concepts *based on laboratory facts* with a free-swinging study of some current problems)

We are presenting three books for the last three approaches:

2. *Chemistry, A Brief Introduction,* 1969.
3. *Chemistry and the Environment,* December, 1972.
4. *Chemistry, Man and Society,* 1972 (out).

Chemistry for Changing Times

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During the 1969–70 school year I was asked to teach a section of Chemistry 100, our course for the non-science student. I agreed to do so rather reluctantly, for I was quite happy teaching organic chemistry and pursuing a modest research program, though I was aware of declining enrollments in chemistry courses and a rise of "anti-science" among many of the students and teachers of the social sciences and the humanities.

This assignment brought a rude awakening. As I searched for a text, I became more and more appalled. Students in the humanities and social sciences were being offered the same sort of physics-oriented chemistry course that was given to majors, only watered down a bit.

Chemical education has changed a lot since I took college chemistry in the mid-1950's. In fact, a veritable revolution in the teaching of introductory chemistry occurred in the late 1950's and early 1960's. It perhaps began with Sienko and Plane's first edition of the textbook called simply *Chemistry* in 1957. It soon pervaded nearly all introductory chemistry courses in both high school and college. This revolution was a shift away from the historical approach and descriptive chemistry and toward the teaching of principles. Such a change was based on the quite logical assumption that, with the very rapid increase in chemical knowledge, one could no longer survey that field in a one-year course. One should therefore concentrate on the principles of chemistry. After all, principles have a little longer half-life than do so-called "facts" about industrial processes.

It seems to me, at least in retrospect, that authors vied with one another to see who could write the more rigorous and more sophisticated "principles" text. References to chemists, if made at all, were usually by last name only. These texts did not give a very good picture of "what chemists do"—or for that matter, did little to indicate that chemists even existed as human beings.

Courses of this type—as exemplified by CBA, CHEM STUDY, and their successors at the high school level and by the "Principles" courses at the college level—were quite successful for students already interested and for those able to deal with rigorous approaches to chemical problems. Students arrived at the next level of education in chemistry much better prepared—but fewer in number. These courses were essentially professional in character; they provided a sound foundation for additional work in chemistry. It was hoped that students could apply the experience gained in these courses to non-science activities. This important aspect of a student's education is often lost to many students because it is offered in the context of a chemistry too aseptic, too pure, too intellectually demanding, and lacking in any obvious relationship to the chemical world in which the student lives. At a time when the exciting action in chemistry was taking place at the interface of chemistry and biology, the teaching of chemistry was moving toward physics and physical chemistry. We were zigging when we should have been zagging.

I should point out that it is not my intention to negate the vital contributions of physics and physical chemistry to our discipline, but merely to point out that the mathematical vigor and aseptic nature of such courses led to the exclusion of large numbers of students from introductory chemistry courses—or to their failure if they did enroll. The courses were less interesting and more difficult to most students.

It is my contention, then, that curricular trends of the last decade or so have been a mixed blessing as far as science students are concerned. We have fewer students, but they are better prepared for future chemistry courses. What is really unfortunate, in my opinion, is that these same trends have pervaded even the courses for non-science majors, where they have caused an almost unmitigated disaster. The bestselling chemistry text for non-science students, for example, has three chapters on atomic structure—and virtually nothing on the chemical problems of the modern world. And yet we wonder why students are turned off by "chemistry."

What are the proper objectives of a chemistry course for non-science majors? Surely we should not try to make "little chemists" out of them by teaching—or trying to teach—"watered-down" principles courses to them. But they do live in a chemical world, and we as chemists can help them to interpret that world, to understand it, and perhaps in some cases, how to change the world.

Let's list some reasonable objectives for a chemistry course for non-science students.

1. Such a course should attract as many students as possible to take a chemistry course. If they don't enroll, you can't teach them anything.
2. The course should involve them in working through just enough cases so that they will incorporate in their life style a sense of how a chemist approaches and solves problems.
3. The course should induce them to relate chemical problems to their own life and living and to understand the significance of these problems.
4. It should excite students to an interest in the subject which is completely open-ended in content—as they take the course and, in time, as they leave the course to live the rest of their lives. Chemistry is not a dead subject to be memorized, then forgotten after the final exam. It is what the student *learns* the rest of his life—not what is *taught* in the course—that is really important.
5. Last, but not least, it should carefully distinguish between science and technology.

How can such objectives be met? Surely not by a watered-down principles course. Extensive expositions on the quantum mechanical atom, lots of stoichiometric and gas law problems, and a rigorous mathematical treatment of kinetics and equilibrium will merely serve to increase the students' fear—even hatred—of chemistry.

To attract large numbers of students, it is necessary to communicate with them. The lecture method traditionally used in college chemistry courses is basically a one-way street. We *inform* the student of what he should know. To reach those indifferent to or even anti-chemistry, we must find out what they want to know. And today's students are asking about drugs, pollution, chemical and nuclear warfare, and nutrition. Since these are chemical problems, their interest can be used to entice them into taking a chemistry course.

Only a minimal treatment of atomic structure and bonding is necessary before embarking on exciting adventures in the realm of structure-properties relationships. In my book I make a game out of molecular architecture by using simple valence rules to construct simple molecules. And a great effort is made to reduce the mystifying symbolism that chemists use to terms that can be understood by nonspecialists.

By approaching chemistry through the students' interest in everyday problems, one induces them to apply chemical data and principles to their own life and living. It is necessary to discuss current news items in order that these students see that chemistry is alive and well—and relevant more than ever to modern living. It is also important to point out that knowledge gained through science increases man's options. Whether the knowledge is used for good or evil depends on man's wisdom—not on anything inherent in science or its methods.

It is important in this course that students are not asked to memorize a lot of facts, formulas, and equations. The "questions" asked may not have answers. The intent of the course is to stimulate thought and discussion. Memorized formulas are soon forgotten. Attitudes often last a lifetime.

By choosing this course, I feel students have indicated that they are not interested in becoming chemists. If they should change their minds, they are advised that there are other courses. Recruiting majors is not a purpose of my course.

For most students it is assumed that this will be the last chemistry course that they will ever take. That doesn't mean that they will be through with chemistry. We live in a chemical world—a world of drugs, biocides, fertilizers, nerve gases, defoliants, detergents, plastics, and pollutants. To understand that world they will need to know some chemistry, and this course is a most important factor in presenting chemistry to the public at large.

We live in rapidly changing times. Indeed, it is said that the only constant thing today is change. Mankind faces some of the greatest problems in the history of the species. These problems have no easy solutions. Quite often we are faced with great dilemmas—with choices restricted to who is to die—and when. Save a few millions now—and imperil the race in the future. Unless one knows what the choices are, how can he choose? And many of the choices involve chemical processes. In fact, most of the problems we face are molecular in nature. And who but the chemist knows about molecules? In this course we look at a lot of molecules. And we look at that one great question, "Can man survive?" from a molecular point of view.

Meeting the objectives outlined earlier involves a careful selection of techniques. Extensive use is made of visual aids—movies, film strips, color slides, and overhead projection transparencies. For example, in presenting the concept of atomic structure I use a filmstrip, "The Atom," from LIFE magazine and the Chem Study film, "The Hydrogen Atom." In presenting the structure/properties relationship in drugs I use overhead transparencies. There are plenty of good movies available for this type of course, many for free loan. Lists of some that I have found effective are found at the end of each chapter.

The format of the so-called lecture sections is perhaps best described as a bull session. Small lectures are sometimes given in response to student questions. Even in large classes, this method has been eminently successful. *I* have never learned so much in my life—even a lot of chemistry. Many students, I believe, share my learning experience.

Students are encouraged to bring in newspaper clippings and magazine articles for discussion. Sometimes these discussions have to be postponed a bit while a little theoretical background is presented, but principles discussed in this way are at least presented in response to student questions.

The number of principles discussed in a course of this type is not great, but we must remember that these people will not become chemists. For what will it profit the profession if these students are able to repeat a few facts or principles on an exam, but wind up hating and fearing chemistry? The objectives outlined have been met in my course to a most gratifying extent. Course enrollment has doubled over a two year period. That student interest continues after the course is evident from the fact that students have joined environmental action groups, collected samples of monitoring of air and water quality, and have helped form and man a "hot line" telephone service for helping other students with drug problems. Perhaps most rewarding of all is the fact that students have come by later to say: "I've always hated chemistry, but you have turned me around."

In summary, it is my belief that chemistry can be presented in an interesting and intellectually honest form to students with little background and no great prior interest in chemistry. A fundamental assumption in a course of this sort is that it must be different from those taught for science majors. Art, music, and literature have been taught for years to the nonpractitioners in separate, different courses. Why not try an "appreciation of chemistry" course? A traditional chemistry course, no matter how "watered down," can only serve to turn off more non-science students and further widen the gap between the "two cultures."

The Challenge of Chemistry

Philip Horrigan

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The 29th Two-Year College Chemistry Conference
The Franklin Institute of Boston, Boston, Mass.
Friday afternoon, April 7, 1972

Last year I had the honor of addressing the Baltimore meeting of the Two-Year College Chemistry Conference. At that time I discussed how I felt about the teaching of chemistry to the non-science major. I emphasized first the importance of this mission. The general public must have more than a "newspaper' knowledge of science so that it can make wise decisions through its representatives on the many scientific and environmental topics that are of great concern to all. Therefore, the presentation of an effective, relevant, retainable course in chemistry for the non-science major is in my opinion of more overall importance than the teaching of chemistry to the science major. The instructor who becomes involved in such a course *must* feel that this is an important mission. On the other hand, if his heart is not in it, success with his class will not be forthcoming.

I further indicated that this effort is indeed a real challenge for the instructor. The non-science majors, although very capable students, generally have a "bug-a-boo" about science and math. They generally enter such a course with fear and trepidation and would probably not take the course at all if it were not required. The type of course that has been generally presented is of the general chemistry type. While general chemistry is a fine foundation course for students who must take more chemistry it certainly did not appear to me to be the proper approach for the terminal non-science student.

Since last year I am very pleased to observe that numerous schools and instructors are now revising their courses in keeping with this line of thinking. Moreover, there are a number of new texts appearing that are following and expanding this trend.

Today I would like to concentrate on the experimental work that should accompany such a course. I am sure we all are aware that students whether majors or not, gain so much more from a chemistry course by being exposed to and involved in corresponding experimental exercises. Furthermore, the students look forward to and enjoy this work. Because of large enrollments and the current financial problems many schools, including my own, cannot provide sufficient laboratory facilities. Therefore, the question is: shall we eliminate the experimental work and provide only a lecture course? If the answer is "yes," the students lose a great deal and, moreover, the instructor has a more difficult job in presenting the course. Many topics can be readily expanded and clarified during laboratory exercises and in addition the lab work lends itself to many exam questions which otherwise are a little hard to come by in a descriptive type of course. If the answer is "no" but lab space is not available, what is the alternative? After I describe the subject matter involved in the experiments that I recommend, I will tell you how these same experiments can be successfully performed in front of a large class with a maximum amount of student involvement.

The types of exercises should correlate quite closely with the subject matter being discussed in lecture. It is a common and legitimate complaint of students, both majors and non-majors, that what they are doing in lab does not relate at all to what they are currently learning in class. As for the sequence of topics in the lecture I feel that, since the discussion of relevant topics can have no real depth if the student has not learned some chemical principles, then the course must begin with a study of atomic structure, bonding, naming, formulas, equations, and the understanding of chemical reactions. Following this can be any combination of applied areas that the particular instructor cares to follow. I find that my students mostly enjoy discussing water and air pollution, household chemicals, food additives and agricultural chemicals.

For the "principle" type of experiments we begin with simple measurement exercises. Here the student learns about the different basic pieces of glassware and equipment with which he will be working and he also learns the metric system in a practical way. An experiment on the Bunsen burner and filtration teaches the student some common operations. He also learns about combustion, what is meant by "solute" and "solvent" and how to conduct an elementary quantitative analysis–the separation and determination of a soluble-insoluble mixture. Another exercise provides insight into physical properties. Flame tests are observed and correlated with the Bohr theory of the atom; and the measurement of boiling points and freezing points of pure water and solutions demonstrates the relationships and transitions of solids, liquids, and gases. In preparation for an experiment which will sort out the elements into metals and nonmetals and into families, the student learns about acids, bases, and salts. The reactions of acids and bases with each other and with indicators are carried out. Also observed is the effect of adding a metal to a simple non-oxidizing acid and the replacement of metals with more active metals. In the following exercise the student studies a number of elements in terms of their shininess, conductivity, and malleability to sort them tentatively into groups of metals and nonmetals. Then, using what has been learned about acids and bases the student, observing the acidic or basic nature of a number of oxides, completes his sorting and concludes what metallic or nonmetallic trends exist in periods and in chemical families. This experiment is best appreciated after showing the Chem Study film on the chemical families. For experimental work to accompany bonding we have the class prepare foam ball models of both ionic and covalent substances. And to gain insight into bonding in substances, the conductivity of molten solids and solutions are recorded. When the topics of chemical reactions and the writing of equations are under discussion in lecture, a number of typical ionic reactions are studied in the lab. Neutralization, gas formation, precipitation, oxidation-reduction are covered. The student must be able to write ionic equations for the reactions studied.

For the instructor who believes in the value of qualitative analysis there are five instructive experiments. We do only the silver group, alkali-alkaline earth groups and the anions. The H_2S groups are purposely omitted. I feel that enough instructional value in qualitative analysis can be attained in the groups mentioned without exposing the students and the school to the hazard and discomfort of H_2S fumes.

There are two quantitative analysis experiments which are applied in nature, and which conveniently introduce the concepts of mole and molarity. One is a titrimetric analysis of vinegar and citrus fruit and the other is a colorimetric determination of Vitamin B_2. As in the qualitative analysis, the student enjoys analyzing his own personally coded unknown. He attains an appreciation of the procedures used and errors involved in standard quantitative work. The non-science student is particularly interested in the application of instrumentation in chemical work. The operation of a colorimeter in a practical analysis is rather exciting for this student.

Introduction to organic chemistry and organic reactions covers three laboratory periods. Foam ball models are used extensively to help the student picture the shapes of molecules, the families of organic compounds and how simple reactions take place. Odors and flammabilities are observed and unknowns are determined. These two properties were chosen since the average person should be aware of the fire hazard of organics (and other hazards to be discussed in the household chemical experiments) and should be alerted to the presence of common hazardous organics by their odors.

Following the organic chemistry exercises are two experiments on polymers. With the aid of foam ball models the student learns what is meant by monomer, dimer, trimer and polymer. He further learns how certain monomers can yield chain structures (thermoplastics) and others can produce highly interconnected three-dimensional structures (thermosets). He learns about free radicals, how hydrogen bonding and chain shapes affect polymer properties. The student prepares Nylon and Bakelite and observes the differences in their properties.

Finally there are seven experiments on pollution and household chemicals. I am sure you are not surprised to hear that of all the experiments the class enjoys these the most. They involve topics of very great importance to all of us and topics that are not just a current fad. The public must continue to demand action in these areas to insure health and even survival for our future generations.

The water pollution studies should be introduced early in the semester. If the instructor asks the students to collect industrial effluent samples to be analyzed later during the actual laboratory experiment, he will find that many students are anxious to take action. Further, if the instructor agrees to report obvious violations to the U.S. Army Corps of Engineers he will find the class even more eager to cooperate. We have operated this way for the last two semesters and have accomplished the cessation of pollution of a beautiful lake by a plastics firm and the current investigation of a wire mill that continues to pollute a local river. The analyses performed are fairly simple—they include pH, chloride ion, total solids, total acidity, and total alkalinity. A recommended colorimetric kit allows quick and convenient analysis for a large number of ions such as iron, copper, sulfate, and phosphate.

The air pollution exercises are equally exciting for the students. A poorly operating burner can represent a soot-emitting smoke stack. The solids are drawn in through a tube and collected on a piece of filter paper. The operation is repeated while the burner is set with an efficient flame. The papers are compared. An inexpensive model of an electrostatic precipitator is then demonstrated by the instructor. Acid fumes in the laboratory air are detected by drawing a sample through a solution containing bromthymol blue indicator. This indicator turns yellow in the presence of acid.

The next exercise in air pollution is devoted to cigarette smoking. If this experiment is performed soon after showing the excellent National Cancer Society film on lung disease it has the greatest impact. Total solids (which include tar and nicotine) are determined for various brands of cigarettes and compared with published reports. The difference between solids in the first and last quarters of a cigarette is also demonstrated. The solids are caught on pre-weighed filter paper. The difference between final and initial weights, on a sensitive balance, gives the total solids values. In the final portion of the experiment the solids absorbed by the lungs of an inhaler are frighteningly demonstrated. The inhaler first blows three puffs without inhaling into the "smoking machine." The filter paper is removed and weighed. Now the inhaler blows three puffs after inhaling. If the student delivers consistent size puffs the results show about 80 per cent retention of solids in the lungs.

The last three exercises on household chemicals are designed to give the student insight into the chemical properties of the components of many products commonly found in the average home. The hazardous alkalinity of drain cleaners, oven cleaners, and detergents is determined. The pH, odor, flammability, total acidity, and total alkalinity of a number of products that the student is asked to bring to class are determined. The student is asked to look up ahead of time the toxicity and other hazardous properties of the ingredients of the products he has selected, and is directed to observe the effectiveness or lack of effectiveness of the labels on his products.

At Southern Connecticut State College our enrollments have been so large and our laboratory facilities so limited that we have been forced to provide our laboratory experience in the lecture hall. There is no doubt in my mind that the best sort of laboratory experience is the genuine one where the student performs the operations with his own hands and makes observations with his own eyes. On the other hand, there are certain advantages to the lab-lecture procedures which I will describe. The students must come to class prepared, just as to an ordinary lab class. The experiment must be read ahead of time, any necessary outside reading completed and, of course, he must bring his lab manual with him. The instructor, with the aid of an assistant (which could be a capable student), sets up the operations usually a day in advance in a nearby laboratory or prep room. Special pieces of equipment, which are more visual or that can speed up certain procedures, can be employed. For instance, a digital pH meter is fine for determining and concurrently displaying pH of samples. Hot plates, magnetic stirrers, colorimeters, and the like can be used to great advantage in front of the class. The operations to be performed in a particular lab-lecture must be rehearsed in advance, with the timing being worked out just as in a TV show. One of the advantages here is that certain tedious operations can be hurried through or even run ahead of lecture. A student in a traditional lab is disenchanted with having to watch something boil or heat for a long time. Interesting displays can be arranged on the lecture table to help amplify and add interest to the topic under consideration. Students enjoy using foam ball atomic model kits to make lattices and molecules while the instructor builds larger models at the front of the room. I make extensive use of the overhead projector. Previously prepared transparencies present the lab subject matter, step by step. Moreover, reproductions of the data sheets from the student's manual are projected and filled in as the experiment proceeds. Student volunteers are used to help the instructor run the experiments at the lecture table. The volunteers make observations and relate them to the class. The students enjoy this involvement and applaud each volunteer when he is through. Another very distinct advantage to the lab-lecture is the fact that the instructor is in direct contact with the entire class through all the exercises. He must explain the experiments and tie them in with his lectures. For this reason lab topics cannot "get out of phase" with the lecture material. This is a very common complaint with all sorts of beginning chemistry courses. The slides that I have brought along will give you a better idea of how we conduct labs in a large lecture hall. In the last three semesters I have used this method to teach almost 1600 students.

In conclusion, it is becoming evident that the correct way to teach chemistry to the non-science major is the non-mathematical applied approach. Furthermore, in the absence of sufficient laboratory space, if the instructor is willing to adopt our lab-lecture procedures, I can guarantee complete success.

Chemistry for Legislators

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Volumes of rhetoric have been produced in the last few years regarding the state of our society in general and of higher education in particular. I believe that an apt description of our moment in [illegible] was given about a hundred years ago describing an era in the previous century.

> It was the best of times, it was the worst of times, it was the age of wisdom, it was the age of foolishness, it was the epoch of belief, it was the epoch of incredulity, it was the season of Light, it was the season of Darkness, it was the spring of hope, it was the winter of despair, we had everything before us, we had nothing before us, we were all going direct to Heaven, we were all going direct the other way–in short, the period was so far like the present period, that some of its noisiest authorities insisted on its being received, for good or for evil, in the superlative degree of comparison only.

The quotation, of course, is from Dickens' *A Tale of Two Cities*, and the time was the period preceding the French Revolution.

We are today truly in a state of revolution in higher education. The list of unsolved problems grows every day, and one wonders how and if educational institutions can survive them. Nearly any teacher can cite a list of problems as well as their projected solutions. One of the most apparent difficulties is that the nature of student bodies and their attitudes have changed dramatically. They are demanding training in new fields that did not exist a few years ago; e.g., Oceanography and Environmental Science. They are demanding relevance, a vague term to most students, but which I believe means that their studies should relate in a practical way to the solution of life's problems. Most important of all, students are now making their wishes and aspirations known in the form of demands. This new approach has put faculties and administrators on edge, has led to extreme reactions in many cases, and to excessive permissiveness in others. In addition to these changes in attitudes there has been the great increase in numbers and social origins of students. The number of students in colleges and universities is expected to double in the seventies. Moreover, a broader spectrum of social and economic classes is represented among student bodies than in earlier times. Certainly, changes in higher education must take into account these factors as well as the new and changing needs of society in general.

My interest here is in the area of chemical education that is complementary to the education of chemists–the education of non-scientists. Since the mass of the population is composed of non-scientists, I chose as the title of these remarks "Chemistry for Legislators." In a very real way, the public is a legislative body. And with the rise in importance of science and technology, and of scientific voices in national policy, a concomitant rise has occurred in the concern of the general citizen over matters relating to science. One might say that the employment of the fruits of science to national goals is much too important to be left to scientists alone, or to an uneducated public.

Therefore, it is imperative not only to satisfy the desires of non-scientists to learn science; it is mandatory that we make science for non-scientists available and palatable to as many people as possible. In universities and colleges, this usually means formal courses. I believe, however, that our jobs as scientists and engineers will, in the present decade, reach out beyond the laboratory and classroom. Already for several years, the National Science Foundation has had a program to provide funds for the improvement of the public understanding of science. The concept of "University without Walls" has emerged at Antioch College and is meeting great enthusiasm. I do not believe that it will be enough simply to speak when invited by local civic clubs, instead we must do all that we can to educate the public in the process, methods, and goals of science as well as in the interrelationship of science and technology. It is important to note that this need cannot and should not be met by academic scientists alone. Industrial scientists and engineers must also do their part. Moreover, it will probably be more effective to communicate at the local level rather than through large, centrally organized channels employing exclusively nationally famous personalities.

Chemical educators have, in the past few years, centered their attention on two problems that have become increasingly aggravated. The first is the training of chemists, chemical engineers, and allied professionals. The second is the science education of non-scientists about which more will be said later. Graduate schools have become increasingly guilty of producing Ph.D.'s whose only motivation is research as carried out in university research labs yet most of whom will never pursue such basic research. These men often become personnel problems when they arrive on their first industrial job and find that their orientation, molded in graduate school, is quite far removed from that of their employer.

I believe that at least part of the problem with graduate education today is betrayed by the frequent use of the word *training*. Ph.D.'s cannot be trained to do creative science, they can only be trained to perform certain techniques. Such training, of course, is necessary but it is not enough. Students must be *educated* so that their talents, abilities, and techniques are developed to the point where they can begin to do creative work, be it in academic research, teaching, or in industrial research and development. It is the nature of this education, both in depth and in breadth, that is undergoing close scrutiny in many universities today.

I shall not pursue this line of argument further because my real intent is to focus on the area that is complementary to the education of chemists: the education of non-scientists. The above comments on training chemists are applicable to the subject of chemistry for non-scientists because in nearly all American colleges and universities the only chemistry courses available as electives for non-science students are those that are specifically designed to *train* chemists. Several polls in our department over the past five years have shown that less than one percent of students enrolled in our freshman general chemistry course have chosen it as an elective. Thus the remaining 99 percent take general chemistry as a prerequisite leading to a major in one of the sciences. One of the avowed purposes of general chemistry is the preparation for subsequent courses. This results in a great emphasis on manipulative skills, techniques, and drill, as well as on a compelling urge to cover all the material necessary for the next course. This purpose is not compatible with the fact that only about 10 percent of our freshman chemistry students are chemistry majors, and of the remaining 90 percent, about half will never take any more chemistry. The obvious solution to this state of affairs seems to be the institution of several freshman courses, each with its own goals.

