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REPORT OF THE CONFERENCE ON INTERDISCIPLINARY ACTIVITIES (SEATTLE, JUNE 28 - JULY 2, 1965).
COMMISSION ON UNDERGRAD. EDUC. IN BIOLOGICAL SCI.
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PROCEEDINGS OF AN INTERDISCIPLINARY CONFERENCE ON UNDERGRADUATE COLLEGE SCIENCE TEACHING ARE REPORTED. SPECIFIC AREAS IN WHICH COOPERATION AMONG VARIOUS SCIENTIFIC DISCIPLINES COULD RESULT IN MORE EFFECTIVE INSTRUCTION AT THE UNDERGRADUATE COLLEGE LEVEL WERE DISCUSSED. PARTICIPATING SCIENTISTS REPRESENTED THE FIELDS OF BIOLOGY, CHEMISTRY, PHYSICS, MATHEMATICS, GEOLOGY, GEOGRAPHY, ENGINEERING, AND AGRICULTURE. THE MEETINGS WERE SPONSORED BY THE COMMISSION ON UNDERGRADUATE EDUCATION IN THE BIOLOGICAL SCIENCES, THE ADVISORY COUNCIL ON COLLEGE CHEMISTRY, AND THE COMMISSION ON COLLEGE PHYSICS. EFFORTS WERE FOCUSED ON SPECIFIC OVERLAP AREAS OF CURRENT INTEREST WHICH INCLUDED (1) THE BIOLOGY-CHEMISTRY INTERFACE--MOLECULAR STRUCTURE, (2) THE CHEMISTRY-PHYSICS INTERFACE--MACROSCOPIC AND STATISTICAL THERMODYNAMICS, (3) QUANTUM MECHANICS, AND (4) INTERDISCIPLINARY EXPERIMENTAL SCIENCE. RECOMMENDATIONS AND PROPOSALS ARE INCLUDED. (DH)

REPORT OF THE
CONFERENCE ON INTERDISCIPLINARY ACTIVITIES

Seattle, Washington

June 28 - July 2, 1965

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During the week of June 28, 1965, a conference was held in Seattle, Washington, to discuss the specific areas in which cooperation among the various scientific disciplines could result in more effective instruction at the undergraduate college level. The two-dozen-odd academic scientists who participated in all or part of the four and one-half days of meetings and working sessions represented the fields of biology, chemistry, physics, mathematics, geology, geography, engineering, and agriculture. Their names and addresses are appended to this report. The meetings were organized and sponsored jointly by three of the college commissions: The Commission on Undergraduate Education in the Biological Sciences (CUEBS), The Advisory Council on College Chemistry (ACCC), and The Commission on College Physics (CCP). Local arrangements were handled by the University of Washington; meetings of the entire group were held in the Edmond Meany Hotel adjacent to the campus, while office and other working space was generously provided by the appropriate departments of the University of Washington.

The genesis of the conference is best explained by quoting from the original memorandum proposing it:

> "As a matter of historical evolution and convenience, the quantitative study of natural phenomena has been divided among the various natural sciences and mathematics; and each of these disciplines now brings to the description and investigation of nature its own methods and insights. On the other hand, areas of overlap of interest and techniques among the various subject matter fields have always existed, and especially in recent years have been increasing rapidly. There has been as well a parallel increase in interest in providing instructional materials which reflect the changing nature of the individual disciplines and, more particularly, the changing and increasingly complex interrelations among them.
>
> "The problems of how best to treat the interdisciplinary aspects of various areas of subject matter have been considered for some time now by the various Commissions concerned with curriculum improvement at the college level. At the NSF Coordination Committee meeting of October 23-24, 1964, the decision was made by the representa-

tives of the Commissions there assembled to try an attack on the problem by focusing on specific overlap areas of current interest. It was agreed to hold a conference of four or five days at the University of Washington in Seattle in late June 1965. To the conference each of the interested Commissions will undertake to invite five or six persons whose reputations in their fields and whose interest in the problems will insure the quality of the results."

As stated in the same memorandum, the purpose of the conference was

"to identify specific problems in areas which are now (or are likely soon to become) of interest in instruction at the undergraduate level in two or more disciplines.....In addition, the conferees will identify persons in their own fields, possibly including themselves, who would be willing to join smaller ad hoc groups which would consider the suggested problems in detail and would undertake to produce new instructional materials (e.g., small monographs, films, etc.) which would make use of the insight and understanding which each discipline can bring to the problem. Such new materials have the possibility not only of providing more comprehensive and comprehendible treatments than now exist, but of providing models for the further extension of interdisciplinary effort and cooperation. It is to be hoped that in time it may be possible to construct courses in which the phenomena of nature are again examined on a broad scale and in which the interrelations and interdependencies of all the various disciplines will become clearly apparent."