A recent study by our chemistry faculty attempted to alleviate these problems of "relevance" and incompatibility in our freshman course. The result sheds an interesting insight into the training process: a meeting was held with representatives of departments that require freshman chemistry of their majors–engineering, biology, physics, premedical. Our suggestion was to initiate two or more tracks of freshman chemistry–one designed specifically for the preparation of professional chemists and engineers, and the others designed specifically to do the jobs required by these other departments. The reaction was overwhelming and negative. All of these representatives felt that the Chemistry majors' course would be more rigorous and difficult, and therefore they wanted their majors in it. The distinct impression emerged that freshman chemistry was for them less of a necessary background discipline than a device for screening out the "inferior" students. We in our pride have for years heartily endorsed our role of executioner. Little wonder that non-science students do not study chemistry!

Getting down to specifics, I would like to discuss some of the things that we are doing in the University of South Florida toward the education of the non-scientist. We are developing several courses both for chemistry majors and for non-science majors: (1) Historical and Philosophical Perspectives in Chemistry, which will be open to non-science students as well as chemistry majors, and which will focus on the nature of science and its relation to other forms of human expression; (2) a course called Science, Technology, and Freedom, open to all students, which examines the social responsibilities of scientists and which involves guest lecturers from departments such as history, humanities, and business, as well as science; (3) a course called Modern Chemical Science–CHM 371.[1] The latter course has been of most concern to me over the past few years and is the one that I shall describe briefly here.

CHM 371 is open to all students and has no prerequisites. The objectives are threefold:

(1) To provide an understanding of some fundamental ideas of chemistry, the nature of chemical knowledge, and the ways it is acquired. Students are led to realize that chemistry, like all sciences, is a human undertaking and not merely the application of some sterile "scientific method" to the solution of problems.

(2) To provide the necessary scientific background required of all citizen-legislators. To this end we conduct discussions on such topics as federal funding of research, the mutual influence of basic science and industry, and science and religion; we also have invited speakers who are particularly active in various areas of chemistry.

(3) To expose chemistry as an aesthetic experience. Chemists, naturally, have a profound interest in chemistry. In addition to its being our livelihood, it is a source of intellectual and aesthetic pleasure. I believe we are often remiss in not conveying this appreciation of chemistry as a beautiful activity not too unlike the arts. One of the aspirations of CHM 371 is to convey to

the student the idea that chemical research is an activity which involves personal human creativity in much the same way that musical composition does.

But what do you teach students who will not use chemistry professionally? Do you teach them how to balance equations or how to solve problems in stoichiometry; or how to solve equilibrium problems? I would answer that none of these techniques is useful to or relevant for these students. Our goals for these students should, I feel, be: (1) an understanding of the basic logic and strategy of chemistry; (2) the scope and limitations of chemistry; and (3) its past and present impact on the philosophical foundations of western civilization. The means by which we try to achieve these goals are presented in the following paragraphs.

Most chemistry courses have evolved into excellent examples of "textbook science": a clear, concise, orderly arrangement of subjects presented in a logical but frequently uninteresting sequence. This approach to textbook writing is, of course, necessitated by the enormous quantity of material that most teachers want to present. But the result of this approach and its emphasis on broad coverage is the omission of a very important aspect of science, and worse than that, the misrepresentation of it. Research does *not* proceed in such an orderly manner. Instead, science develops on many fronts simultaneously often by the pursuit of blind alleys, and through a significant amount of serendipity; it is, as Dr. T. F. Fagley has said:[2] ". . . a wandering dialogue with the unknown." Moreover, the motives of scientists vary greatly. There are thus two sciences–*textbook science* and *research science*. At the end of a freshman chemistry course, students frequently emerge bored and worn down, while the professor emerges with a sense of pride in having offered a good, logical, difficult course in an exciting subject. It seems strange that both professor and students have been involved in the same activity!

In CHM 371, I approach the subject as "research chemistry" and try to minimize the "textbook" approach. This is accomplished by the liberal use of chemical history, not for the sake of teaching the history of chemistry, but for the purpose of examining significant breakthroughs–how they occurred, what else was going on at the time, the impact on science at the time, and the impact on contemporary society, i.e., the nature of the total scientific enterprise. Some examples are:

Ancient concepts of the elements,
The phlogiston theory and its overthrow,
The development of atomic theory from Dalton to Schrodinger,
Elucidation of the nature of the atomic nucleus, and
Molecular Structure and its chemical consequences.

The general overriding ideas developed in CHM 371 are:

I. The relationship between atomic-molecular structure and the observable properties of matter–*the concept of the molecule.*
II. The nature of chemical change–*the concept of the chemical reaction.*

Wherever possible original papers are assigned. Examples of papers by Rutherford, Thompson, the Curies, and G. N. Lewis can be found that are quite readable for these students. Through them, they gain the flavor of the work and times.

Perhaps what I am trying to teach them is exemplified by this proposition: Dalton knew less chemistry than our freshmen. But he knew something that they do not know: he knew how to do science. What is the nature of this activity? An insight into the answer was given by Albert Szent-Gyorgy: "Research is to see what everyone else has seen, and to think what no one else has thought."

John Baxter of the University of Florida some time ago formulated "Baxter's Law: All educational experiments work." The reason, of course, is that the experimenter (teacher) is enthusiastic and sincere, and through his concern for the experiment and students, makes it work. I propose a corollary to Baxter's Law: "The only way to change a curriculum is to change the faculty." The reason for this is simply that professors will teach what they believe to be important regardless of course titles and descriptions. By changing the faculty, I mean causing faculty views and orientations to change.

There is a premise which is accepted as if it were another natural law of education: "What cannot be tested must not be taught." Both professors and students sense this; so, whenever a professor is tempted to digress into an interesting and important, but untestable area, he thinks twice, and, more often than not, returns instead to his lecture notes and to what will appear on the next test. I believe that this tendency must be resisted if *real* relevance is to be achieved in the teaching of chemistry to non-scientists.

Topics such as the social responsibility of scientists, the interactions between science and religion, and research funding should be discussed. Discussions of such topics are also excellent means of impressing upon students the importance of an understanding of the scientific facts, ideas, and concepts to the rational discussion of such topics.

While proselytizing is not an objective of the course, several students have, as a result of CHM 371, changed their majors to chemistry. In doing so, they must begin from scratch with freshman chemistry. These students have told me that CHM 371 provided an excellent background to freshman chemistry and even to more advanced courses; i.e., they knew *why* topics were being presented and where they were leading. It seems that CHM 371 served to "turn them on" to chemistry and its challenges.

This brings me to my final point: perhaps freshman chemistry can be restructured more along the lines explored in CHM 371; i.e., by emphasizing the more dynamic aspects of chemistry even at the expense of organization. In recent years, the high schools have provided better and better chemistry courses. Our response has been to raise the level of freshman chemistry until it is now physical chemistry at the freshman level. Many freshman texts are now written which presuppose a knowledge of calculus and physics!

Perhaps the freshman chemistry course should be changed away from the quantitative physical approach toward the more experimental, descriptive, human approach by which the science actually develops. Perhaps then can we truly begin to *educate* as well as *train* chemists; perhaps then we can begin to entice non-science majors into our courses; and perhaps then we may begin to communicate with the non-scientists who are, after all, our patrons.

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[1] J.E. Fernandez, "A Relevant Liberal Arts Chemistry Course," *Journal of Chemical Education*, **47**, 624 (1970).

[2] T.F. Fagley, "Chemistry and the University," *The Chemist*, July, 1971, pp. 171-77.

SALVATION FOR THE NON-SCIENCE MAJOR

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Many of us are dismayed by a society which is enjoying the fruits of science and technology to an extent greater than at any other time in history yet remains in its thinking essentially non-scientific and, in some cases, actually anti-scientific. The recent upsurge in followers of astrology and witchcraft can hardly stand as a monument to such noble efforts as the Chemical Bond Approach and Chem-Study. We wring our collective hands and ask, "Where have we failed?"

We are not unlike the kindergarten teacher who told a student that if he had to go to the bathroom he should raise his hand. His face took on a most puzzled look, and he asked, "But, Miss Murdock, how will that help?" Clearly, she had not communicated her intended message! Nor, I fear, have we been able to communicate the basic concepts of our faith to these unscientific pagans. Where, then, is the salvation for these souls who fail to appreciate a real-world view of life?

At least for the material portion of the real world, your Education Division's Curriculum Committee feels that for the non-science major there should be a shift in emphasis from atoms to attitudes and from molecules to methods. Is it more important for a history major to be able to balance a redox equation or to understand the problems associated with burning of high sulfur content coal? Note quickly please that to truly understand the latter the student must have some acquaintance with the former.

We have come to the conclusion that it is not the content that is important, but the broad principles learned. If content is not the focus, what educational objectives can be developed for a non-major course? Our committee lists five in their 1970 *Journal of Chemical Education* report (47, 157, 1970):

1. To appreciate the scientific method.
2. To realize the significance of science in our society.
3. To see the beauty in science.

4. To free the mind for imaginative thinking.
5. To develop the facility for critical and unbiased observation.

Clearly, such goals are desirable, but unless these goals can be converted into effective procedures to achieve them, they remain mere statements.

This conversion process begins by noting that our goals are statements of attitude and skills which we hope to develop within the student. If our premise is that attitudes influence the behavior of a person, then we must be able to translate these goals into observable behavior of the student. For example, by a student's behavior in response to a particular task we give him, we should be able to observe if he appreciates the working of the scientific method. By his behavior we need to be able to observe that he really does see beauty in things which are scientific.

Our committee has developed a resource pool of a large number of specific performance objectives. We feel strongly that the key to a successful course for the non-major is that a mature teacher design the course around his own enthusiasm and expertise and according to the needs of his students. Thus, rather than prescribe performance objectives which all must follow, we provide a pool of objectives from which the teacher may choose according to his own unique situation. In addition, we suggest certain instructional objectives as guidelines to the construction of his course.

These guidelines are in the first rough draft form and will be refined but the following examples will demonstrate their flavor:

1. The instructor shall present characteristics, advantages and disadvantages of conceptual and physical models and of theories in chemistry, and shall illustrate them through detailed examination of examples.
2. The instructor shall present for critical examination both the need for efficient communication in chemistry and the means available for achieving it.
3. The instructor shall provide opportunities during the course to insure that each student has had hands-on experience with liquids, solids and gases undergoing chemical transformations.

A particular instructor using these guidelines might choose from the resource pool the following performance objectives:

1. The student shall select one model used by chemists and specify four advantages and four disadvantages of the model.
2. The student shall state one example where the lack of efficient communication delayed a specific chemical discovery and identify the means now available which would have nullified the delay if it had been present previously.
3. The student shall prepare and isolate a compound from aqueous solutions of salts containing the requisite ions.

Obviously, these performance objectives need to be organized into a rational whole which we identify as the course for non-scientists. Later this morning I will show you how such a course can be built from a skeleton based on the three conceptual models of: the atom, the molecule, and the states of matter and the three present concerns of: the effect of science on man, the effect of science on the individual, and the effect of science on the environment.

To summarize, our strategy has been to develop a basic design of just what we wish to communicate to the student (educational goals). Then we develop a means by which we can evaluate the process (performance objectives), and finally we package the subject matter in convenient units based on some rationale (course skeleton). In the past the convenient units were textbook chapters and we were at the mercy of the author's educational goals. Rarely were performance objectives recognized in the collection of problems which may have followed each chapter.

The multimedia approach to learning has made the printed word only one means to assist the student in his learning. Our "convenient units" can now become "learning modules," each one designed at the will of the instructor and collected together to meet the specific needs of his students. The Division has placed one plan for the development of such modules before the National Science Foundation. This project is termed CAUSS–Chemistry, an Approach to Understanding Science in Society.

The CAUSS project is directed by Dr. William Cook, who was aided in the proposal by an Advisory Council of 21 members, headed by Dr. Calvin Vander Werf. We proposed a new Chemistry program for the general student in secondary schools and college. The program will include:

1. The development of modular units, complete with all written experimental and audiovisual study materials and teacher guides, and supplemental kits and packets to enhance group work and encourage independent study.
2. Constant testing and evaluation of all materials from cognitive, affective and psychomotor standpoints, followed by revising, rewriting and retesting.
3. Ever-broadening teacher training, not only in the use of the materials but in molding the attitudes and styles which make a wholesome learning-teaching situation in a program of this type.
4. Continuous communication with teachers' groups, teachers, and administrators across the nation, informing them of the philosophy, goals, progress, available materials, teacher opportunities, and practical methods for the introduction of the new program.

The project will have a central staff with an Advisory Board, but the real work will be at the grass-roots level. About six Regional Centers will be established, perhaps four at universities for work with secondary schools and two at two-year colleges. Regional Directors at these centers will work closely with a cluster of area high schools and their other colleagues to supervise the writing and evaluation of modules. Overseeing this operation on the central staff would be an Associate Director. Dr. James DeRose has been asked to serve in this position.

Material generated at the Regional Centers would be submitted to the two other members of the central staff: the Writer-Editor and the Director of Audio-Visual Aids. Dr. Wendell Slabaugh has been asked to be Writer-Editor. He would also edit a Newsletter to enable the general educational community to keep pace with CAUSS developments.

We are hopeful that CAUSS will reverse the apparent production of general students who are "turned off" to science. But we also wish to recover a portion of the *public* who are either neutral or negative toward science. The thrust here is in the form of another proposal on the Public Understanding of Science. It has three main attacks: 1) adult continuing education, 2) sixty-second T.V. "spots" and 3) a "mobile ministry," "Science-on-the-Move."

The continuing education portion of this project would be designed to appeal to the interests and needs of political leaders and public policy decision-makers at all levels of government. While sponsored by the Division, the programs would be interdisciplinary and coordinated with other scientific organizations and established at institutions with ongoing continuing education commitments.

The minute-long T.V. spots would focus on a single aspect of science. Some idea of nature, of the beauty and problems of science can be made to fit into just sixty seconds. Obviously, this will take great skill and imagination. The fact that under FCC regulations free time is available from the networks for telecasting these spots, the wide audience that can be reached and the potential value of the spots to call attention to longer programs of scientific value hoped to be aired on T.V., all make this project extremely worthwhile.

To reach the public when they venture away from the T.V. "The Science on the Move" program plans to visit State and National Parks in mobile vans to demonstrate how science and technology interact with society. Under my direction we hope to have a pilot project in operation next summer. Each van will be equipped with five Topic Packages, each topic package consisting of three parts: a motivational unit, teaching links, and a layman's library. The topics of the motivational units will be of current popular interest such as drug abuse, overpopulation, pollution, technological advances in the "world of tomorrow" and scientific behavior. These units will probably be 20–30 minute color films. The teaching links, serving to expand concepts presented in the motivational units, will consist of film loops, audio-tutorials and/or laboratory demonstrations. The teaching links will provide the learning bridge between the motivational unit and the lay library. This library will consist of paperbacks with the option available to the visitor to purchase books. (This makes it unnecessary to have a loan system.) Some library materials will be on reserve for reading only in the library.

It is planned that the mobile van will spend about a week at each site with a different motivational unit being presented each night. The presentation will be followed by a discussion led by the touring scientist. A "Science Action Center," a side room adjacent to the van, will contain the teaching links and the lay library. This Center will be open, under the supervision of the scientist, after each evening presentation and during the quiet hours of most campuses (10 am to 2 pm).

I hope you will agree with me that we are on our way toward revitalizing our message to the non-scientist—be he student or a member of the general public. I sense an evangelistic spirit afoot among my colleagues. This new surge of interest and effort in behalf of our unscientific heathen may not turn out to be their scientific salvation but at least I hope for a giant step out of their purgatory of astrology and witchcraft.

INDUSTRIAL REACTION TO CHEMICAL TECHNOLOGY PROGRAMS

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After looking over the Junior College District literature on Chemical Technology, I realized that chemical technology programs are not in the planning stages but are ongoing operations with students already enrolled. Thus, I think it would be appropriate to comment on what I believe will be necessary to make Chem-Tech programs successful.

Industry produces a product which it advertises and then hopefully sells to customers. I view the chem tech program in somewhat the same light. Let us look at this viewpoint further. Your "industry" also has a "product," that is, chemical technicians. As in most cases, this "product" must sell itself as well as its producers as competent suppliers. In other words, you chemical technicians must be *quality* graduates in order for your program to be successful.

What are some of the ways to insure quality of products?

1. Starting with the source of your raw materials (students), you should educate high school and college counselors to the opportunities available in this program. Although candidates for careers in chemical technology are usually in the middle half of their high school graduating class, it should be stressed that this program is not a catch-all for incompetents or persons who are in no way qualified to be in college. Also, professors in this "industry" are obligated to produce a good "product" by selecting and passing only those persons capable of handling the job. In most cases it may not be possible to select the students beginning in the program, but it is within your control to determine which students complete the program. Resist the temptation to carry 15 out of 15 students just to make the program appear successful. If these people are not successful in their jobs, then your "product" has failed the market test.
2. A good curriculum is necessary to produce quality technicians. From what I have seen of the course content offered at the Junior College District, the students should have an excellent education in chemical technology. I would suggest that you consider inviting possible employers (Managers) to give seminars describing working situations and what they expect of their technicians. This would also serve as advertising for your "product" in that these managers would become familiar with your program.
3. Many companies (particularly research organizations) stress the need for continuing education by having the employees attend college at night. Even though the two-year program is not designed to be directly transferable to a four-year (BS) program in chemistry, your graduates should be made aware that the training they have received as chemical technicians will be useful if they choose to get the BS degree.
4. After a period of time, follow up on your graduates by contacting them for suggestions on areas which they feel need improvement in your program. This may be your most valuable feedback. The employer can also provide insight into the effectiveness of your instruction.
5. Keep the program viable by being willing to introduce new technology into the program as it is developed by industry and the sciences.

I am sure that there are many other suggestions that could be listed to make your "industry" successful but I believe the main emphasis should be on the quality of your "product."

Your program must produce chemical technicians who can function with minimum supervision and with little on-the-job training. Otherwise, there is no advantage in hiring them over high school graduates who can be trained on the job.

A COMPARISON OF THE TRADITIONAL CHEMICAL TECHNOLOGY PROGRAM AND THE CHEMTEC PROGRAM

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Presented at the 29th Two-Year College Chemistry Conference
The Franklin Institute of Boston, Boston, Mass.
General Session, Saturday morning, April 8, 1972

Before presenting a comparison of the two approaches, I think it is necessary to make a few introductory remarks of concern related to chemical technology:

First and foremost, chemical technology programs seem to be in trouble. It is not a secret that community colleges and two-year technical institutes are suspending chemical technology programs because of the lack of enrollment. One would feel that because chemical technology programs have been offered for forty some odd years that the in-put of students should not be a problem. Obviously, this is not true. The problem of low student enrollment is generally so prevalent that recently the National Science Foundation "Technical Education Development Programs" grant evaluation committee has rejected all chemical technology proposals. They maintain that the chemical industry voices deep concern over the shortage of technicians; that throughout the country very well established chemical technology programs exist, but they do not understand why students from high schools do not choose to pursue a career in the area. This grand statement on the part of NSF is old news to any teacher of chemistry in the area of chemical technology. I have been active in the area for the past six years, and every conference I have ever attended always discusses the point of recruitment at great length. What is the answer? I don't think there is any one solution. I'll come back to this area of discussion a little later.

The American Chemical Society office of education lists some 200 schools at both the four-year and two-year levels that either offer chemical technology programs or show an interest in starting one. The most reliable surveys show that approximately 85 schools are actively engaged in chemical technology programs.

Of these 85 schools 12 are pilot schools that have been using ChemTeC materials for the past two years. It will be to these last two that we shall direct our remarks of comparison.

What I would like to do is compare the course offerings of a traditional program and one from a ChemTeC pilot school. Both programs that will be illustrated are two-year state colleges that award an associate in applied sciences degree in a career-oriented chemical technology program.

In examining the course offerings, we will consider the areas of chemistry offerings, mathematics and physics. The areas of liberal arts and social studies etc., will not be considered because accrediting bodies in different parts of the country will differ with respect to these last mentioned areas.

1. The chemistry offering from the traditional program is listed as 5 hours lecture and 4 hours of lab. We can assume from the designated hours that the thrust of this beginning chemistry offering is heavy in theory.

   The ChemTeC approach lists 2 hours of lecture and 8 hours of lab for the course listed as ChemTeC I. At RIJC this total of 10 hours is scheduled in 3 blocks of time. A typical scheduling scheme would be 2 3-hour blocks and 1 4-hour block, for a total of 10 hours. These blocks of time allow a maximum flexibility with respect to lecture and lab. This would allow an instructor to spend as much time on an experiment as would be necessary. The lab could be preceeded or followed by a discussion of underlying concepts.
2. The traditional approach lists calculus as the required course in mathematics. I don't think I need to expand on the problems that a student encounters in trying to deal with this major stumbling block in a chemical technology program.

The ChemTeC approach at RIJC is very flexible with respect to its math requirements. If a student is able to handle a rigorous course such as calculus and has the pre-requisites, he is allowed to pursue such a course. If not, the minimum requirements for the AAS degree is a basic technical math couse, that does not include calculus. We find an average student is able to handle this course. In cases where the student can handle only Algebra I and II, we allow them to enter the program as a diploma student rather than a degree candidate. We have found that when the pressure of math requirements are minimal, the student shows greater success in the chemistry and other subjects.

3. The physics course is offered by both approaches. In most traditional programs, this course is again theoretically oriented with emphasis on sophisticated mathematical computations.

   The ChemTeC at RIJC has designed a physics course that includes those topics which augment the underlying physical principles in the chemistry laboratory. The math is kept minimal and the thrust of the course is conceptual.

I thought that a look at the first two years of a BS program might be interesting at this point. The similarity of Chemistry and math offerings between the BS program and the traditional program are striking. The physics offering in the BS program appears in the sophomore year where in the traditional chemical technology program it appears in the first year and the second semester of the second year.

Now that we have looked at the course offering from the two approaches I would like to make some remarks concerning what we might expect as an end product.

Bob Hofstader of Esso Research cited a case history that relates in a very informative way as to what could happen to students of Chemical Technology. A few years ago Esso Research in Linden, New Jersey, hired a group of fifteen laboratory technicians for summer work from local schools. The students were looking for on-the-job summer training and, of course, the company was looking to the time when these students would be graduating from their respective schools and would become applicants for full-time technician positions. At the end of the summer, the professional chemists at Esso made their recommendations purely on the functional aspects of technicians and how they worked out in their groups. The following year when recruiting time came Esso went to the local schools looking for the five top-ranked students (top ranked with respect to Esso's evaluation not an academic evaluation). To the dismay of the company, three of these five had flunked out. A fourth was not interested, and the fifth had transferred to a four-year college.

The fact that three of the top five flunked out points out a hard fact. Industry ranked them high as technician candidates because of the abilities in the lab; and, apparently, the academic subjects which were probably theoretical in content washed them out.

The traditional approach to the chemistry seems to divorce the lecture courses from the laboratory work. This is always a problem in the minds of the instructors, and is mulled over at the end of the year when new texts and laboratory manuals are discussed for possible adoption for the next year. Unfortunately, most chemistry texts and lab manuals used by two-year college chemical technology courses are written for the student that will be going on to the BS rather than for chemical technology. The ChemTeC materials were written with theobjective of integrating the laboratory into the lecture. Therefore, the concepts as presented flow from the lab to the lecture rather than the other way around.

The traditional approach to the chemistry is one of sub-disciplines. This is very similar in approaches to that of a BS program which is geared to prepare the professional chemist or chemical engineer. Because of this basic similarity, the few successful chemical technology students automatically transfer to four-year schools. Those who fail in this endeavor become technicians. The ChemTeC approach is attempting to erase the stigma attached to traditional programs as being "watered-down" offerings from a four-year program. The ChemTeC concept is one of approaching a different group of students with a different kind of chemistry. The group involved with assembling and writing the ChemTeC materials for the past two years spent considerable time in evaluating the kinds of things that a technician would be doing on the job. Once this definition of a technician was obtained, then this different kind of curriculum could be launched.

The technician is an individual who is oriented in applications in the laboratory. To this person the science of chemistry is a tool which makes him an effective and efficient part of a team of workers in the laboratory. Using this basic definition as a guide, we can then surmise that a chemical technician cannot be properly trained in a "watered-down" BS program, or in fact, be a drop-out from BS program, which for the most part are not lab oriented.

Because the thrust of the information deals heavily in the laboratory, the ChemTeC approach deals with the chemistry through experimentation using an underlying theme or concept approach. The laboratory is used to teach the basic chemical or physical concepts. For example, the first major concept, that of "purity," is presented in a novel fashion. The student first separates out the components of washable inks using paper chromatography. Once the concepts of purity and chromatography have been discussed, the student is next introduced to the gas chromatograph as a sophisticated instrument for separations. These first few sets of experiments that are done by the students as their first exposure to chemistry in the laboratory are not only meaningful, but just as important to beginning students, they capture their imagination.

This basic philosophy is the thread of the ChemTeC textural and laboratory work as I see it.

In the sophomore year the ChemTeC III and IV offerings at RIJC show an 18-hour-a-week involvement on the student's part. The large blocks of time assigned to the chemistry allow for even more flexibility than the freshman year's work. We use the time in many ways. Besides the regular laboratory work, some of these are:

1. Field trips to industrial chemistry plants.
2. Guest speakers from industry.
3. Discussion of practicing safety in the lab. (The ChemTeC volume called "Technician Guide Book" is extensively used here.)
4. Discussions on how to interview for jobs.
5. Working on special projects.

Before concluding this talk, I will, as earlier promised, return to the discussion of recruitment of new students. I must say that I personally find it much more rewarding in recruiting students through the ChemTeC approach than in the traditional. I say this from experience because prior to our involvement as a pilot school, we were traditional.

The major argument against the traditional program that I constantly encountered from guidance counselors and chemistry teachers was: "This course looks suspiciously like the more difficult chemistry programs at four-year institutions. If we send you our poorer students, they won't succeed; and why should we send our better students to a "watered-down" program when they will be better off in a four-year professional chemists program?"

The ChemTeC offering is a different one designed for students graduating in the middle of the class. If a student has the ability to work with his hands and mind, if he has always wanted to work in a laboratory situation but was always turned away because of not being able to handle the formidable curriculum, if he is motivated, then this is the student we seek. This ChemTeC offering will prepare the professional technician who will work as a part of a team that solves chemical problems. The fact that we are talking about the practical laboratory-oriented program opens the door to a whole new spectrum of possible applicants.

Typical Traditional
Chemical Technology

	Lect.	Lab	Credits
1st Year 1st Semester			
Gen. Chem. I	4	3	5
Intro. to Cal.	4	—	3
Phy. Elect. light mag.	5	2	6
English	3	—	6

Typical ChemTeC
Chemical Technology

	Lect.	Lab	Credits
1st Year 1st Semester			
ChemTeC I	2	8	6
App. Tech. Math	4	–	3
Tech. Physics for ChemTeC	3	2	4
Comp. I	3	–	3

Typical Traditional
Chemical Technology (cont'd.)

	Lect.	Lab	Credits
1st Year 2nd Semester			
Org. Chem I	4	3	5
Anal. Chem.	3	6	3
Calc. I	4	–	5
Physics– Mech's heat, sound	5	2	5
Eng. II	3	–	6
2nd Year 1st Semester			
Org. Chem. II	4	6	5
Anal. Chem. II	3	6	6
Phy. Chem. I	3	–	6
Calc. II	3	–	6
English Rpt. Wrt.	3	–	4
2nd Semester			
Org. Chem. II	1	5	3
Phy. Chem. II	4	3	5
Instru. Anal.	3	6	3
Calc. III	3	–	6
Nuc. Phy.	3	–	6
English	2	–	4

Typical ChemTeC
Chemical Technology (cont'd.)

	Lect.	Lab	Credits
1st Year 2nd Semester			
ChemTeC II	2	8	6
App. Tech. Math II	4	–	3
Tech. Physics for ChemTeC	3	2	4
Elective	3	–	3
2nd Year 1st Semester			
ChemTeC III	6	12	12
Elective	3	–	3
2nd Year 2nd Semester			
ChemTec IV	6	12	12
Elective	3	–	3

COMPARISON OF TRAINING CHEMICAL TECHNICIANS IN INDUSTRY AND COLLEGE

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In any comparison of the differences in methods of training of chemical technicians by industry and by the college, it is important to note that until quite recently very few colleges offered programs for people mainly interested in becoming chemical technicians. For years, therefore, industry has been forced to train the technicians to meet their needs. The kinds of chemical technicians used in industry can be divided into three main classes:

1. Quality control laboratory technicians are primarily needed to perform analyses associated with plant production. These technicians perform routine tasks and may be quite versatile in that their work requires familiarization with instrumental and chemical procedures, or it may be quite routine and repetitive involving only a few well-defined test procedures.

2. R & D technicians normally work under the supervision of research chemists, depending on the nature of the research. The work these technicians do may be quite routine or it may be exceedingly diverse. Operations common to organic or inorganic synthesis may be required and these technicians, for example, may perform high pressure reactions, vacuum distillations, use cryoscopic technology, and be called upon for the handling of sensitive materials whose properties may be largely unknown.
3. Pilot plant technicians are used by companies who use technicians to operate or construct and modify pilot plants, especially in the earliest stages of development of new processes. Pilot plants may be under the direction of R & D, and are generally supervised by shift supervisors or chemical engineers.

In any review which attempts to consider the differences between the training that technicians receive in a college compared with that received in industry and on-the-job, the single overriding factor is that virtually no colleges were offering training programs for chemical technicians until quite recently. Many junior colleges have offered a degree, such as the Associate in Science degree which could be obtained after two years of a full-time course load in the junior college, or after two years in a four-year (feeder) college. Feeder colleges offer Bachelors degrees and these colleges provided most of the candidates for the advanced degree programs offered at the major universities. The Associate in Science degree tended to be regarded as a stepping stone by most junior colleges, permitting entrance into the four-year feeder college program. Traditionally, people left the academic world after two years with the Associate in Science degree either because of financial problems, personal demands on their time such as marriage, lack of ability, or boredom with the program. It was rarely the intent of the student to enter one of these programs for the purpose of being trained to be a chemical technician. The industrial world realized that colleges were not attempting to train men to be chemical technicians, and therefore assumed this responsibility during the war years and the years of the present war economy which followed. The pressures on American chemical technology to solve nationally important problems were very great. In order to supply a sufficient number of technicians during that period, many industrial companies hired bachelor degree chemists to do technician's jobs. Indeed, some companies hired Ph.D. and Masters degree chemists to do technician jobs, using the argument that they could afford to pay the relatively modest difference in salaries to obtain the very best people to support their technical programs. Most managers of chemical laboratories discovered that degree chemists made poor technicians. The sort of attitude which made a man a good student and a scientist is not necessarily advantageous to the chemical technician. The best chemical technicians have a natural capability of doing experimental work. They like to assemble things, they have an insight into how things work, and they have manual dexterity. Chemical technicians of the best sort are extremely bright and often the intellectual equal of their supervising chemists, engineers, and scientists. They are, however, turned-off by academic programs involving large amounts of reading and report writing, and especially by the required courses in long college programs with many classes in the "humanities" such as poetry, music, history, civic government, English literature, speech, and drama. It is true that although exceptions to such a generalization exist, it has been my experience that the best technicians are very lab-oriented and bored by too much formal mathematics, reading, and writing. While development of such interests might enhance the value of a technician, this point about the practical, lab-oriented nature of a technician must be kept in mind as you compare the Associate in Science degree training with that received on the job in industries for chemical technicians.

About five years ago, a number of articles appeared in popular magazines and newspapers expressing grave concern for the future of American chemical technology because of the great shortage of chemical technicians. Many institutions such as the American Chemical Society, National Science Foundation, and groups associated with employment of the economically disadvantaged began to seriously try to formulate programs geared directly to the training of students to be chemical technicians. A ChemTeC program was devised and jointly sponsored by the NSF and ACS. With some brilliant directing and dedicated participation of educators, managers, and industrial advisors, some serious questions were effectively dealt with and some real progress resulted. Such questions included: What defines a chemical technician? What material should he be taught in a college so that upon graduation the candidate could be considered a chemical technician? Of what duration should such a program be?. As a result of the ChemTeC efforts, pilot schools were established, which offered programs using the materials generated by the ChemTeC project. More than 10 volumes of printed material to be taught in these schools was written, re-written, edited, and revised still again. It will probably be difficult to significantly improve upon that part of the ChemTeC project in the matter of providing colleges with suitable training material. I would, however, make one criticism: there is too much written material and the selection of what is required is left to the instructor. Most instructors feel inadequate in making selections from all this material and simply start at the beginning and proceed as far as they can.

In my company, we have attempted to supplement on-the-job training and to extend the background of some of our technicians by small classroom type sessions, using this ChemTeC material. This training program included approximately two hours of semi-formal classroom training. Chemists or shift supervisors were used as instructors. The maximum class size was five technicians. The program has been continued more than a year. While this program was not under my direct supervision, I followed the results of it with great interest. Undoubtedly, technicians learned a great deal from the program. However, we too made the mistake of not selecting material to be taught, and simply started at the beginning and went as far as we could. We have just recently discontinued this program temporarily because of apathy on the part of the technicians. Should other companies consider such a program, I would strongly recommend that the technicians be allowed to select, from the ChemTeC material, the subjects which interest them, and that this selection should be reviewed by a manager of the training program, and reduced to a timetable not to exceed one year, using a two-hour-a-week classroom period.

To bring our story up to date, the situation of the chemical industry, and indeed of the manufacturing industry, has changed drastically in the last few years. The chemical industry is facing a situation of over-supply of chemists for the first time in recent memory. The chemical industry is not expanding very rapidly; while more is being produced than ever before, it is being sold at a lower price, and at a lower profit. It is difficult to attract new capital for expansion of the chemical industry because the return on investment characteristically has not exceeded 5% recently. The chemical industry will need the very best cost controls, management techniques, and imaginative engineers and scientists, and intelligent and enlightened governmental policies to overcome this present decline in profit and the attendant decline in new manpower needs. These situations affect directly the efforts of colleges to attract candidates to their newly devised chemical technology programs. The industry is simply not hiring very many people.

I would like to focus in more detail on the manpower makeup of the technician's world and its economic facts of life. In our company, and I believe in many other companies, we will prefer now to fill a new technician vacancy with a man who wants to be a chemical technician and has had training from the new college programs. We have in our control laboratory about five technicians for every supervisor. In our R & D group, we have about one technician for every chemist. Starting wages for technicians in our geographic area range from $750 to $800 per month. After about one year of on-the-job training, the newly hired man normally advances from a trainee to an assistant technician. After another year, he becomes a technician and is receiving wages in excess of $850 per month. In addition to wages, the company pays him an additional 10–20% of his wages into benefit programs for insurance and retirement. The technician does not have, in a certain sense, the potential for advancement of the bachelors degree man. However, a bachelor degree man can easily be hired now for $820 per month. The technician can advance to a shift supervisor in our company, a job, which with some experience, may pay $950 per month. A man with a bachelors degree, and a managerial flair can in theory progress through levels of management to higher salaries than this; but in actual practice, very few bachelor degree chemists realize such salary increases and promotions. Furthermore, the technician has some benefits which the salaried man does not have. As an hourly employee, he receives premium pay for shift work, and overtime pay for additional hours he is asked to work.

The chemical technician is a real contributor, and a valued, highly respected employee in our company. Similar counterparts are the instrumentation and electrical technicians, and all these technicians are treated as if they were plant operators as far as salary and company benefits are concerned. This salary and opportunity is sufficient to attract excellent people to these openings. However, at the present time except for government pressure on behalf of members of minority races, technician openings are rare.

I think colleges that have programs for training technicians may look forward to industry's regarding these programs as sources of men with better qualifications than those who have not had them. In this sense, colleges will have an outlet for their graduates. However, in order to assure and broaden industries' utilization of these graduates of the chemical technology program, a real effort must be made to make known the value of this training to industry, and the training must be kept practical and really be of value. The colleges may then expect more interest from industry and support to their chemical technology programs. However, planners for chemical technology programs should keep in mind that for most members of the chemical industry this is a time of tight money.

Colleges with chemical technology programs can honestly indicate to candidate students that becoming a chemical technician is truly a worthwhile and satisfying professional goal. It is my opinion, however, that at the present time, an over-supply of chemical technicians from two-year college programs could soon exist if the number of people graduated from them increased drastically, just as an over-supply now exists of chemists, engineers, physicists, and mathematicians.

MAKING CHEMISTRY MEANINGFUL TO THE NON-CHEMIST
RALPH BURNS

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Presented to the Instructional Methods Timely Topic Forum

27th Two-Year College Chemistry Conference,

St. Louis, October 30, 1971

Making introductory chemistry courses meaningful and interesting for the non-chemist is a challenge many of us face. How do we keep the course current? Can we interest students in reading such publications as Chemical & Engineering News, Chemistry, Science, Scientific American, and even the science section of news magazines?

Some instructors may choose to assign weekly reports, cite references to lecture notes, or to suggest articles for persual. Another approach is to use small group discussions for studying current topics. Small groups have certain advantages. If the course is structured for two separate laboratory sessions per week, one of these weekly 2 to 3 hour sessions may be set aside for small group discussions of timely topics. A new topic need not be selected for each discussion session, since some topics may require two or three sessions for a thorough discussion. Discussion topics can generally be correlated with other lecture and laboratory topics.

Topics selected for discussion groups should be kept current. Topics involving some degree of controversy promote the best discussion and student involvement. Pollution, scientific research, chemistry and the economy, consumerism, the role of chemistry in medicine and drugs, drug abuse, food additives, and nuclear energy are examples. Articles pertaining to to each of these areas have appeared in recent issues of C&E News and other publications. Some paperbacks can also be used as supplements. The Challenge of Chemistry by Phillip A.Horrigan (McGraw-Hill Book Company), for example, offers a bried introduction to several of these topics and has an interesting, provocative approach. If a few copies of this book are placed on reserve in the library, students will not need to purchase it themselves.

The topic of pollution works well early in the course when ions, including phosphate, and molecules, including oxides of nitrogen and sulfur, are emphasized. Three small group discussion sessions are suggested for this topic. An experiment related to pollution, such as the Winkler determination of dissolved oxygen, can be performed in the concurrent laboratory session.

Motivating students to persue reference material is a challenge. If the instructor keeps a running file of clippings from journals, such as C&E News, these can be photocopied and placed in three-ring binkers on reserve in the library. We found this approach more effective than simply listing references for students. Binders are indexed for subdivision of the material into areas such as air, water, and land pollution, so that both pros and cons of topics are represented.

Within each two to three hour time block, a class can be divided into small groups of 6 to 8 students per group. Each time block can be used as follows; small group discussions during the first

75 minutes, six-minute presentations by the group leader addressing the entire class during the next 25 to 30 minutes, and a concluding 10 to 15 minute discussion with all students participating and interchanging ideas. The 75 minutes suggested for intragroup discussions allows for maximum interchange of ideas and for preparing the group report. Students are encouraged to include chemical, biological, environmental, sociological and economical aspects of the topic studied. Group leaders can be appointed by the instructor, so that all students can serve in this capacity, with new leaders being appointed to each session. The class canbe regrouped as topics change if desired, but some students prefer to keep their same groups.

We use portable cassette recorder to tape the presentations of group leaders and also the informal class discussions whicn follow. The tapes are placed on reserve in the library for students to use while preparing for later small group discussions. Groups are encouraged to use these tapes for documentation and for preparing questions to ask other groups during the next session.

Some unexpected side effects were noted when the recorders were used. Group leaders had improved presentations. Some students reported that they enjoyed having their comments recorded. Also, during large group discussions the portable cassette recorder microphone may be easily held near the speaker. These recordings kept discussions orderly, with only one person speaking at a time, while others waited to make pro and con comments. A considerable amount of listening as well as talking resulted. Students had a tendency to identify with their groups during large group discussions. Each student made one of more contributions to the large group discussions. Later, on class evaluation forms, several students mentioned the discussions as being one of the best-liked parts of the course. Students read the reference materials provided, plus additional material, to be prepared for group discussions and for challenging other groups. Following discussions on each topic, each student wrote individual reports which were graded.

For discussion topics that require two or three sessions, such as pollution, the first was used to survey the topic, define terms, and suggest methods of collecting data. The small group discussions of the second session centered on disagreements and inconsistencies in material presented by the group leaders and on possible solutions. The third session was used to summarize findings, present conclusions, suggest possible solutions and list additional investigations. These discussion topics, then, can be approached in a similar manner to research investigations. Perhaps students will profit from learning this technique of approaching problems.

Each instructor can have his own modifications to this approach, but I hope each instructor will experiment with the use of small learning groups and also discussions of timely topics. The attitude of the instructor and his enthusiasm for student expression appear to be prime factors in the success of such approaches.

An Audio-Tutorial Approach in General Chemistry Using the Popham Paradigm

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The 29th Two-Year College Chemistry Conference
The Franklin Institute of Boston, Boston, Mass.
Friday evening, April 7, 1972

Why develop a multi-media instructional approach when it involves more time, energy and a strong committment to support this approach on the part of an institution?

There are several arguments which indicate such an approach is justified; perhaps the most salient is that traditional approaches to education have proven ineffective with non-traditional students. *Chemical Education for the Underprepared Student*[1], the proceedings of a conference of the same title includes some important conclusions with respect to teaching chemistry, placement and achievement tests, and innovative techniques related to the underprepared student. According to this report, many educators have assumed that they cannot communicate with students of low proficiency in language skills and have placed too much emphasis on students being able to assimilate concepts and take notes while being inundated with lecture material.

John Rouche points out that approximately 75% of low achievers drop out of college[2]. Certainly, we in the two-year college experience our share of underachievers and high attrition rates. What can be done about this? John Carrol[3] in a proposed educational model implies that if one mode of instruction is administered to a group of stude normally distributed with respect to aptitude, then the results of achievement will be normally distributed. If, however, two aspects of this approach are changed, i.e., the time allotted for achievement and the modes of instruction to more flexible approaches then the critical relationship between aptitude and achievement will be dramatically reduced.

At Burlington County College we have experienced decreases in attrition in our general chemistry transfer course from over 50% in 1969 to 11% in 1971. While several factors may have been responsible for this decrease in attrition rate such as the addition in 1970 of an introductory chemistry course, the addition of more elaborate learning activities to the program and the use of a test center in 1971 resulting in more instructor-student interaction in class, I believe the use of a programmed audio-tutorial approach utilizing accepted learning principles[4] has been the major factor in helping students become oriented with respect to chemical concepts.

The audio-tutorial exercises comprise one of four modes of instruction in CHE 105 and complement one general assembly session designed to set the tone for a unit of study, an independent study mode which includes a host of learning activities such as multi-media exercises designed to assist students in reaching specified learning objectives and one small group session designed to tie up any "loose ends" a student may have before taking a unit test.

The audio-tutorial exercises are scheduled in an open lab format permitting the student to work at his own rate and convenience. Each exercise includes the following principles and have been described by James Popham in an experiment designed to modify teacher behavior:

1. Specification of a behavioral objective
2. Rationale
3. Preassessment
4. Appropriate practice analogous to test conditions
5. Programmed sequences increasing in complexity
6. Active student responses
7. Immediate feedback to student concerning his response
8. Post test as an evaluation of the attainment of the objective

The rationale includes much affective information such as relevant applications of each exercise.

The exercises are largely quantitative experiments commonly found in many first semester general college chemistry laboratory programs. The introductory exercise, Mathematical Processes in General Chemistry, includes such topics as scientific notation, fractional and linear equations and proportions, and is intended to prepare students for eventual computations. Dr. R. Denny[5] has developed the Mathematics Skills Test (MAST) with a correlation of .963 between mathematical ability and success in general chemistry. We plan to use this test in placing our students this fall.

The exercises that follow include the previously mentioned learning principles and represent a composite of laboratory, lecture, affective information and safety precautions through the medium of taped programmed exercises. The titles are:

Measurement
Calculation of Avogadro's Number
The Hydrogen Spectrum
Atomic Structure
Bonding
Stoichiometry
Heat of Reaction
Molecular Weight of a Volatile Liquid
Crystal Structure
Percent Acid in Vinegar
Freezing Point Depression
Equivalent Mass of a Metal
Water Pollution

Briefly, the exercise, "Water Pollution," is constructed as follows:

The student is given some reasons why this experiment is worthwhile. Examples of adverse physiological and environmental effects due to high levels of pollution are given. A chart published by the United STates Public Health Service is shown indicating the maximum permissible levels of each pollutant. Through subsequent frames the student is led through calculations involving parts per million for various pollutants and then asked to quantitatively determine the PPM of pollutants such as chloride in a given sample and in tap water. After a series of frames in which the student is given examples of how to select a maximum wavelength using a spectrophotometer and how to construct a calibration curve he is asked to determine the number of PPM of pollutant in a given sample. This exercise consists of fifteen frames in which the previously described learning principles are utilized and is followed by a post test.

The exercises were given in a strict sequence which corresponded to each unit of activity.

In conclusion, I would recommend considering several factors in reducing attrition rates in general chemistry: an introductory course, utilization of a test center and the use of accepted learning principles in developing self-instructional materials.

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[1] *Chemical Education for Underprepared Students.* Robert I. Walter, Editor. Chicago, Ill. January, 1971.

[2] Rouche, John E., "Salvage, Redirection or Custody?" *American Association of Junior Colleges,* Washington, D.C., 1968. pp. 26-40.

[3] Bloom, Benjamin S., "Learning for Mastery," *U.C.L.A. Evaluation Comment:* Vol. 1, No. 2, May 1968. p. 3.

[4] Popham, W. James, "An Experimental Attempt to Modify the Instructional Behaviour of Student Teachers," *Journal of Teacher Education,* Vol. 16, March, 1965. pp. 461-465.

[5] Denny, Rita T., "An Analysis of the Relationship Between Certain Mathematical Skills and Chemistry Achievement," ERIC Information Analysis Center for Science and Mathematics Education Report, March, 1971. p. 196.

TEACHING SCIENCE TO THE DISADVANTAGED STUDENT IN AN URBAN COMMUNITY COLLEGE

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Teachers Association, Cleveland, Ohio, October 7–9, 1971

Most of my experience has been teaching chemistry to the underprepared student; however, the principles which I wish to enunciate would apply to the teaching of any science or mathematics. That this is true, and that this type of student has almost universally identical characteristics was brought out in a conference held in Chicago on September 10–12, 1970. Instructors of sciences and mathematics were gathered there, coming from various locations in the country; two-year colleges, four-year schools; black colleges, Chicano, mixed ethnic and black; as well as well-financed and poorly-financed schools.

This type of student will be described in this paper, but first we shall discuss some of the problems in the current approaches to teaching science.

Educators worry about the problems, yet often they offer little more than rhetoric as a solution. I have heard the expression "revolving door policy" at Cuyahoga Community College and at Two-Year College Chemistry Conferences so many times that I gag at its utterance. "The attrition rate is too high," "We have an open door policy but we lose too many students after a quarter or two." We all wring our hands in despair; the faculty blames the administration and students; the administration criticizes the faculty and students; everybody blames the counselors, and the poor student, if he hasn't drowned in this cesspool of recrimination, blames the school. Thus, very little is done except on an individual hit-or-miss basis.

This problem cannot be solved unless all participants do their part. We all must admit that perhaps our approaches, or maybe even our roles must change.

We tend to follow rigid sequences of courses that were set up 50 to 60 years ago in spite of the fact that the course material has changed considerably. Of course the two-year college is hamstrung to a certain extent because many of its students transfer to four-year institutions; it cannot deviate excessively. Very often, however, curricula that pertain *only* to the two-year college itself are hampered by these practices. For example, technical programs in two-year colleges often have unrealistic requirements, e.g., expecting a student to have as much mathematics (or almost as much) for a two-year technology degree as he would need for a four-year engineering program.

In spite of this, changes are possible. We have often hidden behind the "four-year syndrome" in order to avoid making changes. All parts of the college tend to resist change–the administration because it may cost money, the faculty because it may change their status, and the student because he is "used to a certain approach." Surprisingly enough, the 40 to 50 year old student resists changes in approach less than the 18 year old; the older person, having been out of school for 20 to 30 years, anticipates change (with fear) while the younger student does not. In spite of the younger students' criticisms of "dull lectures" he only accepts different approaches with a great deal of resistance.

This situation is not helped by the book publishers who refuse to publish books unless they follow the "old style." Unfortunately, few of the reviewers for these companies are instructors teaching the disadvantaged student; practically all are from "better" four-year or two-year schools. Their reviews tend to indicate, for example, that college students never need arithmetic reviews, etc.

Why do these problems exist? Why didn't colleges face these problems in previous years? Has anything changed fundamentally in college education?

Since World War II the United States has changed the concept of college education as being for the rich and upper middle class only, to a concept of college education for all (who have the potential). If we are to make such a system function we must be realistic; we must recognize the fact that some students should not be in college. Yet this is a difficult decision to make because we tend to make choices of this type based upon tests which are slanted toward a certain mode of living. Even the I.Q. tests are often "stacked" against the inner city student (*white* as well as *black*) because they are based upon supposedly universal information that is unknown to the inner city student. In addition, suburban and private high schools prepare their seniors for such tests as the A.C.T. and S.A.T., for example, by giving them tests of this type beforehand. The inner city student and older students are seldom given this aid; consequently, they are faced with a traumatic experience when taking these required exams. Many students of this type are so shaken up by this that they forego the "pleasure" of even trying to attend college.

Furthermore, we must recognize that the concept of the "melting pot" in the United States is a farce and that we are living in a pluralistic society. The effect of this multiplicity of cultures upon education must be understood. Comprehension of this point is particularly needed in urban schools–both in the two-year and four-year colleges, as well as the public school systems.

How do we solve the problem? Before even discussing what can be done to help the disadvantaged student we have to know him. We must understand his characteristics, abilities, self-image, etc. Thus, this point will be covered in great detail. It was found at the Chicago conference mentioned earlier that the characterizations of the underprepared students (particularly in urban schools) were consistently the same. This was true in spite of the fact that many cities were represented and various cultural and ethnic backgrounds were discussed. The groups discussed included northern blacks, southern blacks, Chicanos, and ethnic whites.

The characteristics of these students could be summarized as follows:

1. Poor mathematics background as evidenced by such tests as the University of Toledo Placement Test. Their math deficiencies include the inability to handle fractions, decimals, and obviously, algebra.
2. No high school chemistry course or a poor course taken in an inner city high school. Why are science courses (as well as others) often poor in the inner city? Old buildings, poor equipment, overcrowding, and/or inexperienced instructors can produce this situation. Even the extraordinary

experienced teacher who remains in the inner city high school more often than not becomes frustrated, then finally disillusioned. Hence, poor courses result.

3. A tendency for this type of student to pursue short-term goals rather than long-range planning with deferred gratifications.
4. A severe lack of self-confidence. This includes an inordinate anxiety about tests rooted in inadequate preparations but more because of a negative self-image. This anxiety is particularly true of women, doubly so for black women. It has been my experience that black females have suffered a double dose of "brainwashing." They are told they can't make it in mathematical subjects because they are black and also because they are women. In cases that I have investigated personally, black girls that had the ability (in my opinion) but whose self-image was close to destroying them had something in common—a male counselor (generally white) who told them they lacked college ability, etc.

   These anxieties generally resulted in a tendency to be noncompetitive and resistant to time pressures and therefore unwilling to take examinations. This can be overcome, at least partially, by allowing the students two hours (whenever possible, or an indefinite time period) to take a one-hour exam. It has been my experience that the average time actually taken is the same but the idea of extra time calms down the worrier.
5. The underprepared student has bad study habits and an inability to concentrate. This often is due to a noisy home environment in which the student must study.
6. A necessity for outside employment. (70% of Cuyahoga Community College students work either part-time or full-time.)
7. A repulsion by apparently cold instructors who convey a highly impersonal subject matter. (If this problem can be overcome at the beginning of the course, the "battle" is half won.)
8. Boredom with repetitious drills on routine, seemingly irrelevant topics. This may be the reason that programmed materials and the normal approach to "college arithmetic" do not succeed.
9. A tendency to emphasize memorization of "formulas" while avoiding mathematical solutions to problems. This often results in a tendency to retain an erroneous method for solving a problem. This is probably one of the most difficult tendencies to overcome—even in cases in which students have been warned about a specific pitfall, many still fall right into it.
10. These students are extremely weak in English. Their reading ability is very poor; their writing ability is worse.

How do we teach these students? Is the job impossible? Should the job be done elsewhere?

Often we hear the comment, "This kind of student doesn't belong in college. We have to change the school system." I am sure that we have to change the entire approach to education; we have to change the "system," particularly in the inner city. It is possible that in cities in which state universities and/or community colleges are located, cooperative programs could be developed in which the colleges and the school systems can develop new programs of study.

However possible the above may be, we still must concern ourselves with the current underprepared students, otherwise we permit an entire generation to be flushed down the drain. My own personal objective is to work with those already in college or coming to college.

Part of my approach in solving the problem has been to produce my own materials. Books, films, etc., published for students in "remedial" courses are inadequate. I use quotes about "remedial" because in the State of Ohio we cannot teach "remedial" courses in college, consequently we use euphemisms such as "Introduction to . . . ."

Unfortunately the books published for this purpose, in addition to the usual dull passive voice approach of most science texts, only seek to "simplify" the material by including fewer and less complex concepts and problems. This approach fails. I have been forced to write my own text. After using it for three years with only moderate success I am now in a position to rewrite—a complete reorganization is in order. This original text started with a mathematics review beginning with fractions and ending with algebra. I am now convinced that this is not the correct approach. The text should start out with chemical principles; the math should be added surreptitiously when there is a need to know. For example, fractions and decimals could be included when studying stoichiometry and algebra can be included when studying the gas laws. There are other possibilities; the above are simply illustrations of how this material can be integrated into the text.

I am convinced that attempting to teach the student mathematics in a remedial course, especially with programmed materials, will fail. The student is bored and/or insulted. "Why are they teaching me fifth grade stuff?" We know why, but the point is almost impossible to sell unless the material is "dressed up" and taught on the need-to-know basis.

In addition to the text we made a large number of audio tapes that discuss the book and the problems contained therein. Crude single-concept films were made. We attempted to introduce humor into these. The biggest problem with these films (in addition to my inexpert photography) was the fact that we generally introduced more than one concept in the film and tended to assume that "all students know this or that." At present the book is being rewritten. I am attempting to write the book in a breezy style, bringing in relevant examples whenever possible. For example, when discussing the gas laws I shall use pollution examples.

The book will *not* be written in the passive voice except when absolutely necessary because this type of student is often a poor reader and would be bored to death by the typical dull passive-voice text. In addition, as before, each chapter will be introduced with a list of behavioral objectives explaining what the student should be able to do after completing the chapter.

In the present edition of the text (the one being used) the use of the objectives was not very successful. I have found that it is very difficult to convince students that we are *really* telling them what they should learn, hence "what is going to be on the test." A certain amount of space in the new edition, and time in the class, will be used to demonstrate to the student how the statements of the behavioral objectives can be used to study.

A new text, however, is not a complete solution; the approach for these students must be multifaceted; lectures, discussions, audio tapes, single-concept films and/or slide sets are all needed. A single approach will not work—some students can grasp best by listening, some by seeing, and some by doing (laboratory). At present, for example, we are preparing single-concept slide sets using a cartoon approach. It should be noted that it takes 30–50 man hours of work to produce a good single-concept slide set that contains 10–20 slides.

In addition to the above we believe that an open laboratory-tutoring room is needed, i.e., a laboratory open 40–60 hours a week. The student can come in, do his assigned experiment(s), listen to tapes, watch film loops, etc. The attending instructor can give any special help needed. Most of this material cannot be bought on the market at the present time. Thus, what is needed on the market is not simply a new text, but a "package," i.e., a text, a series of coordinated experiments, audio tapes and single-concept films or slide sets. There are many good chemistry films on the market but they are not satisfactory for this course or these students. Contrary to the rigid "professional" a little humor, in addition to simplicity, is needed in these presentations.

But all the best equipment, films, ideas will come to naught unless the right instructor is chosen to teach the course. He must be sympathetic, yet must have the ability to "push" the student. Modern approaches are worthless unless the student cooperates. This cooperation is not easy to achieve for several reasons. The underprepared student is generally conservative (relative to education) and tends to accept lectures and reject the "modern devices" such as single-concept films, etc. Most students, well prepared, as well as those we are discussing, tend to hold on to the lecture like Linus holds on to his blanket—this is security, this is what he knows and is "used to." The instructor has to sell the modern approach.

The second difficult problem faced is that due to cultural or ethnic differences. Black students *tend* to be reserved when they have a white instructor and the reverse is equally true. This is particularly true with the disadvantaged student. The problem is not one only of black-white but also ethnic-nonethnic, etc. Empathy must be built up between the student and the instructor in spite of their racial, ethnic, and/or cultural differences. This can be done when and if the instructor makes an honest effort to do so. He must convince the disadvantaged student that he (the student) can "make it," the materials are available to enable him to do so, and that the instructor will help him to accomplish this feat. This is not an easy task; it takes almost a supersalesman to do the job.

Going from the individual instructor to the department we have this to say: if the department is relatively small, one instructor should develop the course and teach all sections of lecture and laboratory. In larger institutions where several instructors teach the course, it should be under the "control" of one person. This person can design the material (with consultation if possible) and determine the schedule of lectures and laboratories.

An auxiliary problem is the class size–granted it is easier to teach a small class, particularly when teaching underprepared students, facts must be faced. The cost of education is skyrocketing, salaries and supplies and equipment are all going up. The only way to overcome this problem is to increase "productivity," i.e., have more students per class. The problem we face is that we don't really know how to teach small classes of underprepared students and obviously don't know how to teach large ones. The open laboratory-tutorial room may do the job, i.e., permit us to have large, economical classes yet give the student the chance of a one-to-one relationship with the instructor. Much experimentation and change has to be expected to complete the task. However, if both faculty and school administrators forget the rhetoric and decide that the job *must* be done, it will be done.

The administration must be willing to do more than spend penny-ante funds, with or without Federal grants, in order to encourage curriculum development; the faculty must be willing to do the development, and while doing it resist the temptation of accepting gadgetry and change for the sake of novelty. Experimentation must take place, and one must concede that in any set of experiments (even well designed) there will be considerable failure. *Nobody* has all the answers, neither educational specialists, science faculty, nor school administrations. But changes must be made or we might as well close the two-year urban colleges, reject the open-door policy, and forget the premise that education in and beyond high school should be available to all.

However, with all the difficulties presented, solutions can be found. The Two-Year College Chemistry Conference and the National Science Teachers Association, as well as others, are addressing themselves to these needs.

We must face the fact that a revolution in education is needed in the United States; if this doesn't occur, along with changes in community relationships, we may face a violent revolution in this nation and face its dissolution. We have solved some mighty problems in the past, hence we should be able to face and solve the present ones.

The Use of the Mini-Computer in the Freshman Chemistry Laboratory

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This is a description of our program for utilizing the small computer as an integral part of the beginning chemistry courses at Essex Community College. The main idea behind our program is to introduce the student to the computer as early as possible in his college career and to have him analyze his own data using programs written in the BASIC language.

The Changing Freshman Laboratory

There has been a trend toward introduction of several of the classical experiments from the former quantitative analysis course into the freshman laboratory in recent years. These exercises include gravimetric, volumetric and spectrophotometric analysis. Reports of the effect of this trend upon the students have been mixed. However, the ability to obtain, record, and manipulate numbers is an essential feature of science and one which can afford the student an opportunity to develop and test critical techniques. However, the quantitative nature of the exercises greatly increases the chance of arithmetic errors and the time required for computation. In addition, it was found desirable to introduce the concept of error analysis into the laboratory including:

1. Calculation of the standard deviation
2. Plotting of the normal error curve
3. Least Squares analysis in conjunction with Beer's Law plots and kinetic studies
4. The derivative method of endpoint detection in conjunction with titration exercises

Finally, we are making some effort to introduce the student to computer simulation of natural phenomena such as NMR splitting patterns and radioactive decay.

Consideration of the Programs

The programs used in the course can be classified into two kinds:

1. Simple programs which can be used to calculate the percentage SO_3, H_2O, KHP, soda ash, etc. of materials commonly analyzed in elementary laboratory. These programs can be easily understood by students with only the briefest exposure to the BASIC language.
2. More difficult programs used in the calculation of least squares, endpoint analysis, etc. Those students who are enrolled in the computer courses can understand these programs. We recommend that students take an elementary course in the BASIC language concurrently with their chemistry.

Data Analysis: Early and Often

We have introduced error analysis into the laboratory on the elementary level presented by Masterson and Slowinski in their text "Mathematical Preparation for General Chemistry" (Saunder, 1970). Emphasis is placed on the significance of the mean, the average and standard deviations, the shape of the normal error curve, and on least squares analysis of linear functions. In at least one instance, a student's lamentations on the lack of correlation of the sharpness of his curve and the quality of his grade revealed an error on the instructor's part!

We feel that it is important to expose the student to the idea of transformation of data into more useful forms as soon as possible. The least squares analysis and the derivative method of endpoint detection are examples of this and illustrate applications of elementary calculus such as the properties of a curve at its inflection point and the minimum point of a function. Before the computer, we felt that to ask the student to perform these calculations required an undue amount of computational time. The computer can do it in a few seconds.

Computer Simulation

The acquisition of a Varian EM-300 spectrometer moved us to introduce the student to the simulating capabilities of the computer. We introduce the student to the NMR in his freshman year in order to expose him to the fact that his high school mathematics training, i.e., the coefficients of the binomial expansion and Pascal's triangle can find use even in a sophisticated phenomenon such as NMR. In addition, the computer allows him to compare the regular variation in the spectra of AB protons with respect to changes in the $\Delta V/J$ values obtained on the instrument with theoretical spectra obtained by changing a variable in simple equations and having the results plotted on a cathode ray tube.

Procedures and Hardware

Our hardware consists of a 16K Hewlett-Packard, 2100A mini-computer, teletype, high-speed printer, cathode ray tube, and an X-Y plotter. We make use of all of these pieces of equipment in the chemistry program. The computer programs for the quantitative analysis exercises are written in the BASIC language during the laboratory period by students. The data is handled by marked cards and the processing of the data can be handled by one of the students who is taking a computer course. There are some problems caused by mechanical errors in marking cards, but these can be edited out by the student handling the data processing.

Conclusions

The introduction of the small computer can have the following beneficial effects:

1. Elimination of arithmetic errors.
2. Evaluation of data using methods of error analysis without excessive computational time.
3. Computer simulation of natural phenomena.

However, some difficulty can arise in generating enthusiasm for the computer among one's colleagues, and one must make certain to emphasize the problem-solving techniques in class so that the computer will not take the place of understanding, but rather will enhance understanding by easing the burden of excessive calculation.

ADVANTAGES OF USING MODULAR AND LOW-COST INSTRUMENTATION

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Meeting with a group of two-year college teachers brings memories of old times, since my first teaching position was in a two-year college. That was Blackburn College in Illinois.

The subject matter of this talk can be broken down into three parts:

(1) *The advantages of using instruments.* This is analogous to the advantages of riding rather than walking—you can cover more ground with less effort, but you run the risk of losing touch with nature. The instrumentation must always be the servant of chemistry, not the other way around. An earlier speaker this afternoon mentioned the complexity of the Winkler analysis for dissolved oxygen, and the relative difficulty of the standard analysis for sulfide. Both of these can be carried out by instrumental means. The sulfide analysis, for example, becomes extremely simple with a commercially available sulfide-specific electrode. Just attach this electrode to a pH meter and read the sulfide ion concentration.

(2) *The advantages of using modular instruments.* By a modular system I mean one in which the components needed for each single function are assembled together in a single package. As many as needed of these modules can then be interconnected to form the complete instrument. The advantages are two-fold: (a) the student gains greater insight into the nature of the instrument because he must understand the relation of each module to each other module and to the whole system, and (b) greater economy can be realized because of reduced inventory requirements. For example, a modular amplifier can be utilized in a wide variety of experiments instead of spending most of its time idle, as it might well do if it were built into a specialized instrument which is used for only one or two experiments each year.

(3) *The advantages of using low-cost instrumentation.* Somehow I cannot feel that much persuasion is needed in this direction! We must of course take care lest we waste money on equipment which is inexpensive only because it is poorly made. Just as with a watch: a cheap one can hardly be expected to last as long and to keep time as well as a more expensive model. On the other hand, the expensive watch will not last any longer than the cheaper one if it is stepped upon. So perhaps we must compromise here.

With that introduction, I will show you a few slides. The first is intended as a passing commentary on *progress* in instrumentation. It shows, side-by-side, advertisements of a certain instrument company taken from chemistry journals of 1941 and 1971. You will note that the two instruments pictured are apparently unchanged in thirty years, except that one of them is now painted gray rather than black. This could be interpreted as a complete lack of progress, or as an indication that they did a pretty fine job of design thirty years ago. I suspect that the truth is somewhere in between.

Next, follow a few slides depicting the system of modular instruments manufactured and marketed by A. R. F. Products, Inc., of Raton, New Mexico. I had a hand in the original design of this system, and hence am more familiar with it than with other comparable lines. Essentially, the A.R.F. system consists of a number of modules in transparent plastic cases (for visibility) which can be interconnected by patch-cords to instrument any experiment in electrochemistry which requires only DC, such as pH measurement, polarography, electrodeposition, and coulometry. Also included is a small spectrophotometer (A.R.F. calls it an "absorptionmeter"), which can operate through the visible spectral region, and a thermal conductivity gas chromatograph. The latter two ordinarily make use of an amplifier and output meter or recorder which are common also to the electrochemical assemblies.

I will not show you some slides of other modular systems for comparison. One such is the Sargent-Welch "Chem Anal." This is built primarily around optical units which can be joined together in a variety of configurations to form different types of optical instruments.

Another interesting system is that of Thornton Associates, Inc., Waltham, Mass. The Thornton instruments play a role in physics teaching comparable to those of Sargent-Welch and A.R.F. in chemistry. I have seen these displayed at a physics show, and was quite favorably impressed.

The last modular system which I will illustrate is that of McKee-Petersen Instruments, Inc., Danville, California. They start with a rack or framework, which one might designate a "main frame," to borrow a term from computer parlance. A large, flat, module which fits on the bottom of the frame contains the power supply. All other modules are inserted in the sloping front panel, automatically making contact internally with the power supply. The modules consist of electronic circuits such as signal sources, attenuators, various types of amplifiers and read-out devices. They are interconnected by patch-cords which plug into the panel. McKee-Petersen also provides several optical instruments separate from the main frame.

I would like to emphasize the advantages in using and teaching with *operational amplifiers.* They can provide the maximum service with minimum required knowledge of electronics. This is because the amplifier design is already done for you by the manufacturer. You can learn all you need to know about the use of "op-amps" in a day or two of concerted study. Manifolds are available from several companies, which contain about six amplifiers and associated components. The user interconnects the amplifiers by patch-cords on a panel, and can readily synthesize numerous fully usable instruments. I show you a slide of the circuit diagram (taken from my textbook) of a polarograph built around three op-amps. This is an example of a fairly sophisticated instrument easily built up on an op-amp manifold.

Finally, I wish to mention a recent development involving not modular, but low-cost instrumentation. The slide shows a picture of my friend Joe Nelson with a pH meter on his hat! Joe is the research director of a small company, Chemtrix, Inc., Hillsboro, Oregon. He has designed a small, battery-operated pH meter which sells, complete with glass electrode, for a bit under $100. At Seton Hall we have bought ten of these for our freshman chemistry laboratory.

INTRODUCING CHEMISTRY WITH A GAS CHROMATOGRAPH

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An invited paper developed through experience with the introduction of chemistry with the approach developed by The Chemical Technician Curriculum Project. The author has been a member of the ChemTeC Writing Team.

Experiments used to introduce laboratory experiences in beginning chemistry courses many times are a repetition of experiments the students performed in high school courses. The negative attitudes this approach produces can be dispelled by using instrumentation for introducing a student to meaningful experimentation. Our experience shows that even for a student with no previous exposure to chemistry, this approach is profitable. Actually handling equipment, such as a gas chromatograph, excites the student. He actually investigates chemical systems instrumentally. He knows that instruments are used in the real world, but at this point in his education he has not personally had contact with much chemical instrumentation.

A student benefits from this early experience with instrumentation in the following ways:

1. He is virtually assured of good results for experiments.
2. He sees chemistry as it is commonly practised.
3. He realizes that chemistry no longer is relegated to reactions in test tubes.

The student can gain this experience with a minimal awareness of adjustable parameters and operational conditions. Remember that we are talking about a student in the first week of his freshman year!

Before introducing the class to the gas chromatograph, the instructor should graphically demonstrate some of separating liquid mixtures into their pure components. Separating the components of some washable inks using simple chromatographic grade paper provides an excellent example.

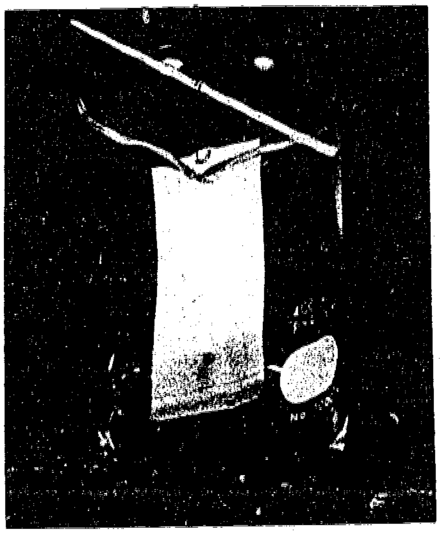


Figure 1. Experimental set-up for paper chromatograph

Inks that have been found suitable include:

Single Colors

Sheaffer: washable blue; washable peacock blue; permanent red; permanent black
Parker: permanent turquoise; permanent red; washable royal blue; permanent blue-black

Mixed Colors

Sheaffer: washable black; washable emerald green
Parker: washable black; permanent green

Other colors can be used with advantage. Inks based on solid suspensions and marker inks, stamping inks, etc. (which are not water based) give poor results.

Washable black inks have at least two, and usually more, color components. You may also mix the inks to provide further examples of separation. Students who finish early can make their own mixtures for analysis.

The paper chromatograph experiments very graphically demonstrate the concept of a mobile phase carrying the components of a sample with varying degrees of success and thus depositing them (in this case colors which make up the original ink) in different locations. The student can see that different colors have reached areas of different distances from the initial spotting point. This idea is used as a model for explaining how most pure substances in a mixture reach the detector of a gas chromatograph at different times.

A demonstration lecture can now be used for acquainting students with the gas chromatograph.[1] The ChemTeC Project Writing Team has produced a short film introducing the techniques of using a syringe, injecting liquid samples and adjusting a recorder pen. The film also describes the features of a low cost gas chromatograph.[2] The demonstration lecture should extensively use the analogy between the model developed using paper chromatography and the physical methods employed in gas chromatography.

Table 1

Paper Chromatography Model	*Physical Methods in Gas Chromatography*
1. Spotting sample on chromatograph paper.	1. Injecting sample into chromatograph column.
2. Eluting solvent (H_2O in this case) pushes sample spot up the paper.	2. Carrier gas (He) pushes sample (now a gas) through the column.
3. The separated pure colors appear at different distances from the sample spot when solvent stops moving.	3. The components of the original mixture separate and appear at different times at the detector.
4. The unaided eye is used to observe the separations in the chromatographic paper. From this permanent record measurements and data are collected and used in analysis.	4. The detector in the GC sends a signal to the recorder. These tracings become the record of the separations. From this, measurements and data are used for analysis.

Recommendations for an Introductory Experiment using a gas chromatograph.

Basic Equipment

A. Gas Chromatograph – teaching models (e.g., Carle, Gowmac, ARF, etc.)
Two columns: (i) 8% w/w General Electric SF96 on 80–100 mesh silanized support
(ii) 12% w/w Carbowax 400 on 80–100 mesh silanized support or equivalent
B. Recorder
C. Helium
D. Pressure regulator
E. Microliter syringe
(to deliver 0.5 to 1.5 all volumes)
F. Bubble flow meter

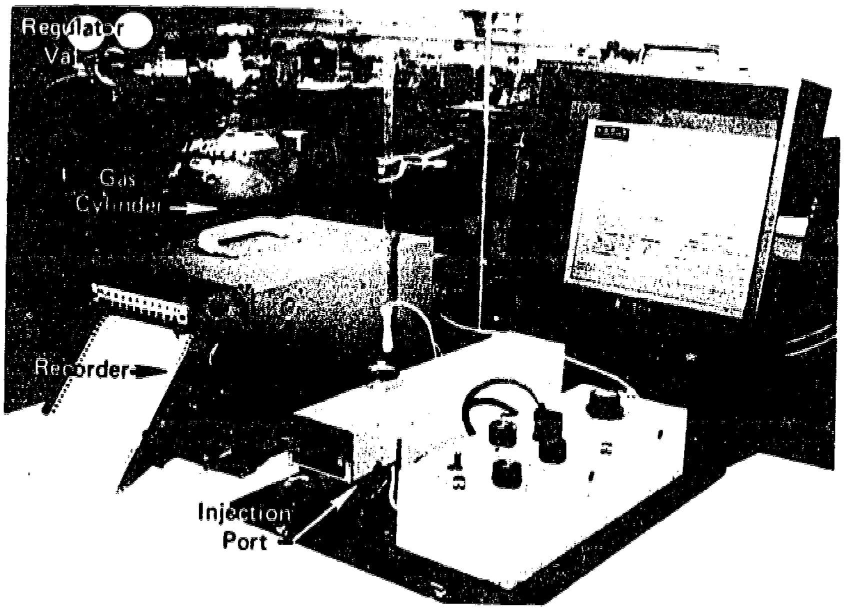


Figure 2. Typical gas chromatograph unit for beginning student

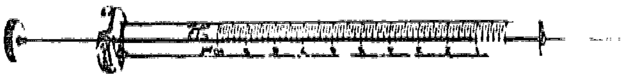


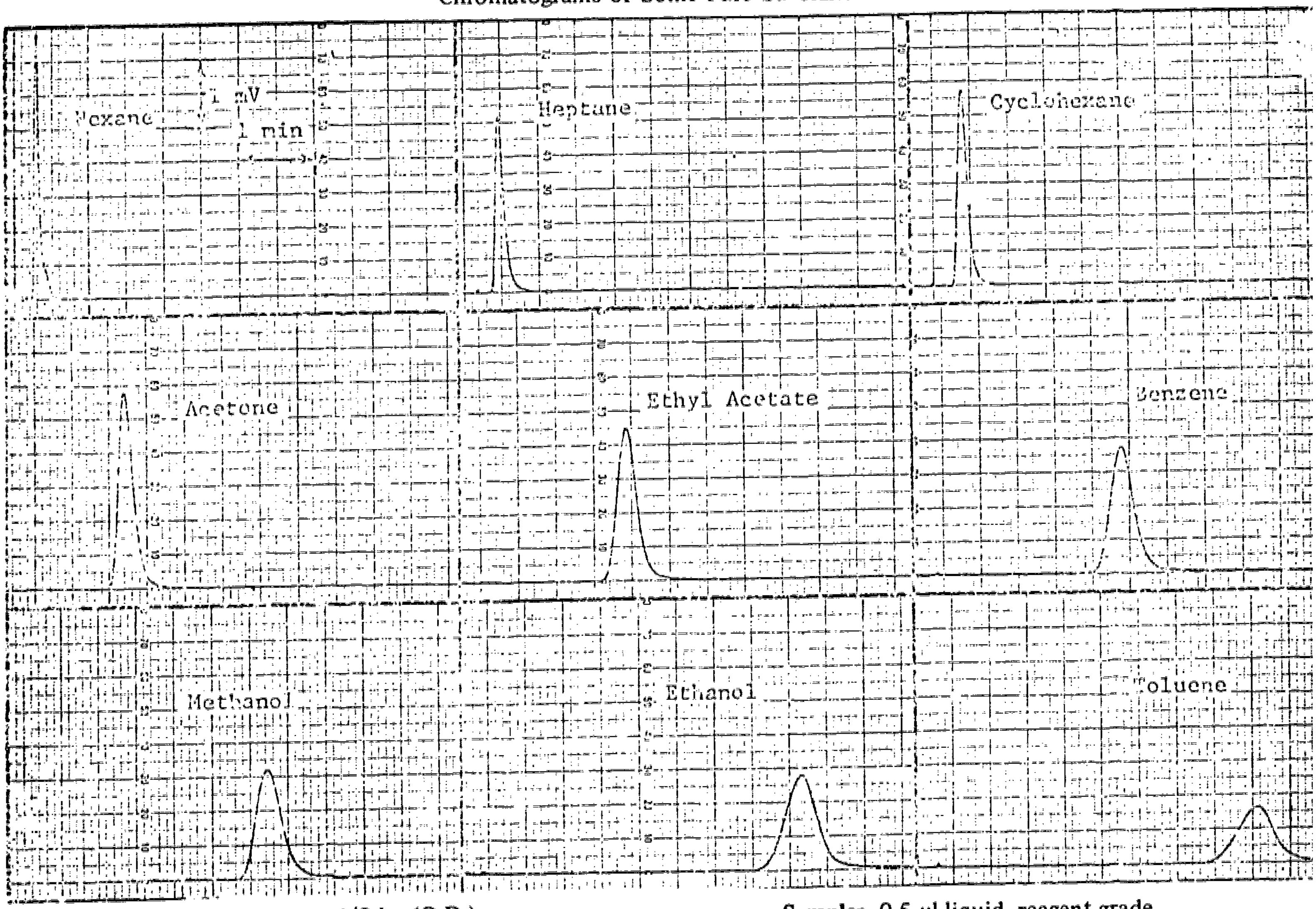
Figure 3. Student grade syringe

Reagents: Ethanol, Benzene, Ethyl acetate, Cyclohexane, Toluene, Heptane, Hexane

Commercial Products: Non-flammable cleaning fluids: e.g., Carbona, Aero.
Astringents: e.g., Max Factor.
After Shave Lotions: e.g., Aqua Velva, Mennen, British Sterling.
Finger Nail Polish Remover: e.g., Cutex, Max Factor.

During a pre-laboratory session or a previous meeting, each student should be given a number of chromatograms and make an accurate measurement of retention times.

Table 2
Chromatograms of Some Pure Substances



Column (i) 6 ft. x 1/8 in. (O.D.)
(ii) 12% Carbowax 400 (Polyethylene Glycol) on 80–100 mesh silanized support
(iii) 60°C

Flow 20 mil/min

Samples 0.5 μl liquid, reagent grade

Scale 50 mV full scale

Time 1 inch/min

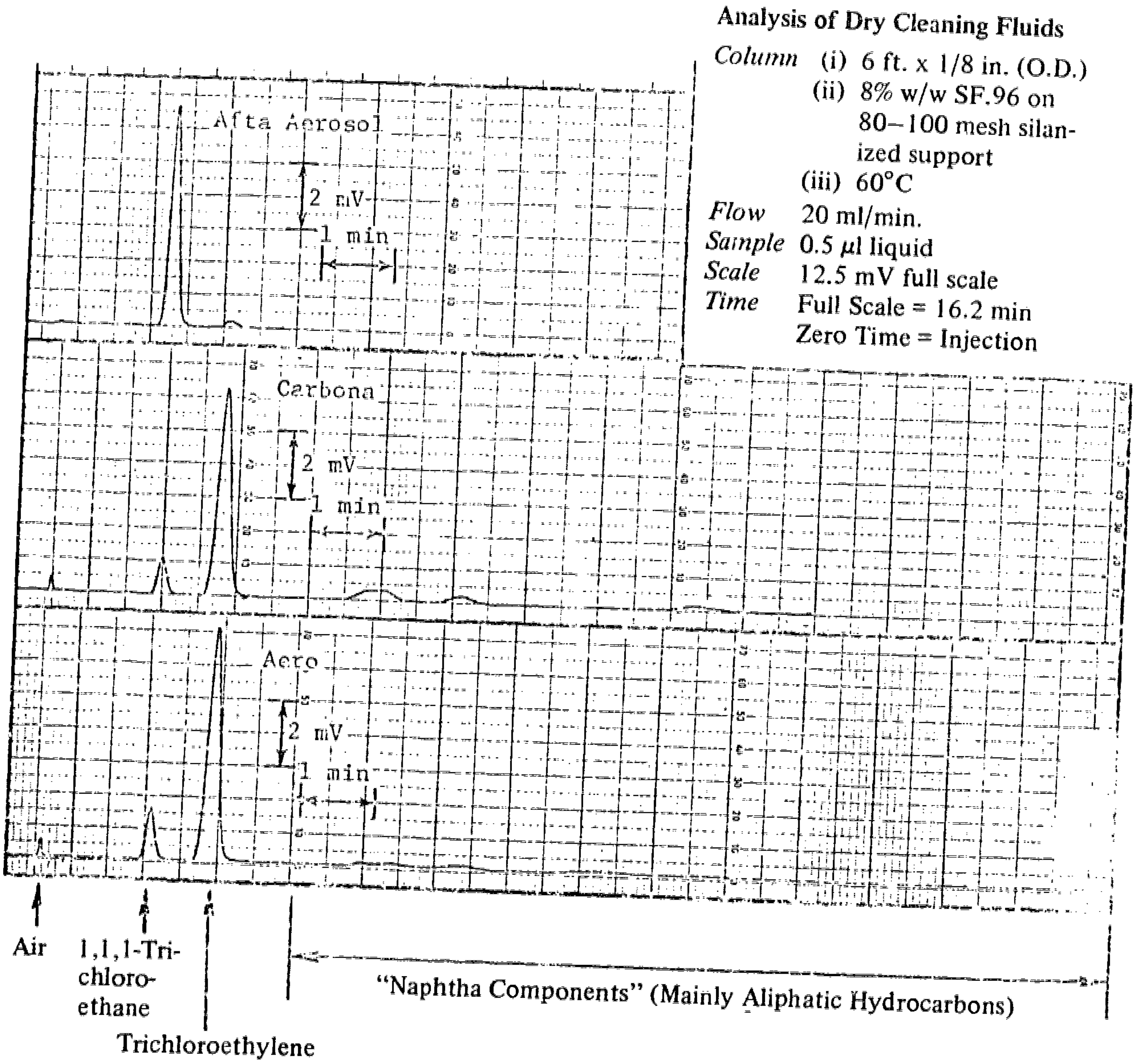
Note unresolved impurity in hexane appears as small shoulder.

From this measuring exercise, students can prepare a data table entitled, "Retention Times of Known Substances." These retention times are used to identify substances in an unknown mixture. To simplify the students' exposure to the gas chromatograph, all parameters on the instrument are preset by the instructor. All the average student operator must do is to properly clean and fill a microliter syringe with the pure, known sample assigned to him and inject it into the column.

Now that the student can identify substances by measuring the retention times from the sample(s) he has run, he can be assigned a commercial product and identify its components.

Table 3

Chromatograms of Some Commercial Samples



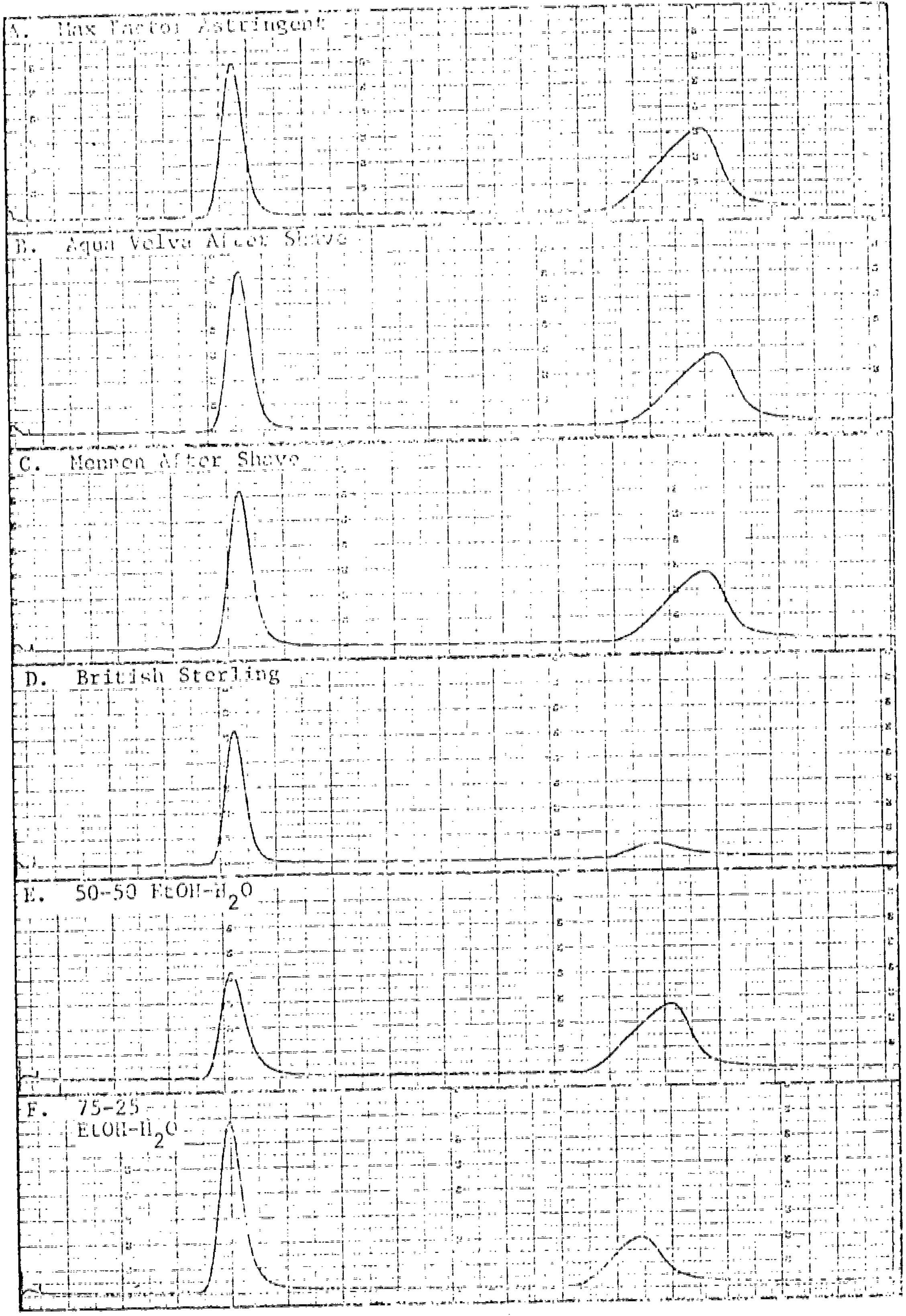
Analysis of Dry Cleaning Fluids

Column (i) 6 ft. x 1/8 in. (O.D.)
(ii) 8% w/w SF.96 on 80–100 mesh silanized support
(iii) 60°C
Flow 20 ml/min.
Sample 0.5 µl liquid
Scale 12.5 mV full scale
Time Full Scale = 16.2 min
Zero Time = Injection

The three major ideas demonstrated in the above experiments are:

1. Chromatographic separations occur because each component in a sample behaves differently from the other components (for the systems chosen).

Analysis of Astringents and After Shave Lotions

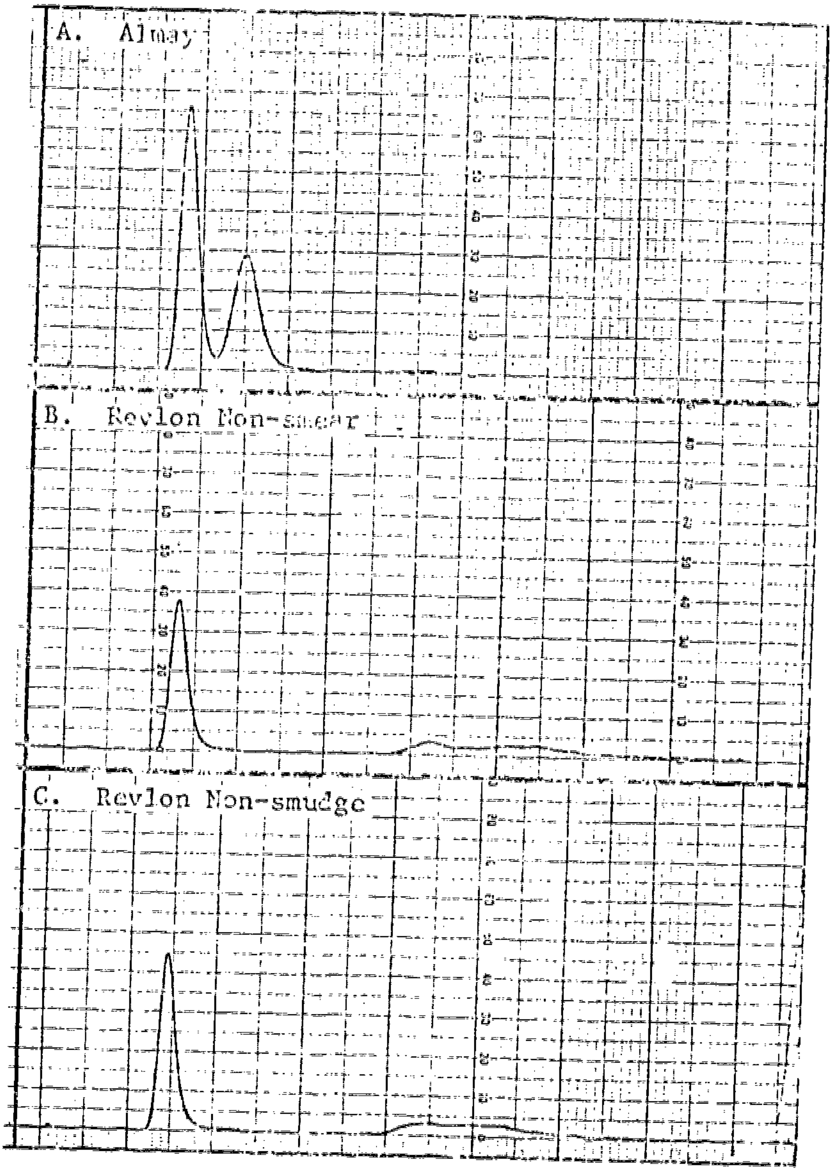


Column (i) 12% Carbowax 400
(ii) on 80–100 mesh silanized support or equivalent

Flow 20 ml/min

Sample 0.5 μl

Analysis of Fingernail Polish Removers



Column (i) 12% Carbowax 400
(ii) on 80–100 mesh silanized support or equivalent

Flow 20 ml/min
Sample 0.5 μl

2. Instrumentation is commonly used in chemistry and need not be overwhelming or frightening.
3. Measurements made or graphs can be just as valid as the volume and weight measurements more commonly associated with chemical measurements.

The paper chromatography experiment presents no equipment problems. The washable inks must be supplied by the student to maximize the effect of the experiment. In approaching the gas chromatography experiment, the limiting factor is the number of available GC units. The experiments can be organized so students will have work to do as they await their turn with the instrument. The ratio of students per gas chromatograph should not exceed 5 to 1. Three component mixtures are complex enough for the beginner, but one might prepare a few more complex systems for the better student. We have had much success in capturing the students' interest by using this approach in the freshman laboratory. Suddenly, chemistry presents some sensible aspects to the student. He, for example, will find that most aftershave lotions are ethyl alcohol-water mixture plus some perfume additives. This, to his amazement, is true whether he has paid 89 cents or $7.00 for the same volume of lotion.

The student is also exposed to the ideas of pure and impure substances, and that impure substances can be separated into their pure components by chromatographic methods. As the students extend their knowledge and techniques for using the gas chromatograph, they proceed to experiment on the calibration of the GC detector. As a final use of gas chromatography in the freshman laboratory, the students may use an exercise using ester exchange systems in the study of chemical equilibrium.[3]

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[1] *Modern Chemical Technology,* Revised Version, Vol 1, ChemTeC Project Writing Team, American Chemical Society, Berkeley, Calif., 1971.

[2] Carle Model 8000 with Westronics Recorder single speed, single pen action.

[3] *Modern Chemical Technology,* op. cit.

SUPER 8mm CHEMISTRY FILMS

Norman V. Duffy
Department of Chemistry, Kent State University, Kent, Ohio

During the past few years, numerous new audio-visual aids have been made available to the general chemistry instructor.[1] One of the more easily utilized (and less expensive) of these learning aids in chemistry has been the super 8mm film. There are now more than two hundred commercially available super 8mm chemistry films, most of which are sold through publishers in silent, four-minute, closed loop, Technicolor cartridges. This format is particularly convenient for classroom or individual instruction of single chemical concepts. These cartridged films are low in cost (approximately $25 each) and the necessary projector (approximately $150–$175) is usually readily available.

These single-concept super 8mm films cover a wide range of topics of interest to the general chemistry student. Numerous films are available on basic laboratory techniques, which may be viewed individually by the student in the laboratory, and which enable him to carefully view and review simple laboratory manipulations and instrumental operations. A new series of films emphasizes laboratory safety and first-aid.

Several available films may be used to replace or supplement lecture demonstrations, providing each student with essentially an identical view of a chemical reaction or manipulation. There are several series of films which demonstrate and explain chemical principles—films designed to be viewed repeatedly and reflectively by students, or designed to be viewed with frequent use of the "freeze-frame" device available on the Technicolor projector. These include series on spectroscopy, ionic reactions in aqueous solutions, and atomic and molecular orbitals.

The super 8mm format has also enabled chemistry professors who have inexpensive, amateur quality photographic equipment to produce their own single concept chemistry films which fill their own individual needs.[2,3,4] A number of these "teacher-produced" super 8mm films are available at cost through the AC_3 film clearinghouse.[5]

The accompanying table lists most of the super 8mm chemistry films which are commercially available, including the format of the film and the distributor.

Super 8mm Chemistry Films

Authors	*Series Title (No. of films)*	*Topics*	*Format*^{a}	*Distributor*
Anderson, D.G., Patterson, A.	Yale Chemistry Films (30)	Introduction to Chemistry, Introduction to Laboratory, Class Demonstrations, Oil Drop Experiment, Mass Spectrometry	A (others available on request)	Encyclopedia Britannica Educational Corp.
Bragg, L.	Bubble Model of a Crystal (2)	Deformation and Dislocation, Structure and Boundaries	A,B (black and white)	Ealing Films Inc.
Casanova, J., Mangravite, J.A.	Techniques of Organic Chemistry (37)	Manipulation of Liquids and Solids (19); Chromatographic Separations and Spectroscopic Methods (18)	A	Holt, Rinehart, and Winston, Inc.
Chem Study	None (13)	Various^b	A	Modern Learning Aids
Davis, J.C.	Spectroscopy Series (10)	Concepts underlying spectroscopy and the essential features and applications of techniques	A	Holt, Rinehart, and Winston, Inc.
Daw, H.A.	None (2)	Diffusion and Properties of Gases	A,B	Ealing Films Inc.
Duffy, N.V.	Ionic Reactions in Aqueous Solutions (10)	Qualitative Analysis and related theory and techniques	A	Holt, Rinehart, and Winston, Inc.
E.D.C.	None (1)	Bragg reflection of waves	A,B (black and white)	Ealing Films Inc.
Fitch, R.M., Fitch, J.T.	General Chemistry Laboratory Techniques (12)	Filtration, Recriptallization, Pipetting, Titration, Weighing, etc.	A,C	Kalmia Company, Concord, Mass. 01742
Hargreaves, S.W.	None (3)	Fractional Distillation, Electrode Potential, Addition Polymerization	D	Longman Group Ltd. Pinnacles, Harlow, Essex
Heinemann Ed. Books	Secondary Science Films	Various^c	A,D	Heinemann Ed. Books 48 Charles St., London W.I.
Lewis, J.L.	None (2)	Electronic Excitation, Ionization	D	Longman Group Ltd.
Lippincott, W.T., Barnard, W.R.	General Chemistry Laboratory Films (10)	Various^b	B,E,F (sound)	W.B. Saunders Co.
Miller, F.	None (2)	Critical Temperature, Paramagnetism of Liquid O_2	A,B	Ealing Films Inc.
National Film Board of Canada	None (2)	Production of Sodium by Electrolysis, Rutherford Scattering, Thomson Model of Atom	A,B	Ealing Films Inc.
O'Connor, R.	Fundamental Techniques of Chemistry (10)	Various^b	A,B	Harper and Row
O'Connor, R.	Laboratory Safety (5)	Basic Laboratory Safety, Handling Reagents, Accident Prevention, Lab. Emergencies, Lab. First Aid	A,B	Harper and Row
O'Connor, R., Fower, B.	Fundamentals of Chemistry (20)	Various^b	A,B	Harper and Row
Slabaugh, W.H.	Single Concept Films in Chemical Education (20)	Various^b	A,C,D	John Wiley and Sons Inc.
Tabbutt, F.D.	Mathematical Concepts of Chemistry and Physics (10)	Various^b	A	Appleton, Century, Crofts Inc.

Thompson, J.J.	Energetics (3)	Heat Energy Changes, Entropy Changes, Spontaneous Changes	D	Longman Group Ltd.
Wahl, A., Blukis, U.	Atoms to Molecules (8)	Various[b,d]	A,D	McGraw-Hill
Whitney, R.M.	Laboratory Techniques (10)	Various	A	Ealing Films Inc.
Whitney, R.M.	Lecture Demonstrations in Chemistry (10)	Various	A	Ealing Films Inc.

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[1] "Topics-Aids, Instructional Resources for General Chemistry," R. O'Connor, H. Zeitlin, and A. Zeitlin, *AC_3 Publication #48* (1970).

[2] "Teacher-Produced Instructional Films in Chemistry," R. O'Connor and W. Slabaugh, *AC_3 Publication #31* (1967).

[3] W.R. Barnard and G. Tressel, *J. Chemical Education,* 46, 461 (1969); 48, 143 (1971).

[4] W.R. Barnard, *ibid.*, 47, 318 (1970).

[5] For information, write to: Dr. Rod O'Connor, AC_3 Clearinghouse, Department of Chemistry, The University of Arizona, Tucson, Arizona 85721.

RESOURCE MATERIALS FOR TEACHING CHEMISTRY TO NURSING STUDENTS

Rena Turner
Fairleigh Dickinson University
Rutherford, New Jersey

Presented at the 29th Two-Year College Chemistry Conference
The Franklin Institute of Boston, Boston, Mass.
Concurrent Section, Saturday morning, April 8, 1972

Every chemistry teacher assigned to teach nursing students faces the challenge of introducting biochemistry of the cell most often in a brief one semester course. Although there are numerous texts designed expressly to serve his needs, he must prune harshly while developing the concepts that will lead to an understanding of the molecular basis of life. Often he remains a stranger to the real hospital situation and to the responsibilities of the nurse. Reading about the many applications of chemistry to health care does not always furnish the key to relating these directly to the student at this point in the nursing student's development. The resource material to help bridge this gap can be developed quite easily by any interested teacher. It is a creative expression that grows out of a desire to improve the course and a little research in the local hospital.

This approach was developed through a cooperative effort – the result of a healthy exchange of ideas contributed by participants in a National Science Foundation–sponsored Summer Workshop on Chemistry for Nurses which took place during 1970 at Rutgers University, Newark, N.J. Under continuing Foundation sponsorship, it was given a fair trial the following summer by a task group of eleven chemistry teachers who visited various hospitals in their areas, conducted interviews with directors of various departments, and pooled their research. The unanimous response was a sense of personal stimulation derived by each participating teacher. All were impressed with the responsibilities the nurse is faced with. Interviews with directors of pharmacy, central supply, inhalation therapy, hemodialysis, intensive care, clinical laboratory and nuclear medicine reinforced their convictions that a good background in chemistry is of tremendous value to the nurse.

What made this such a personally rewarding experience? The hospital visit is to the teacher of chemistry for nursing students what research is to the biochemist. It affords insight into the current applications of chemical, physical and engineering principles used in health care. This insight can only be gained by individual experience. Suddenly an excellent way of relating something you saw at the hospital to teaching an important chemical principle will suggest intself.

The cellophane tubing used to demonstrate dialysis in the chemistry laboratory is the same as that used to dialyze blood in the kidney machine. Metric conversions *are* important. The doctor may prescribe a dosage in milligrams for a drug that is labelled in micrograms. The success of inhalation therapy depends upon continuous monitoring and understanding of the blood gases and pH.

There is no better way to turn a student on during the course of a lecture than to supply yourself with a rich source of applications to the concepts being taught—acquired in the very hospital where he or she is obtaining training. This is particularly important to students in the associate degree program because time spent by them in the hospital is so much more limited than time spent "on the floor" by students in the diploma programs.

What I am suggesting then is the importance of establishing and maintaining contact with the local hospital for the purposes of orienting yourself to the hospital environment, learning the responsibilities of nurses and enriching yourself with the many applications of chemical and physical principles you will witness.

When the motivation is present, a phone call to nursing services, introducing yourself and explaining your objectives, will usually result in arranging several key interviews. The rest is up to you. There is nothing new in education except individuality.

Use your portable tape recorder if you have one. And if you are into photography, you may develop some worthwhile slide sequences on film strips.

HOW EXTENSIVE ARE AUDIO-TUTORIAL SYSTEMS USED IN CHEMISTRY IN THE TWO-YEAR COLLEGES?

Floretta Faubion Haggard
Claremore Junior College, Claremore, Oklahoma

Presented at the Symposium on the Systems Approach to Chemical
Education, 27th Two-Year College Chemistry Conference,
St. Louis, October 29, 1971.

Junior colleges holding membership in the 1970 American Association of Junior Colleges served as the population for this study. A letter and accompanying card were sent to each junior college president in order to obtain the names of the chemistry faculty. Each member of the chemistry faculty was contacted by card and asked to check if the first general chemistry course was instructed audio-tutorially. For this study, an audio-tutorial approach means the use of a multi-faceted, multi-sensory system enabling the student to direct his own activity in attaining behavorial objectives for each unit. The individuals utilizing the audio-tutorial approach were sent a questionnaire designed to determine the characteristies that constitute an audio-tutorial program in the first year general chemistry on the junior college level.

The extensiveness of the utilization of the audio-tutorial programs in the two year colleges is illustrated by the following results:

1. 662 of the 798 or 83% of the colleges responded to the card inquiring about audio-tutorial instruction.
2. 45 of the 662 or 6.8% of the respondents utilized the audio-tutorial program, either partially or completely.

Probably, the percentage incorporating audio-tutorial instruction in chemistry courses would be higher if the population had not been limited to the 1970 members of the American Association of Junior Colleges.

SYMPOSIUM

THE CHEMISTRY OF WATER; ITS POLLUTION; TREATMENT AND USE

The Twenty-Eighth Two-Year College Chemistry Conference
San Antonio College, San Antonio, Texas

Introduction:

The specific area that was decided upon for this symposium was water pollution. We looked at water pollution from four different aspects: (1) the chemistry of polluted water, (2) the causes of water pollution, (3) the determination of water pollution, and (4) its treatment. We want to look at both fresh water and at sea water. The talks will be followed by a panel discussion of four people from the junior colleges who will tell us more specifically how we can expose our students to information on the various aspects of pollution.

Dr. E. A. Eads, Professor of Chemistry, Lamar University, Beaumont, Texas

The Chemistry of Water Pollution

Natural surface and ground waters in the United States have dissolved, suspended and carried volatile materials within certain concentrations as listed in the following table:

Table I

	Parts Per Million (mg/l)				
Type	A	B	C	D	E
Silica (SiO_2)	2.4	12	10	9.4	22
Iron (Fe^{2+})	0.14	0.02	0.09	0.2	0.08
Calcium (Ca^{2+})	5.8	36	92	96	3.0
Magnesium (Mg^{2+})	1.4	8.1	34	27	2.4
Sodium (Na^+)	1.7	6.5	8.2	183	215
Potassium (K^+)	0.7	1.2	1.4	18	9.8
Sulfate (SO_4^{2-})	9.7	22	84	121	11
Chloride (Cl^-)	2.0	13	9.6	280	22
Nitrate (NO_3^-)	0.53	0.1	13	0.2	0.52
TOTAL DISSOLVED SOLIDS	31	165	434	983	564
TOTAL HARDNESS AS $CaCO_3$	20	123	369	351	17
	Equivalents Per Million				
Ca^{2+}	0.29	1.80	4.59	4.79	0.15
Mg^{2+}	0.12	0.67	2.80	2.2	0.20
Na^+	0.07	0.28	0.36	7.96	9.35
K^+	0.02	0.03	0.04	0.46	0.25
TOTAL CATIONS	*0.5*	*2.78*	*7.70*	*15.43*	*9.95*
HCO_3^-	0.23	1.95	5.56	5.47	9.00
SO_4^{2-}	0.20	0.46	1.75	2.52	0.23
Cl^-	0.06	0.37	0.27	7.90	0.62
NO_3^-	0.01	0.00	0.21	0.00	0.01
TOTAL ANIONS	*0.50*	*2.78*	*7.79*	*15.89*	*9.86*

From U.S. Geological Survey Water Supply paper 658.

This may be considered average saline ion concentrations for surface and ground waters. These data do not include the estuarial salinities of our coastal waters. When fresh water mixes with sea water, other criteria are used as average concentrations of salinity. The saline pollution of surface waters occurs mostly from oil field brines discharged into streams and lakes. The salinity of many oil field brines are found in ion concentrations of from 33,000 mg/l to over 100,000 mg/l. One must examine a suspected polluted water sample for high salinity when the total dissolved solids are above those concentrations for surface waters. Sewage effluents offer a source of high chloride, sulfate, phosphate, and common cations. The chloride ions would be difficult to remove. The sulfate and phosphate ions are also being studied with a view to the removal at their source from detergents or from the sewage treatment plants. Poor water quality due to salinity has been a minor pollution problem in the United States. Usually this salinity has been a problem assigned to natural waters in certain sections of the country. However, in some areas of our nation mine water discharges have been a major problem.

The introduction to some of the standard methods of analysis for such ions as Cl^-, S^{2-}, SO_4^{2-}, NO_3^-, NH_4^+, PO_4^{3-}, and CO_3^{2-} could be taught in general chemistry along with their significant concentrations.

The legal impact of the use of standard methods of analysis–(APHA), (AWWA), (WPCF) and (ASTM)–should be taught since information gained by chemical analysis may be admissable court evidence for pollution. Hence, the knowledge of the regulations on water quality will require introduction along with the implementation of the regulations by the Texas Water Quality Board, 1108 Lavaca St., Austin, Texas.

Chemistry students should be taught that information gained by chemical tests and syntheses may be subpoenaed. Therefore, one should not sample and analyze an industrial discharge without written permission from the firm in question.

Zealous students may be prosecuted for trespassing on private property. Students would not be restricted from sampling international waters or waters adjacent to international waters to determine their water quality. Other saline factors which have proved to be pollutants are the heavy metal salts and many of the transition metal ions: Chromium(VI), Beryllium, Silver(I), Copper(II), Nickel(II), Zinc(II) and iron being among the most common ions. However, occasionally others are discharged. Heavy metals and metaloids have been reported in water and seafood, i.e., dimethyl *mercury*, tetraethyl *lead*, and certain arsenic compounds.

pH is not conclusive as a pollution parameter unless a body of water is found to be very acid or extremely alkaline. Extremely wide ranges of pH values within the same body of water may indicate that pollutants are being received by the body of water. Polluted water is frequently regarded as natural water receiving excessive organic wastes from domestic discharges or poorly treated sewage and industrial effluents which have usually been dumped into the body of water. Both effluents create a demand on the dissolved oxygen. Usually discharges which carry a high organic load of pollutants remove the dissolved oxygen from the water faster than it can be absorbed from the air at the surface of the water. The aerobic bacteria in the water uses the dissolved oxygen to live on and the organic wastes for food. Overfeeding can remove more oxygen than would ordinarily dissolve in a balanced system. When most of the oxygen is removed, the aquatic animals begin to die. Ultimately all living organisms will die except the anaerobic bacteria and parasites which live in the absence of dissolved molecular oxygen. Temperature is an important factor when one considers studies of bodies of water. The solubility of air in water varies with temperature: cool water will dissolve more gases than warm water. Saline water will dissolve less O_2 than normal surface or ground water.

At a total pressure of 760 mm Hg under any other barometric pressure, p (mm or P′, in.) the solubility, S′ (mg/l) can be obtained from the corresponding value in the table by the equation:

$$S' = S\frac{P - p}{760 - p}$$

S is solubility at 760 mm (29.92 in.) and p is the pressure (mm) of saturated water vapor at the temperature of the water. For elevations less than 3,000 ft and temperature below 25°C, p can be ignored. The equation then becomes:

$$S' = \frac{SP}{760} = \frac{SP'}{29.92}$$

Table II*

Chloride concentrations in water, mg/l

°C	0	5000	10,000	15,000	20,000
			Dissolved Oxygen, mg/l		
0	14.6	13.8	13.0	12.1	11.3
5	12.8	12.1	11.4	10.7	10.0
10	11.3	10.7	10.1	9.6	9.0
15	10.2	9.7	9.1	8.6	8.1
20	9.2	8.7	8.3	7.9	7.4
25	8.4	8.0	7.6	7.2	6.7
30	7.6	7.3	6.9	6.5	6.1
50	5.6	–	–	–	–

*Standard methods for the Examination of water and Wastewater, 12th edition (1965).

Tests for organic pollutants are generally unique. Problems encountered are initially analytical. The actual identification of the organic compounds has not generally become possible because of the rapid change in the composition of the organic pollutants due to the life processes which constantly occur within a body of water. This observation has been true with water soluble pollutants and where insolubles are acted upon by bacteria, fish, and other life within a system. The organic content of a system is usually regarded as simply a system which devours oxygen (O_2) from the water. A method to measure this process is the B.O.D. (biochemical oxygen demand): a bioassay process where a sample is tested for dissolved oxygen, then incubated in a temperature controlled oven at 20°C for five days (up to 20 days), then retested for the presence of dissolved oxygen. When no dilution is used, the difference in the oxygen consumed by the sample is recorded in mg/l of B.O.D. When dilution is needed because of the high organic load which would remove all or most of the dissolved oxygen, a dilution technique must be used. A chemical oxygen demand test which uses chromic acid to digest the organic materials in the presence of mercury and silver catalysts is often run on sewage and industrial effluents. This is a chemical test which measures the amount of dichromate used by iodimetry recorded as mg/l of C.O.D. This test is more directly related to the actual organic chemical load borne by a stream. The readings are usually much higher than the B.O.D.

Both of these tests require careful work performed under supervision. Many times errors are introduced into the samplings. Measurements may be required for legal documentation when evidence must be presented for defense or prosecution of a polluter.

Several approved devices which measure organic pollution loading are known as total oxygen demand (TOD), total carbon and manometric oxygen analyzers. They are in use in monitoring effluent discharges. These and other monitors are valuable tools, useful and necessary in preventing the dumping of poorly treated wastes into the environment. At this point, it would be well to point out the research needs for the development of more sensitive and precise monitors to prevent accidental discharges from reaching our air or water resources.

Certain instances of water pollution identification may not require chemical tests. The 1899 Refuse Act may be enforced by observing and collecting a sample from a polluter discharging effluent, solid or liquid, which has been put into a waterway or waters adjacent to international waters. Prosecution under this act is performed by a U.S. attorney in a federal district court. Citizens may attempt to enforce this act of 1899 in a Qui Tam suit and collect up to 1/2 the fine if a conviction is imposed. However, if the polluter is not convicted, the plantiff may be required to pay for the court costs and attorney's fees. I hasten to mention that certain federal courts are now requiring chemical analyses of oil spills, chemical discharges, bilge and ballast discharges and many other pollutants pouring into our waterways, streams and lakes. All of these discharges are sources of dissolved oxygen-consuming materials with high BOD requirements, in some instances over 1000 mg/l. Surface and ground water should be within about 3–6 mg/l, ordinarily, where no pollution from natural or man-made discharges is being received by the basin or body of water.

Thermal pollution is noted when heated water discharges are added to lakes, streams and rivers. Most regulations presently restrict the temperature increase so that it will not exceed 4°F over the ambient temperature of the receiving waters. These criteria are presently being studied and may be changed. Many authorities differ on the effects of heated water discharges upon certain receiving waters and their contribution to pollution. In many lakes hot water discharges may cause irreversible biochemical changes. However, in other instances warm discharges may aid a flowing body of water or produce no apparent change in the ecosystems.

It may be suggested that polluted water is present when the following conditions are visually observed:

1. Oil films
2. Brightly colored streaks or black water
3. Foam
4. Odor
5. No signs of life such as minnows, plankton or shore birds
6. Stained shoreline with dead plants or no plants whatsoever
7. The presence of dead fish
8. The presence of trash, lumber, poles, boxes, cans and other foreign floating materials

Leo Newlands, Texas Christian University, Fort Worth, Texas

Chemical Analysis of Polluted Water

As you are aware, pollution of this nation's waterways has been going on at least since the Industrial Revolution and pollution will probably continue until which time we can at least legislate some of the pollution out of existence. It's not enough just to enact laws against pollution; we must enforce the laws. Certainly, our recent legislation and the creation of the Environmental Protection Agency have been steps in this direction. I am looking forward to a few things from the EPA. Since water pollution will not stop overnight, it is necessary for us to be able to detect and to quantify these pollutants after they have reached the aquatic environment. This is also necessary for maintaining pure waters after they have been cleaned up. It is obvious that most of the pollutants that can occur in an aquatic environment are either of a chemical or a physical nature. Therefore, all of the analyses or the majority of the analyses we perform to detect polluted water are either chemical analyses or physical analyses used to supplement the chemical analyses.

The first slide we see here is a listing of the chemical tests that we normally perform to determine pollution. The first test listed is a *nutrient test*. Nutrient tests are done primarily with phosphorus and nitrogen, although there are other tests and certainly other things implicated in nutrients. The second test is for *carbon* and it is subdivided into two categories: the organic carbon and the inorganic carbon. Under organic carbon are the organic pollutants. This is extremely important from the standpoint of the oxygen demand on the strain that Mr. Eads just talked about. We have both total organic analysis and also analysis of organic compounds which serve individual commodities—specifically, such things as pesticides, detergents, fats and grease—all sorts of organic compounds. Tests for the individual organic compounds are in my estimation very important; although there is very little that we have been able to do up to now. They are important from the standpoint of their accumulation in the environment and their potential processes from the accumulation of these compounds. The inorganic carbon includes such things as the cyanides, carbonates, bicarbonate system and the free carbon dioxide. Carbon dioxide could also be listed under the nutrients which have been implicated recently.

Thirdly, I have listed *dissolved oxygen* and this is probably the single most important determination that you could make on a sample of water. If someone brought you a sample of water and said that you could run one test and one test only, perhaps the best choice would be the dissolved oxygen test. Not only does it give you some idea of at least the amount of light that is present or could be possible in the stream; it also gives you an idea of the state of some of the chemicals and some of the elements in the stream. It tells you in what form you might find nitrogen—in other words, whether you find nitrogen in a nitrate or as ammonia, or sulfur as a sulfide or sulfate.

The fourth test listed is *alkalinity and acidity*. This is a titration that we run to determine the buffering of the water. Notice that I did not use the term "buffer capacity," because the buffer capacity in pollutional words is a mathematically-derived commodity. It is not something that you measure. You measure the parameters and derive it mathematically.

The fifth test, *hardness*, is just a measurement of the calcium and magnesium that occurs in the water, which we will discuss later.

Test six is *pH*. This is a measurement that, in conjunction with the dissolved oxygen, can be very important. pH does not really have as much importance in aquatic systems as it does in some of the other systems, principally soil systems

The last test listed is *metals*. I have on this slide a listing of what I call water trace elements. These are subdivided into common elements, the scarce elements, and the rare elements. Certainly this subdivision is quite arbitrary and is the subject of much debate among researchers in the field. The nice thing is that most of these elements can be determined analytically by atomic absorption. Those of you in the two-year colleges who do not have access to expensive instruments may detect these same metals by certain coulometric and gravimetric methods. So this is just a listing of what I call the water trace elements.

The second slide shows a listing of the physical parameters that are formally measured in the water pollution laboratories. Certainly this includes specific conductivities. Solids, both suspended and dissolved, give you some idea of the particular matter in the water. Turbidity, directly or indirectly, relates back to the solids because if the water contains high amounts of suspended solids, it is also going to be quite turbid. Turbidity is an operationally defined procedure whereby you pass a beam of light through the water and measure the amount of refraction of the light. Color is given by direct comparison to color standards. Temperature is very important from the standpoint of thermal pollution and its effect on the wildlife of the water. The last physical parameter that I have listed here is odor.

In addition to all of these, we have what I like to define as water pollutional type tests, and may include many of the tests that we have already talked about. Certainly the tests nere include taste, odor, and the suspended matter and color which we have already mentioned. I might point out that we are concerned principally with four forms of nitrogen in polluted water. We are concerned with ammonium, nitrite, nitrate, and organic nitrogen. It is important for us to know which form of nitrogen occurs in the water. We are concerned principally with three types of phosphorus -ortho, poly, and organic. Phosphorus is a very important element to determine principally because of its direct connection to detergents and subsequent pollution. Of all these factors, the demand tests that I have listed here are especially important. They give us an idea of what type of demand the water may place upon some particular substance. The chlorine demand test is important economically because it may tell a water treatment operator or a waste water treament operator the amount of chlorine he needs to add to a particular sample of water in order to erradicate or to affect the killing of any pathogenic organisms. We have talked about the importance of the oxygen demand test; it is subdivided into biochemical oxygen and chemical oxygen demand.

When waste is dumped into a body of water it can affect the depletion of the oxygen in one of two ways. It may deplete the oxygen supply either biologically or it may do so chemically. If waste is highly organic in nature, then this factor will probably exert a great effect on the biological demand of oxygen and will deplete the oxygen biologically. However, if it is some reduced chemical, namely ammonia or sulfide or some other chemical, it is going to effect a very strong oxygen demand chemically from the stream. One of the real problems is the fact that the biochemical oxygen demand is a bioassay or biological test and, as a result of that, is subject to all of the limitations and variations of any biological test. For most municipal waste you suspect that the BOD would probably be as high or higher than the COD. On the other hand, if you find a very industrial chlorinic waste, you might expect the COD to be much higher.

One of the recent tests, total carbon (sometimes called total organic carbon or TOC), is just a method of determining the amount of organic carbon present in the sample. There have been a large number of correlations run between total organic carbon and BOD and certainly a relationship does exist. There are two principal disadvantages to this total organic carbon, TOC analysis: (1) the instrument required to perform this particular analysis is very expensive, and (2) all of the organic material that might be present or might be indicated by the instrument is not necessarily oxidizable. All of the organic matter that is in a body of water is not necessarily oxidizable.

As two-year college chemistry instructors, probably one of your major concerns is how to relate chemistry to modern daily life. I think one of the easiest ways to do this is to relate chemistry to pollution. You should include in your curriculum some of the pollution analyses and the theories behind them. Instead of talking about chelates and maybe running a chelate titration in lab, perhaps you could run calcium and magnesium using EDTA and explain how you are determining the hardness of water. When you talk about resins and resin columns, why not talk about the way you soften water by replacing calcium and magnesium with sodium. Instead of talking about the same redox reaction, talk to your students about the chemical oxygen demand analysis whereby you measure the amount of dichromate that has been reduced by a particular waste.

Dr. Dean Martin, University of South Florida, Tampa, Florida

Pollution of Sea Water

We make two mistakes in education these days. One is assuming that a person has not had a course, say, in pollution, and that he knows nothing about the subject. The second mistake we make is assuming that if a person has had the course, he does know something about it!

I do not propose to tell you what you should teach, but here is some source material that I think you might find interesting. I do not propose to offer a commercial message, but if you were to look at the eight references on page 1, you might find it of interest. Let us recall a few years ago that a man named Walt Kelley suggested in the comic strip *Pogo* that the principal cause of forest fires, if I can recall the quotation correctly, was "forests." If there were no forests then obviously there would be no forest fires. Well, what is the principal cause of the pollution of sea water? The principal cause along that same vein is "us and it." We ought to know something about "it," so let us look at "it."

Among the challenges that we face in connection with sea water are: What is in it, what is in it for us, and the problems of analysis that Professor Eads has already described in "The Chemistry of Water Pollution." How do we use the stuff that is useful to us? Right now we use magnesium, water, sodium chloride, bromine and fish, but not much else. We haven't worried about depletion, perhaps, but really the things that are of immense importance to us are the related problems of pollution of the ocean and of food. About four percent of the world's food supply comes from the ocean. This supply is not going to last a lot longer. By way of conversive knowledge, we believe that the earth has been around for about two thousand million years. We believe that the sea as a chemical system has not changed ostensibly for about 200 million years and it has been predicted that in twenty-five years, if we keep at our present pace of polluting the ocean, the ocean will die. Now, for something that has not changed for 200 million years, twenty-five years is a mighty short time; so we need to worry about the characteristics of sea water and how it affects us.

Looking at it as I did a few years ago as, let us say, a simple-minded chemist, it seemed to me the characteristics of sea water were the following:

1. *It is dense.* It is about two percent denser than fresh water. This is tremendously important, because it provides one of the major circulation methods or mechanisms of the ocean, the density current (the other being wind-driven currents).
2. *It is salt.* Two constituents, sodium and chlorine, make up about 85% of the weight of dissolved salts. If you add nine more constituents, you pick up about 99% and there are eleven so-called Ocean 11 constituents. The weight of sodium relative to chlorine remains everywhere constant within the limitation of our method. As we improve our methods we find that there are certain differences which become very significant.

   One of the problems that we face is the immensity of the ocean. The volume of the ocean is about 320–330 million cubic miles, depending on whose estimate you look at.

What is one cubic mile? Obviously it is one mile long, one mile wide, and one mile deep. Sea water, let me tell you, is a very dilute solution, but if you take enough of it there is a lot of salt. Look at the magnesium. There are thirty million tons of magnesium in a cubic mile of sea water. What does this fact mean? It simply means that there is more magnesium in sea water than we have ever needed in the past or will likely need in the conceivable future. Magnesium is a war metal. Its principal production has occured in 1944, during the Korean War, let us say 1952, and during the Viet Nam War, about 1969. The peak production was something like 800 thousand tons, far from the amount of magnesium in a cubic mile of sea water.

This immensity troubles us; dilution should be the solution to pollution. If all of the waste matter that we have or are likely to have were dumped into the ocean and mixed uniformly, we would have no problem. In actuality, the mixing does not occur uniformly; nor is it rapid. One may think of the ocean as being a well-mixed system in geological time. Now what does this mean? It means that within a thousand years probably every parcel of water that comes in contact with the atmosphere is thoroughly mixed. So, the ocean from our limited standpoint is not well-mixed.

3. *The ocean is a source of organisms.* If one had a thousand pounds of phytoplankton and had to eat the phytoplankton, he would do all right. Unfortunately we can't eat phytoplankton and so a food chain is involved. Dissolved plankton that emerge from a thousand pounds of phytoplankton weigh about 200 pounds. The small animals that eat dissolved plankton represent a smaller body of material. The medium-sized predators that eat it and finally the even larger predators represent a much smaller ratio. If you lifted the top and wanted a tuna fish, you could get about 1.6 pounds of tuna, contaminated with mercury, from about one thousand pounds of the phytoplankton.

   The thing that keeps the ocean from being a desert (and 80% of it is a desert having no organisms present) is the fact that some fish consume phytoplankton directly.

The ocean we are most worried about is the coastline. Within the 200 mile limit as defined by Peru, anything that affects plankton affects us. What do the phytoplankton do? One of the things that they do is produce oxygen by means of photosynthesis. It has been demonstrated that mercury compounds retard the rate of population, at least in the laboratory, for phytoplankton. Is this going to affect our oxygen supply? We think not. Suppose that we are not marine chemists but simply freshman chemistry students. We will look at Equation number one as a simple representation of photosynthesis. A model of carbon dioxide is converted to some form of organic carbon plus a mole of oxygen. It requires light and a catalyst called chlorophyll. As long as phytoplankton remain alive, there would be no problem. However, in the Gulf of Maine and perhaps in the Gulf of Mexico, phytoplankton has a very limited lifetime. In Maine it grows in the spring and it dies in the fall. What happens when it dies in the fall? In Equation number two, Biological Oxidation, a mole of organic carbon reacts with a mole of oxygen to produce a mole of carbon dioxide. Now if you add Equations one and two, the net process is that nothing produces nothing. Once the phytoplankton were buried, the oxidation process did not occur. Now I don't think they are producing oxygen that we are breathing, despite what you read in the Sunday comic strip.

If that bound organic carbon were involved in the reduction of sulfate by means of sulfate-reducing bacteria, then sulfide would be produced, carbon dioxide would also be produced, and there would be a net increase in the amount of oxygen. If we are destroying the sulfate-reducing bacteria or the phytoplankton, then indirectly we are affecting our oxygen supply.

If one defines pollution as the addition of any substance, organism, or factor that has a deleterious effect on the biota, then in a given chemical environment, anything as innocuous as an automobile engine becomes a serious problem. One of the serious problems of the ocean is that it is not picking up carbon dioxide because the ocean is a reasonably well-buffered system. The amount of carbon dioxide in the atmosphere is increasing. We are unfamiliar with this so-called "greenhouse effect"; so what effect is this going to have?

We need a second model to define it. We can assume that there are two layers, an upper layer and a deeper layer in the ocean. We can use a method of following the pathway of carbon by means of radioactive carbon tracer studies. The result is that in the deep sea layer the mean residence time of carbon dioxide is in the order of five hundred years which means that it is not picking up as much. In the surface layer alone it is in the order of thirty years, so we have a real problem. Carbon dioxide is presumably increasing in the atmosphere.

Dr. Peterson in "The Environmental Science and Technology," in 1969 made some predictions. One was a temperature increase of about four degrees. In the temperate climate we would have more rain, less snow. In our area the sea water would rise about an average of four feet and we might experience more earthquakes and more volcanic activity that would produce more carbon dioxide in the atmosphere. We would find weather shifts and that the Arctic Ocean would be open six months of the year. The rise of four feet in sea level could affect us in south Florida. We are at about 4–5 feet above sea level, so we would find some serious problems.

We are faced, however, with yet another problem, that of dust. As it turns out, the effect of dust is somewhat in reverse. It is probably going to cool and cause a temperature decrease. Maybe these two effects will be balanced. We may be balancing ourselves in this way by pollution from carbon dioxide and fossil fuels versus pollution from dust. We must have more information, however, before we attempt to handle the problems.

All of us eat. We need to worry about fifty-five pounds of waste per day per citizen. Where does this go? Ultimately, I can assure you that it goes to sea. Can the sea handle this waste disposal? Let us worry about the oxygen reservoir. Looking at three reservoirs—the atmosphere, the deep layer of the ocean, and finally plants—there are something like 60,000 moles of oxygen per square meter of earth's surface in the atmosphere. That is a tremendous reservoir. As far as the deep sea layer is concerned, it is much smaller. There are about 250 moles of oxygen per square meter. Plants seem to be keeping ahead of the system and there may be a net gain of about eight moles of oxygen per square meter. What does this mean in terms of the pollution? Let us look at the deep sea reservoir. Can the ocean take it? If one dumped the entire product of land photosynthesis into the ocean, its oxygen demand would be used up at the rate of something like fifty moles of oxygen per square meter. One can say that in about five years the ocean deep sea layer would be in serious trouble. If on the other hand we assume that there are 10^9 human beings, each has only about 100 kilograms of carbon as waste per year. This annual oxygen demand is dumped into the ocean and its oxygen demand would be something like 0.01 mole of oxygen per square meter. When you divide that number into 250, it comes out to a much, much happier figure.

We are looking at about ninety percent of the ocean, or the deep sea layer, and that is really not the part we are interested in. We are interested in the part that we can see when we walk along the seashore. We are interested in the estuaries. Eighty-five percent of the commercial catch in the Gulf of Mexico spends some portion of its time either in Tampa Bay or an estuary not unlike it. Around Tampa Bay there are sewage plants; every triangle or every dock that you see here in this slide is a sewage disposal plant, and better than ninety-nine percent of them are inadequate. A tremendous amount of material is being dumped here, impurities of the type that have a deleterious effect. Not that they are using up carbon dioxide, but this stimulates other organisms—an organism such as fungus, for instance. In hundreds of square miles of area off New Jersey there is some fungus that attracts and kills fish so that in this area there is an absolute desert. This is something that we have done. Presumably some unknown chemical that we have provided has stimulated the growth of something bad. In Lake Apopka we have stimulated, by the use of various nutrients, a fungus that attacks not only fish but alligators and any other organisms. We have upset the balance.

How bad is it? In glorious or hideous technicolor, the parts that are colored are polluted; they are bad for swimming and therefore bad for oysters. This much of Tampa Bay, all of Hillsborough Bay, Old Tampa Bay, and so forth. In a nearby area, one was once able to find oysters. Now a person taking oysters out of that area would be fined by the state authorities.

Unfortunately many of the problems are questions we don't have answers for. Consider the question of oil on the sea. How much of it is there? Right now we know that 700 million tons of oil are transported each year. In theory if every ship crashed, 700 million tons would be added to the sea. The amount that is actually spilled and dumped is somewhere between one and one hundred million tons a year. The ultimate fate is still in question; but it is on the surface areas where photosynthetic activity is at a maximum, and I think it is more deadly than we have been led to believe.

Here is a fish kill. It is the sort of fish kill that one tends to blame on industrial firms. This particular fish kill was, however, not one caused by industry. It is a fish kill caused by red tide, a natural phenomenon, the first of the plagues that was visited upon Egypt (Exodus 8:20, 21). Something triggered the occurrence of organisms that in large concentrations give rise to discolored water. Something like 1/2 billion fish were killed in the 1947 outbreak.

In Tampa Bay ninety-five percent of the phosphate that comes here is probably not from domestic but from industrial sources, or it comes from phosphate sources that were there before the industry came. If you look at the amount of phosphate that has intruded into Tampa Bay at nearby Charlotte harbor and try to relate it to the red tide outbreak, you find an interesting thing. The outbreaks occur when there is a minimum amount of phosphate. Now we raise our question again: to what extent does an individual chemical introduced into the water affect the ocean? We do not know. The county commissioner in Hillsborough County suggested that anyone who spits anywhere in the county is probably affecting the environment. I suspect that he was not too far wrong. I think this is an extreme point. The conservationists would certainly disagree with me. The people who say we do not have a problem would represent the other extreme. I would leave you with the thought that truth is rarely found at extremes. We do not know fully the magnitude of the problem, but I hope that in twenty-five years we do not have a dead ocean. The answers to these questions will be found in these references and other sources. I have offered you some thoughts. You will have to decide for yourself how accurate my assessment is.

MR. WALTER DEDEKE

The Treatment of Waste Water

I would like to emphasize what pollution is. There are probably as many definitions as people you would ask for definitions. I think of one that is commonly accepted: when something has been done to the water to make it less desirable for some purpose, then this is pollution of the water. Now this covers a multitude of sins, from taking the paint off your boat to killing fish, to turning the lake that you just built your summer house on to the color of red. This is certainly pollution, whether it kills any fish or not.

Pollution can be broken down into several forms; for example, disease-producing organisms and toxic materials. (By toxic materials, let's not use the newspaper definition. Here any time a fish dies, he has been poisoned. This is not necessarily true. If you remove the oxygen, he smothers. If you remove his food supply, he straves to death.) Toxicity is something that some of my predecessors were much better versed in than I am. As I understand it, it is anything that enters the cell of a creature and kills it by so doing.

Then there are physical changes that may be caused in the water: pH changes, inorganic chemicals, and organic chemicals. I think this covers the list pretty well. Pollution is basically the change in the biota in the water. If there were no change in the biota in the water, then you would have no pollution.

I live on Galveston Bay, and a lot of plant effluence and city effluence are dumped into Galveston Bay. The oxygen depletion in Galveston Bay is due to the entrance of materials coming from these plants and some is from septic tanks. If this material were kept concentrated and away from Galveston Bay, a sewage treatment plant could be made to destroy this organic material. pH could be regulated. The pathogens could be killed, and this could be done in many small areas.

I do not know the curricula of two-year colleges, but if you are breeding any biologists, please point them toward ecology and not the traditional taxonomy. Right now in the water treatment business a biologist is not very useful. You can have the most beautiful analysis of slime or industrial waste and you get back a list of from seventeen to seventeen thousand Greek names. That biologist doesn't know what one, single, solitary one of those bugs does!—what he eats, what he puts out, whether you want him or whether you don't want him, how to get rid of him or how to keep him. So here we are, working on something occurring in the ocean, lakes and waters, something we don't even understand. The emphasis has to be put on ecology. The primary thing is the bugs and the relationship of these little bugs to each other and the water.

One other thing that has not been brought out is that the creatures in the water are acclimatizable. You can start with a quart of ocean water and put in a drop–normal arsenic today–and you can breed a strain of bugs tomorrow in that water that will live on arsenic and die if you remove it. The examination of population biota in water is another pollution indicator which has not yet been mentioned. In well water, in good water, we have a wide distribution of kinds of creatures. Those which can live under those conditions, food supply, temperature, etc., will persist and they will multiply to keep up with their food supply. Those who cannot will pull in their heads like turtles, form a spore, and wait until conditions get better. In good water you have a wide number of types of bugs. In polluted water, you usually have a higher total population, but the kinds of bugs are fewer, sometimes down to one. We have noted this in our pilot plant work. Of course, you do not get a pure strain, but slide after slide will show only one kind of critter. In a water treatment plant you have the advantage that you can acclimatize. We give them the best kind of care that we know how, without knowing anything about them. These animals acclimatize themselves to these conditions.

I don't believe that a BOD is very useful. The BOD came in about two hundred years ago when the River Thames, which is the sewer of London, became so thick that one could almost walk across it. It was decided that something had to be done about sewers. So someone, I do not know who it was, thought that it was the lack of oxygen in the river, so oxygen was what was looked at. Now the BOD test consists of taking some carefully prepared sterilized water and putting in certain amounts of various and sundry chemicals that we think the little varmints need. Then we take a sample of bacteria, a seed, from the municipal treatment plant, and put it in there. How many of these bugs ever saw a seed phenomenon before? How many of them ever saw a molecule of glycogen before? acetone? ethyl acetate? There are about one hundred thousand different materials in our waste at the plant. If you titrate your BOD's almost hour by hour, you will see that the utilization of oxygen is practically zero for a period of time and then slowly increases so that it becomes almost linear and then breaks off into a plateau. Later on you get another plateau with nitrogen. This first low curve is these poor varmints trying to learn what the chemicals are. They are trying to become acclimatized. It is possible to take a sample of any waste and by picking the properties you can get any answer you want. All the way from zero on up. You put the bugs in your sample, and then you put the sample in the dark for five days at 20°C.

Over the years the engineers came up with some very empirical numbers to multiply by. DOD is supposedly the amount of oxygen that these little bugs will take in order to use up X gallons or however you want to put it. Don't forget that you start out with 8 ppm of DO and you cut it down to 2 ppm. Presumably you don't take any answers if you have a DO of less than two. So what keeps people from wondering about oxygen limitations? You know very well that in a laboratory some of these varmints are killed or inactivated by a drop of DO, one ppm. Yet you accept a 6 ppm drop in that bottle. Then you have to multiply it by working backward from the treating plants. They can take a BOD from human waste and design a municipal treatment plant from it. But you can't do it with industrial waste, because you don't have the two hundred years of experimentation and you cannot spend ten million dollars too often to build a plant that is not going to work.

SMALL WATERSHED STUDIES: A USEFUL METHOD FOR DEVELOPING ENVIRONMENTAL STUDIES IN THE COLLEGE CURRICULUM

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Presented as the Keynote Speech to the Environmental Education Symposium,
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Small watershed studies provide an excellent method - both research and instructional - for developing environmental science at the college level. Environmental science has been defined as the study of natural processes, their interactions with each other and with man, and which together form the earth systems of air, water, energy.

and life. The chief emphasis of environmental science is on systems: tying together the myriad elements of the physical world distinguishes environmental science from science as a whole.

The present environmental crisis signals the fact that the finely adjusted mechanisms of ecosystem cycles have begun to break down. It is important, more now than ever before, that we understand rigorously the ecosystem processes. Quantitative information concerning:

1. the distribution of chemical elements in the environment,
2. their rates of uptake, retention, and release in various ecosystems, and
3. predictive capabilities of the environmental impact on the above brought about by modification of ecosystems,

will be required for a healthy environment. For those of us in the teaching profession the education of students in the understanding and appreciation of the interactions of ecosystem processes and their significance in modern society should be a prime goal.

Susquehanna University (in Selinsgrove, Pennsylvania) has assembled an interdisciplinary team of chemists, biologists, geologists, a computer anaylst, and a regional planner to study biogeochemical cycles in a small watershead in Central Pennsylvania. The data derived from this study provides the foundation for monitoring or experimenting with select land-use changes such as clear-cutting, fertilization, pesticide application, or urban development.

This approach has proven to be a successful device because:

1. A small watershed is a natural unit of suitable size for intensive study at the ecosystem level.
2. It provides a means of reducing to a minimum the effect of variables of geologic input and losses.
3. It provides a method whereby such important parameters as nutrient release from minerals and annual nutrient budgets may be calculated.
4. It provides a means of studying the interrelationships between biota, select nutrient cycles, and energy flow in a single system.
5. It provides a method to test the effect of various land-management practices and environmental inpacts on the basic nutrient cycles in natural systems.
6. Finally, it can serve to coordinate the science education of students, and, at the same time, to provide a useful and needed service to the community at large.

THE ROLE OF SCIENCE DIVISION HEADS IN REGIONALLY ACCREDITED JUNIOR COLLEGES IN THE UNITED STATES

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Presented at the 29th Two-Year College Chemistry Conference
The Franklin Institute of Boston, Boston, Mass.
Concurrent Section, Saturday afternoon, April 8, 1972
(Study completed at the University of Mississippi, March 1970)

The purpose of this study was to examine the role of science division heads in regionally accredited public and private junior colleges in the United States. The study was restricted to those colleges holding regional accreditation as of February, 1969, and to those having the divisional organizational structure.

The scope of the science division head's position was examined in terms of personal data and background; role definition; selection, appointment, and status; general activities and responsibilities; administration; teaching; instructural evaluation; greatest obstacle to effective role fulfillment; and chief satisfaction in serving as science division head.

The data were analyzed for differences and similarities in the role in public as compared to private junior colleges and for interregional differences and similarities in the role. The data were also compared with the division head 's role as outlined in junior college faculty manuals.

Procedure

Procedures used in this study were as follows: (l) A preliminary survey instrument, mailed to the deans or presidents of 600 regionally accredited junior colleges, was used to identify 343 colleges having the divisional organizational structure and to obtain the names of the division heads. (2) A five-page, 62-item questionnaire was used to collect data in the principal investigation. Usable returns were received from 285 (83.1 percent) of the junior college science division heads in the study. Public junior college science heads accounted for 80.7 percent of these respondents. (3) The usable, returned questionnaires were tabulated by hand and the results reported in narrative and tabular form in terms of percentages.

Findings

The findings of the study are summarized as follows:

1. In general, the role of science division heads in accredited junior colleges in the United States is relatively uniform from region to region and among public and private colleges. Some major disparities in the data did exist. Markedly lower salaries were paid respondents in private as compared to public junior colleges, and regional salaries were lowest in the Southern and New England Associations. Public junior college science heads spent more time on administrative duties, administered larger budgets, and supervised more teachers than did respondents in private colleges.

2. Most science division heads in this study were officially designated by their colleges as teachers (69.5 percent) rather than as administrators (30.5 percent). The respondents viewed themselves as primarily faculty (59.3 percent), but believed their deans (59.7 percent) and their faculties (56.8 percent) viewed them as having a status somewhere between administration and faculty.

3. Data indicated that while junior college science division heads often shared decision-making power in a variety of administrative-decisions, they alone seldom held the final power to decide in such matters as faculty hiring, retention, salaries, promotions, and the size of the divisional budget.

4. The two procedures most used by respondents in evaluating divisional instruction were encouraging faculty to make self-evaluations and classroom visitations by the chairman.

5. Respondents (60.0 percent) had too little time for effective performance of their assigned tasks, had teaching loads that were too heavy (67.0 percent) when compared to the amount of administrative work demanded of them, and were critically short of time for reading and research intheir teaching fields (50.0 percent).

6. The three responsibilities most often mentioned by respondents as making the greatest demands on their administrative skill were: the handling of human relations problems, class scheduling and assignment of teachers, and budget preparation and administration.

7. The obstacles most often mentioned by the respondents as the greatest impediments to effective role fulfillment were: their inability to gain and maintain the trust and confidence of their teaching staffs, lack of time, and trying to fulfill the dual roles of administrator and teacher.

AN INTRODUCTION TO THERMODYNAMICS

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Prepared for Publication in *Chemistry in the Two-Year College*

Thermodynamics as a word for students is a disaster; too many letters, too many syllables, too many Greek stems. As a subject, the disaster commonly deepens: too many equations, too pure an approach, too much rigor (often, intellectual rigor mortis). Paeons of praise to the power of the subject are usually followed by pallid problems more puzzling than penetrating. And so the student reacts "phooey." Perhaps we confuse rigor with clarity, purity with reality, logic with psychological effectiveness.

A partial insight into the "logic" of present thermodynamics comes from the chronology of "discovery" of its four laws. The second was discovered first, the first second, the third third (hooray), and the zeroth (how's that for logic) was stated last (and still is not listed in many treatments).

As with most ideas, thermodynamics grew as a means of coordinating human observations, simplifying their interpretation, and predicting future behavior. We teachers could well use this triumvirate of traits as a goal for students.

Since all who read this will have been exposed to some thermo, let me briefly outline a suggested treatment, then amplify.

Life is a system displaced from equilibrium, and energy must be used to maintain it. The more complex the life the more energy is required. First accidentally, then casually, then increasingly systematically, humans have explored energy uses and sources. They learned to maintain a fire for heat, to use the wind, and waterfalls to do work, to make fireworks and gunpowder, to use fire to do work, to control a large number of energy sources to do work or provide heat. By the nineteenth century it became clear that some quantitative relationships existed between heat, work, and the energy required to generate them.

Quantitative measurement requires that some things be unchanging. Measurement of length (e.g. a metre) requires a defined unit (e.g. a metallic bar or a fixed wavelength of light). But if everything were fixed and unchanging there could be no measurement. Indeed, one of the main uses of measurement is to study change. The study of change, in turn, is greatly simplified if some quantities are conserved, i.e. they are unchanged in amount regardless of the change. Most measurements combine these three elements: units, change, conservation. Were everything conserved there could be no change; were everything changing there could be no measurement.

The present framework of thermodynamics describes change in terms of an intensive quantity (temperature) which becomes the same in all systems which are in contact (zeroth law), an extensive quantity (energy) which is conserved (first law) under defined conditions (isolated system), and an extensive quantity (entropy) which always increases in any total change (second law) and which is zero when the temperature is zero (third law). Within this framework there are two main approaches: one based on observation and interpretation in terms of bulk properties (classical thermodynamics), and one based on molecular properties (statistical thermodynamics). The two approaches are now completely consistent and may be used interchangeably depending on available data. Both concentrate on the relationships between energy, heat, work, and temperature and interpret changes in the framework of the four laws.

There has been considerable argument as to whether thermodynamic ideas can be applied to interpreting living systems. The accumulated experimental evidence is now so great, however, that few informed persons question the application. Experimental evidence on living systems varying in size from single cells to a tropical rain forest are as consistent with the four laws of thermodynamics as are measurements on non-living systems. Since students tend to be more interested in living than non-living systems, it seems reasonable to try to teach thermodynamics from this more interesting point of view. Learned in this way, thermodynamic knowledge may well prove more interesting, more valuable, and more readily retained and used.

Growth and Conservation

Single cells are often cited as simple forms of living systems. Observation, of bacteria for example, shows that new cells form by division of existing cells (not by spontaneous generation as originally suggested). We may write:

$$1\ \text{cell} \rightarrow 2\ \text{cells}. \tag{1}$$

The new cells quickly become indistinguishable from the original cell and one might be tempted to modify the idea of spontaneous generation to say that cells reproduce indefinitely by generating new cells and remaining unchanged themselves. It was quickly discovered, however, that cells divide only within a narrow range of conditions of temperature and chemical surroundings (food, or nutrients). Furthermore, the process of cell division is found not only to require food but to produce chemical wastes. The production of chemical wastes is also accompanied by the production of heat. Thus a more complete description of cell division would be:

$$\text{cell} + \text{food} \rightarrow \text{cell} + \text{cell} + \text{waste} + \text{heat} \tag{2}$$

If each new cell is identical to the parent cell we may write

Net Growth Equation: $$\text{food} = \text{cell} + \text{waste} + \text{heat}. \tag{3}$$

If the living system is merely maintaining itself, with no net growth, we can write as a

Net Maintenance Equation: $$\text{food} = \text{waste} + \text{heat} \tag{4}$$

A common food is carbohydrate and for its use we can write

Net Carbohydrate Food Equation: $$(C_6H_{10}O_5)_{n(s)} + 6nO_{2\,(g)} = 6nCO_{2\,(g)} + 5nH_2O_{(g)} + \text{heat}. \tag{5}$$

If we make measurements for cellulose, a well defined carbohydrate, and let n = 1 for a mole, we get

Net Cellulose Food Equation: $$C_6H_{10}O_{5\,(s)} + 6O_{2\,(g)} = 6CO_{2\,(g)} + 5H_2O_{(g)} + \text{cal}. \tag{6}$$

Accurate measurements show that net equation (3) is completely consistent with the conservation laws of thermodynamics. To be specific, atoms, mass, and energy are all conserved.

We see that, in chemical terms, the original cell has acted as a catalyst for the net reaction (3). The original cell provides a path for the reaction, but is then regenerated ready to repeat the process if the conditions remain favorable. "Favorable" here, as in all chemical reactions, means that *every* nutrient must be present, that the temperature must not vary beyond a well-specified range, and that the wastes must escape. For example, the heat produced must escape or the temperature will rise and eventually exceed the range in which the original cell can perform its catalytic function. If heat and wastes do not escape, or all nutrients are not supplied, cell division will diminish in frequency and finally cease. The cells may become dormant, or they may die. Dormancy of as much as 5,000 years has been found in plant seeds. Death, meaning loss of catalytic activity, is a more common result, especially in multicelled organisms where different types of cells exist and are interdependent.

The evidence, then, is overwhelming that living systems are accurately described by the conservation laws, but it is equally important to remember that each living system has very specific requirements for nutrients and for waste disposal. Why is this? Consider the nutrients, or food. One requirement is that all the necessary atoms be present in the food. Since carbon, hydrogen, oxygen and nitrogen constitute the great bulk of living systems, and all of them are present in the atmosphere, the earth, and the waters upon the earth, this requirement is relatively easy to meet. (But do note that the total population of all living systems in a particular environment may indeed be determined by a limiting amount of *one* of these atoms, or some less common but still vital one. Thus, available nitrogen may limit ocean populations and available phosphorus limit fresh water populations.) A more stringent food requirement is that the nutrient atoms must be present in molecules such that their net conversion to new cell material generates heat. Thus no living system exists on H_2O, CO_2 and N_2 alone since there are no reactions among them which can produce molecules suitable for synthesizing living systems with the simultaneous evolution of heat. Photosynthetic reactions make such reactions possible by utilizing photons which effectively excite H_2O, CO_2, and/or N_2 to high energy states which can then react to produce suitable molecules and, at the same time, liberate heat. For example, in the photosynthesis of carbohydrates about one third of the photon energy appears as heat. The balance is stored as chemical bond energy (potential energy) in the synthesized carbohydrates as shown for the formation of one mole of $C_6H_{10}O_5$ in the

Net Photosynthetic Equation:

$$\text{cal (photons)} = 6CO_{2(g)} + 5H_2O_{(g)} = C_6H_{10}O_{5(s)} + 6O_{2(g)} + \text{cal (heat)} \qquad (7)$$

A still more stringent requirement is that the food contain molecules with which the catalytic mechanisms in the cell can react. For example, human beings cannot use cellulose as a food (as in equation (6)), but can use glycogen. Both are glucose polymers, but the structural formulas differ. Humans do synthesize enzymes, maltases, which decompose glycogen into glucose. They cannot synthesize any enzymes to do the same for cellulose. Cows and termites, on the other hand, contain in their gut bacteria which can and do syntehsize an enzyme capable of converting cellulose to glucose. Thus cows and termites ingest cellulose, the bacteria convert it to glucose, and the cows and termites further digest the glucose, from that point on using the same enzymes that humans use. You may wish to be thankful to cellulose decomposing bacteria the next time you enjoy a steak or hamburger, or (as in some countries) a termite patty.

Food must thus meet three criteria: 1) it must contain the atoms required to synthesize the living system; 2) it must react within the system to produce heat; 3) it must react with the catalysts in the living system. All these criteria are consistent with the thermodynamic laws of

Conservation of Mass and Energy: In any total process the mass and the energy remain constant in amount. Corollary: In chemical reactions the number of each kind of atoms remains constant.

Example. Add equation (6) to (7), nothing that each is the reverse of the other as far as atomic transformations are concerned.

Net Cellulose Food Equation: $C_6H_{10}O_{5(s)} + 6O_{2(g)} = 6CO_{2(g)} + \text{cal (heat)}$

Net Photosynthetic Equation: $\text{cal (photon)} + 6CO_{2(g)} + 5H_2O_{(g)} = C_6H_{10}O_5 + 6O_{2(g)} + \text{cal (heat)}$

Sum: cal (photons) = cal (heat, energy, mass, and atoms are conserved (8)

Reversibility and Living Systems

The photosynthetic synthesis of cellulose and its degradation as food to CO_2 and H_2O are the exact reverse of one another as far as the atoms and molecules involved. These may be written more simply on a single line using a double arrow to indicate the reaction may be carried out in either direction with identical conservation of energy, mass, and atoms.

Net Reversible Equation: $C_6H_{10}O_{5(s)} + 6O_{2(g)} \rightarrow 6CO_{2(g)} + 5H_2O_{(g)} + \text{cal}$ (9)

Now note that equation (9) is not the result of a purely theoretical or intellectual discussion but is a succinct summary of thousands of independent experimental observations on cellulose systems. Regardless of whether one studies the synthesis or degradation, he observes that atoms, mass, and energy are conserved. Equation (9) is merely a highly condensed way of presenting the experimental observations. The quantities of atoms, molecules, mass, and energy produced when the reaction occurs in one direction are exactly the same as the quantities used up when the reverse change occurs.

In fact, all reactions have this same property of reversibility and every chemical equation actually represents two chemical reactions: a forward one and a reverse one. Thus, hydrogen burns with oxygen to produce water and energy, but the same amount of water decomposes into hydrogen and oxygen when that same amount of energy is supplied, e.g. in an electrolysis experiment. We may thus again represent both reactions by writing a single

Net Reversible Equation:

$$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(l)} + 116\text{ kcal} \quad \text{or} \quad 116\text{ kcal} + 2H_2O_{(l)} \rightarrow 2H_{2(g)} + O_{2(g)} \quad (10)$$

Which equation one writes depends on the direction of the change he wishes to describe, but the quantities involved remain unchanged. To repeat: all chemical equations describe two reactions, a forward and a reverse; since energy, mass and atoms all are conserved in any total change, the quantities in the equation are the same regardless of the actual direction of change. Every direction of atomic-molecular reaction can be reversed.

A common response to this last statement is, "Nonsense. I'd like to see you reverse the frying of an egg." A good point, but the key word is "you," not "reverse." I cannot, of myself, do it. But I can get it done merely by feeding the fried egg to a chicken. A nice new egg will result which will be essentially identical to the earlier one in atomic, molecular, and energy content. When one thinks he has discovered an irreversible reaction it is a wise precaution to ask where his reactants came from. Most commonly they were synthesized at some past time from products such as he just made. It might help to remember that a chicken is an egg's way of making another egg. Similar cycles abound in other living and non-living systems.

Direct evidence for reversibility is obtainable in many systems. Heating water causes it to vaporize, cooling causes condensation. So we write:

$$10.5\ \text{kcal} + \text{H}_2\text{O}_{(l)} = \text{H}_2\text{O}_{(g)} \qquad (11)$$

Heating an aqueous solution of table salt, NaCl, saturated at room temperature causes salt to dissolve. Cooling causes salt to precipitate. So

$$\text{Cal} + \text{NaCl}_{(s)} \rightarrow \text{Na}^+_{(aq)} + \text{Cl}^-_{(aq)} \qquad (12)$$

And so for every reaction. Any chemical change can be reversed. The relative amounts of atoms, masses, and energies will be unchanged.

Dynamic Equilibria

A well known concomitant of the reversibility of chemical reactions is the existence of chemical equilibria. When a set of molecules is sealed in a container amounts of atoms and mass will be observed. Molecular collisions will occur, new molecules will form, old ones disappear. With a large number of molecules colliding over a long enough period, all possible species will be explored. Some will be more long-lived (stable) than others. The concentrations of the long-lived stable species will be larger than those less stable. But even the long-lived species will occasionally undergo so vigorous a collision that they split apart into shorter-lived species. Eventually a state [illegible] dynamic equilibrium results. [illegible] possible species are present and reacting as can be demonstrated by isotopic tracer experiments. Each "forward" reaction occurs with exactly the same frequency as its own reverse reaction. The relative concentrations remain unchanged. Consider a

Generalized Dynamic Equilibrium: $3A + 2B \rightleftarrows 3C + D$ (13)

It can be described using its

Equilibrium Constant Expression: $K = \dfrac{[C]^3\,[D]_2}{[A]^3\,[B]^2}$ (14)

Equilibrium constant expressions are always written in terms of some function of the concentration of each molecule involved in the equation. Square brackets, [,], refer to concentrations in moles per liter. Each concentration is raised to a power, e.g. $[C]^3$, equal to its coefficient in the chemical equation describing the equilibrium, e.g. 3C. By convention, the concentration terms of species on the right side of the chemical equation (the products) are placed in the numerator, the concentration terms of species on the left side (the reactants) are placed in the denominator. The value of K for any temperature is fixed and the concentrations will eventually reach values which give the numerical value of the equilibrium constant when they are inserted in the equilibrium constant expression. If, at some time, their value is less than that of K, net reaction occurs to the right toward equilibrium. If greater than K, net reaction proceeds to the left toward equilibrium.

Equilibrium constant expressions can be written for any system for which a chemical equation can be written. Values of K can be determined by direct measurement on the equilibrium system or from the thermodynamic properties of the molecules involved, assuming these properties have been measured. We shall return to evaluating K later.

Equilibrium and Living Systems

Most parts of most living systems are displaced from equilibrium, so direct calculations of equilibrium conditions do not describe the systems. However, quantities like the pH of physiological fluids, partial pressures of gases, and solubilities of bone may be so close to equilibrium that equilibrium constant expressions describe the systems and their behavior quite well.

But we have already pointed out that living systems are displaced from equilibrium. In fact, their properties of change such as growth, reproduction, organ function require that they not be at equilibrium. After all, chemical equilibrium, though dynamic, can involve no net change. Yet change is innate in all living systems. In fact, when equilibrium comes to pass in any large measure in a living system death usually ensues. And, vice versa, death is followed by a large scale increase in equilibria in the system.

Living systems have achieved highly effective means of avoiding equilibrium. The simplest one can be readily understood in terms of the equilibrium constant. Concentrations of reactants appear in its denominator and tend to decrease as equilibrium is approached. Living systems, therefore, operate to keep the concentrations of these reactants high compared to their equilibrium values. They do this by constant or periodic feeding (depending on their reserve storage capacity for food) and by storing enough food internally to tied over short external food supplies. The camel's ability to survive for weeks without food or water is well-known. Humans also have reserve stores. For example, glycogen stored in the liver can quickly be converted to blood sugar, glucose, to maintain its concentration well above the equilibrium value and thus insure continued reaction. Similarly, the diving marine animals can store oxygen for their extended underwater excursions, which sometimes last an hour. You might consider how much oxygen a whale must store for a 20 minute dive.

A second effective way of avoiding equilibrium is to keep product concentrations low, as you should see from their appearance in the numerator of K. This is not quite so simple as keeping the initial reactant concentrations high since the product of the first step in a series of reactions becomes the reactant in the next step. Since there may be 10-20 steps in a total reaction sequence (say from glycogen to carbon dioxide) the system must control intermediate concentrations at each step so they neither rise too high (and reverse the proceeding reaction) or fall too low (and prevent the next step). This problem is further complicated in that enzymes (as with all catalysts) catalyze both the forward and reverse reaction for each equation.

One method by which concentrations of intermediates can be controlled in enzymic reactions is called allosteric hindrance. In this mechanism the enzyme not only has a site which catalyzes the conversion of product to reactant, it has a second site where the product molecule can adhere and, in so doing, deform the catalytic site and diminish its catalytic activity. Thus, as product concentration rises more and more product molecules are adsorbed on the deactivating site and conversion of reactant to product diminishes. This cuts down the supply of product molecules until their concentration again drops as they are used up in the next step so reactivating the enzyme for the first step. This control system can maintain the concentrations of intermediates in a rather narrow range and prevent both piling up of concentrations and reversal of reactions.

A second control method is shunting to storage when concentrations rise above optimum values. For example, a rise in blood sugar leads to glycogen formation rather than merely increasing the rate of oxidation of glucose toward carbon dioxide and water. If the concentration of blood sugar rises so rapidly that neither the oxidation or storage mechanism can control the input, glucose shock and possible loss of consciousness occurs. If glucose shock results, from such activities as eating maple syrup too rapidly, the lack of consciousness turns off the supply and gives the other mechanisms a chance to catch up. But shock is neither a pleasant nor safe experience and less dramatic signs of satiation are better heeded.

Other control methods designed to avoid equilibrium states also exist. For example, though all body chemical reactions can be reversed and many are, the reversal of reactions usually occurs at a different site and is catalyzed by different enzymes than the forward reaction. Otherwise reversal could only occur if concentrations changed by going through the equilibrium state. At equilibrium the system is slow to respond because of the small driving forces and control mechanisms tend to be sluggish. The use of adenosine triphosphate (ATP) as an energy source provides good examples. Cleavage of a P–O bond in ATP to form adenosine diphosphate (ADP) plus $HPO_4^=$ commonly couples with and drives other reactions in living systems. At most such sites the ADP is quickly cleaved again to adenosine monophosphate (AMP) and removed to prevent reversal to ATP. The AMP is then reconverted to ADP and ATP by a different set of reactions at a different site. Thus the ATP–ADP–AMP equilibrium state is avoided.

If you have kept close track you will have learned that three of the variables determining the direction of a chemical reaction (all of which are innately reversible) are concentrations of reactants and products, temperature, and the production of heat. We shall now explore more quantitative relationships of these and other variables.

Systems and Conservation

Energy, matter and atoms are conserved in any chemical reaction but it is clear that these need not be conserved in every system. You can pour water in and out of a glass. Light energy leaves the sun. Trees acquire atoms and become more massive. If we treat the glass, the sun, or the tree as the system of interest, energy, mass, and atoms are not conserved in them.

Table 1 outlines a scheme for describing systems which we shall find useful. It classifies systems depending on whether they do or do not conserve energy and/or mass.

System, SYS, refers to a region which is enclosed by real or imaginary boundaries and the fundamental question is whether or not energy and/or mass can cross these boundaries. Everything outside the system is called surroundings, SUR. System plus surroundings is called the universe, UNI.

Table 1

Types of Systems as Related to Conservation of Energy and Mass

System	*Energy*	*Conserved Mass*	*Examples*
Isolated	Yes	Yes	universe, thermos bottle, chemical equilibrium
Closed	No	Yes	sealed glass container, the earth
Open	No	No	unsealed container, factory, living system

Many of the changes you observe are interpreted in terms of loss and gain of matter and energy (if the system is open), or loss or gain of just energy (if the system is closed). This is to say that many of the systems with which we deal are open or closed systems. You have also learned that open and closed systems must be treated in different ways. Compare an electric light bulb and a candle. Both can emit energy but the candle must also be allowed to get rid of its combustion products and have access to air whereas the light bulb filament must not have access to air. The light bulb must be maintained as a closed system, the candle as an open one. Neither could emit light if it were isolated since no isolated system can lose energy.

Open Systems and Steady States

As you might surmise, it is more difficult to obtain simple mathematical generalizations about open systems than about closed or isolated ones. This stems directly from the fact that less is conserved in an open system, so the [illegible] are variables. One type of open system, of great importance to living systems, is not subject to [illegible] difficulty. These are steady state systems. In such a system [illegible] ter and energy enter the system in one form and leave it at the same rate but in some other form. [illegible] factory is a good example. Raw materials and electrical energy enter. Finished products and [illegible] leave. The factory remains essentially unchanged at all times. It is in a steady state.

[illegible] dle aged humans are essentially steady state systems. They take in air, water, food, sunshine and eliminate heat and waste. They remain almost unchanged. For example, weight may vary only a pound or so during the year even though about ten tons of air, food, and water enter the body annually. The rate of entry equals the rate of elimination; the body is at steady state.

Steady states are characterized by a series of sequential reactions, all proceeding at the same rate. Each one produces products which then react in a subsequent step at the same rate so their concentrations do not vary with time. Mass and energy enter and leave the steps in the sequence at constant and equal rates. The system processes and alters the form of the matter and energy but does not use up or produce either one. Figure 1 represents the flows and changes characterizing a steady state system.

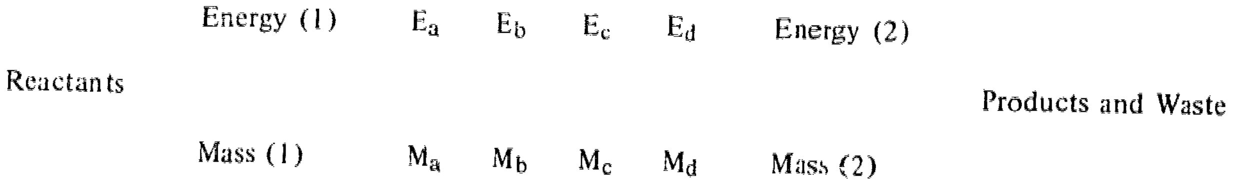

Figure 1. Mass and Energy Flows in a Steady State System. $E_1 = E_a = E_b = E_c = E_d = E_2$ and $M_1 = M_a = M_b = M_c = M_d = M_2$ [illegible] represents energy flow per unit time and M represents mass flow per unit ti[illegible] em is constant in time but has the net effect of converting E_1 to E_2 and M_1 [illegible] series (a through d) of sequential reactions all proceeding at equal rates.

Many living systems exist close to steady states and a most important attribute of every living system s its continuing demand for obtaining food and for eliminating waste, both at the same rate. The same dea applies to nations where the GNP [illegible] closely related (assuming a close to steady state situation) to gross national demands and to gross national waste. All products wear out and eventually become waste.

Recycling

The net effect of a steady state system is to convert reactants to products which (since all products wear out) then become waste. Since no set of surroundings can contain an infinite supply of reactants, the net effect of a steady state system (itself unchanging) is to deplete the reactants it must have and increase the wastes that are useless to it. Steel mills use up iron ore, coke, and limestone and eventually lead to an accumulation of scrap automobiles, tin cans, etc. As iron ore becomes scarcer and more expensive operators of steady state steel mills begin to eye scrap metal (which is getting more and more common and, probably, cheaper) as a source of new steel. The general public encourages this idea as scrap litter increases and becomes more and more offensive. Other steel wastes such as slag and stack gases are also attracting more and more attention.

Communities of humans also require food and generate wastes. As the communities increase in size their waste production increases and food requirements become greater. Small communities can grow their food close by and drop their wastes almost anywhere. Larger communities find it worthwhile to use as much waste as possible as fertilizer, to process sewage to pure water, and even to sort out scrap metals for further processing. After all, the atoms from the reactants are still in the waste, why not reprocess them to reactants and eliminate the waste problem? Why not recycle?

The idea of recycling is especially attractive if we recall that all chemical reactions are reversible and that the amount of energy required to reverse a reaction just equals the amount generated when it occurred. Why not run each process backwards converting waste to reactants? We might model such recycling as that used in living systems in the ATP → ADP → AMP → ADP → ATP recycling discussed earlier. We could run the steel mill from iron ore to steel and set up a counter process to recycle the scrap. Similarly let humans convert food to waste then set up a counter process to convert waste back to food.

If we look at natural systems we find recycling is common. We have already discussed the use of cellulose as food, its conversion to CO_2 and H_2O and subsequent recycling to cellulose. See equations (6) and (7). For another example, rain falls as pure water, becomes contaminated with soil, waste, and dissolved materials as it flows toward the oceans, then is reconverted to pure water by evaporation, cloud formation, and subsequent rain fall. In fact, a multitude of cycles operate in nature. Both energy, mass, and atoms are conserved in these cycles, though different parts of the cycles occur in widely separated places.

Humans have been studying natural recycling for hundreds of years and have been exploring other recycling techniques for almost as long. You may not have thought much about the associated problems, but you actually are familiar with some of them. Why, for example, do we not recycle automobile tires? or shoe soles? or clothing? Why are bottles and newspapers more readily recycled but still difficult? Why are cars difficult to recycle to steel plate, and why are city dumps containing all those cans a poorer source of iron than iron ore?

You might respond to these questions in many ways but your responses would certainly contain the idea that recycling tires is impossible because the tread has been "lost." So also for shoe soles and clothing, part of the material is "gone." But with both bottles and newspapers not so. Their use leaves them essentially intact and the major problem is one of collection. But note, the fundamental problem is the same with tires and bottles. It is that of collecting dispersed matter. The tire system is more open than the bottle system. Matter escapes more widely from tires, so recycling is more difficult with tires. A second problem found with tires and cars, less with newspapers, and still less with bottles, is that of contamination or mixing. Bottles need only remelting to give molten glass for new bottles. Newspapers when shredded give fibers for further paper goods. If the ink is removed or bleached the resulting paper is only slightly grayer than the original. Tires and cars are so heterogeneous in content that separation into useful starting materials is difficult. The problems of collecting dispersed materials and sorting them into useful starting materials is a major problem in recycling and always requires the expenditure of energy so adding to the cost.

The rain water and cellulose cycles also must deal with the dispersal and mixing problems but now the system is so large (the whole earth) that there is no loss of atoms. The earth acts essentially as a closed system. Of course, the atoms from a tire are not really "lost," they just leave the tire. The tire system is small and acts like an open system from which atoms are lost to the surroundings. These atoms may well eventually reappear in another tire by way of either natural or synthetic rubber but the time scale is so long as to be of little merit in considering recycling of tires. Closed systems are easier to recycle (all the atoms are still present) than open systems but both require an outside source of energy.

In natural cycles the energy for collecting and sorting the dispersed and mixed materials comes almost entirely from the sun as we pointed out in the cellulose cycle as well as the rain water one. But how is it that sunlight is necessary? Remember that the amount of energy required to reverse (cycle) a chemical reaction just equals the amount involved when the forward reaction occurs. Why couldn't the earth operate as an isolated system and recycle its matter by recycling its energy? The experimental answer is that cycling of matter in the absence of net energy flow has never been observed in spite of thousands of attempts. Thorough study since the early nineteenth century of this problem of energy flow has led to the formula of thermodynamics, some of the most widely applicable and most simply stated ideas generated by humans.

We have identified two problems in recycling: mass tends to disperse and it tends to intermingle or mix. We shall find that energy also tends to disperse but let's consider mass only for a bit longer.

Efficiency of Recycling Mass (Atoms)

Suppose that the mass in a system is cycled many times and that each cycle reclaims a decimal fraction, f, of the earlier cycle, say $f = 0.8$, due to unrecoverable losses from dispersal and mixing. Then the second cycle will start with 0.8 of the reactants in the first cycle. The third cycle will start with 0.8 of the reactants of the second, or 0.8 x 0.8 of those in the first, and so on. The nth cycle will produce f^n material for the next cycle. Thus, the reclaimed fraction r of original reactant available after n cycles is

$$r = f^n \qquad (15)$$

If each cycle requires a time τ for its completion then the number of cycles in total time t will be $n = t/\tau$, and substituting in equation (15) we get the

Mass Recycling Equation:

$$r = f^{t/\tau} \qquad (16)$$

where f (fraction recycled) and τ (time for one cycle) are variables determining the amount of original reactant, r, available after an elapsed time, t.

If you examine equation (16) you will find that lengthening τ is usually more effective than increasing f if it is desired to keep r as large as possible after time t. Thus recycling cars ($\tau = 7$ years) produces a much larger r after 20 years than recycling bottles ($\tau = 0.3$ years) if f is the same in both cases. Similarly increasing τ for cars by 50% is a more effective change than decreasing the unrecycled cars by the same 50%, say from 0.2 to 0.1. Recycling may be highly desireable but, unless τ is rather large, and f approaches 1, there is no enormous decrease in demand for new materials to keep r large. Nor is the rate of waste generation greatly diminished.

Thus, mass recycling with complete conservation of mass might be possible in principle, but, due to dispersal and mixing there are always losses within each cycle. The amount of energy which would be required to collect and separate all the waste from any open system is so great that mass "losses" become inevitable even though mass is completely conserved in the system plus the surroundings.

The Recycling of Energy

The recycling of water in a space ship is probably as efficient in mass cycling as any process designed by humans. One method involves collecting the waste water and distilling fresh water from it. Another involves electrolyzing the waste water to H_2 and O_2 gases then recombining the H_2O. Since the space ship operates almost as a closed, or even isolated, system, the conservation of water and energy can be quite closely achieved. Thus, by careful conservation or recycling of hydrogen and oxygen atoms the system can produce pure water almost indefinitely. Can it also recycle the energy? This is one of the most thoroughly explored questions in science, both experimentally and theoretically. You yourself have accumulated a great deal of evidence on this point.

You have dropped many objects. They may bounce a few times, then they come to rest. Energy is conserved but you have never observed such an object to raise itself to its original position. The energy does not recycle the system even though still there. A steamship moves by burning fuel most of whose energy pushes water aside and heats the ocean. Energy is conserved but you scoff at the idea of powering that or another ship using the energy from the ocean. Bulk objects in motion generate heat by friction and slow down, but heating them does not restore their motion. Sunlight allows a plant to grow producing fiber and oxygen. You know that light will be emitted if the plant is then burned in this oxygen, but probably will not be surprised to learn that the energy of combustion of the plant (though equal to the net energy absorbed in growing it) cannot substitute for sunlight in recycling the CO_2 and H_2O into another plant. Energy is conserved in all these processes, indeed in all total processes known in the universe, yet it cannot be recycled. Each use of energy in any process renders that energy somewhat less useful in continuing or recycling the process. It is as though energy remained constant in amount but got tired from doing work.

The observation that energy gets less useful with use may be interpreted in a rather straightforward way. Consider first the problem of the dropped object. All its parts, while dropping, moved in the same direction. When it hit they could not do so. They could and did conserve energy by continuing to move but in random directions, oscillating around average positions. This random motion is called heat and can be measured by the temperature rise in the dropped object. Careful measurements show that the heat gain exactly equals the energy of motion of the falling object. Friction, similarly, converts net bulk motion into heat, that is into random motion at the molecular level. Steamships are a special case of friction. Our model seems reasonable in saying that once energy converts into random molecular motion it cannot spontaneously reconvert into ordered bulk motion.

The interaction of plants with light requires a small extension and invokes a particle model of light. These particles are called photons and each photon carries a fixed quantity of energy which can vary from photon to photon. Photons from the sun, we find, have a higher energy content per photon than photons from the burning of plant material. Thus, the process will not recycle because the photons from combustion have more randomly distributed energy than those from the sun. The degradation of solar photons causing photosynthesis into the larger number (less ordered) photons from a flame is quite analogous to the degradation of energy of the ordered motion of a dropping object into the varied amounts distributed as heat among the constituent atoms.

The answer to date is that no one has discovered a method for recycling energy, and all the observed data and theories suggest it cannot be done in any actual system.

Our observations, without exception, are that: (1) all uses of energy tend to produce heat (regardless of the original form of the energy), (2) heat spontaneously flows only from regions of high temperature, T_1, to regions of low temperature, T_2, (3) such heat flow (as in (2)) occurs whenever two regions of different temperatures are in contact, and (4) the conversion of heat, q_1, into work, w, is accurately described by the equation of

Thermal Efficiency:

$$e = \frac{w}{q_1} = \frac{T_1 - T_2}{T_1} \qquad (17)$$

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