To accomplish these purposes, most of the activity of the conference was conducted in small working sessions. Following a general discussion of long- and short-range problems and perspectives, the new materials being developed for instruction within each of the disciplines, and the goals of the conference, the participants were organized into four working groups. These working groups were charged with the investigation of interdisciplinary problems and opportunities in the following areas:

(1) The biology-chemistry interface; molecular structure.
(2) The chemistry-physics interface; macroscopic and statistical thermodynamics.
(3) Quantum mechanics.
(4) Interdisciplinary experimental science.

Each of these working groups met separately, starting on the afternoon of Monday, June 28, and continuing through the afternoon of Thursday, July 1, with the exception of a general meeting on Wednesday morning, June 30, for preliminary progress reports from each of the groups. The conference concluded with final reports from the groups on the morning of Friday, July 2.

The true record of what the Seattle Conference on Interdisciplinary Activities accomplished is contained in the final reports of these working groups. Although the reports were presented orally to all of the participants at the conference, they represent the work and consensus only of the group which prepared them. The four reports follow, each preceded by the names of the persons participating in the group. It is to be hoped that they will serve as a stimulus for further discussion and, most importantly, for the active development of interdisciplinary courses and materials. These future activitites should involve not only many of those who took part in this conference, but also other scientist-educators who are concerned with cooperation and coordination among the various scientific disciplines.

Report of the Working Group on the Biology-Chemistry Interface: Molecular Structure

Charles C. Price, Chairman (Department of Chemistry, University of Pennsylvania)
Konrad E. Bloch (Department of Chemistry, Harvard University)
Judith Bregman (Department of Physics, Polytechnic Institute of Brooklyn)
Robert H. Burris (Department of Biochemistry, University of Wisconsin)
Aubrey W. Naylor (Department of Botany, Duke University)
Marcus Rhodes (Department of Botany, Indiana University)

This working group at the interface of biology and chemistry concerned itself primarily with interdisciplinary matters related to molecular structure in the broad sense. Throughout its deliberations, the group sought avenues and mechanisms of communication, as well as specific projects that would provide substantial aid in teaching in the borderline areas. The conclusion was reached that a series of monographs that could be used to supplement the first and second year biology, chemistry and physics courses would have exceptional value.

In the teaching of freshman chemistry, a strong trend has existed for some time toward a physical chemical approach to the subject. A need is recognized for examples from biological materials that can be used effectively to illustrate chemical and physical concepts. It was noted that a topical series of Momentum Books under the editorship of Professor Walter C. Michels is being published by D. van Nostrand for the Commission on College Physics. This series is proving to be popular among both students and faculty. These paper backs are intended to provide supplementary reading on a wide variety of topics mentioned but not usually treated in depth in undergraduate physics courses. At a more elementary level the Biological Sciences Curriculum Studies group is publishing a successful topical pamphlet series. It was concluded that the time is especially opportune to produce monographs of an interdisciplinary nature that will broaden the bridges already established between the sciences.

Specifically, it was thought that monographs should be designed to provide enrichment material on topics that are currently treated only briefly in formal courses. The books or booklets would be used alike by inquiring students and instructors as supplementary reading or as special assignments. The information should be supplied in an interesting form and in depth to stimulate and challenge those going into the sciences, engineering, and education.

Discussion led to the rough delineation of nine monographs. Among the several topics considered, those that seemed to be most pertinent for the series at this time are:

(1) Interactions of radiation and matter,
(2) Geometry of molecules,
(3) Macromolecules,
(4) Catalysis,
(5) Electron transfer phenomena,
(6) Chemical evolution,
(7) Surfaces, films, and membranes,
(8) Information storage and retrieval in molecular systems, and
(9) Organic reaction mechanisms.

While rough outlines have been formulated, the ideas exp[illegible] to be considered as tentative and merely as suggestive guidelines; i.e., they are non-restrictive. It is recognized that a thorough search for pertinent available publications should be made before specific writing projects are launched. In general, however, it is thought that even if there are treatments of some of the topics in print, the viewpoint is not likely to be the same as is desired, and that there is ample room for some duplication.

To implement the production of a series of monographs, the group recommends that during the fall of 1965 a group of writers be recruited to produce monographs during the summer of 1966. Each monograph group should meet at least once during the winter to formulate general guidelines. During the summer of 1966, the writers should be paid to produce monographs as group efforts. The monographs in mimeographed or photo-offset form should be tried in selected institutions during the 1966-67 academic year, and in view of this experience should be revised in the summer of 1967 for letterpress printing in paperback form. It is hoped that at least three monographs will be launched in the first summer and others in subsequent summers. In this way, full advantage can be taken of experience as it accumulates. The present list of titles is not considered exhaustive or all-inclusive, and it is expected that the list will grow. Responsibility for this monograph series should be accepted by CUEBS and ACCC, and aid from physicists should be sought for specific monographs.

The topics that have been selected for development fall into three categories. The majority are on material that is currently covered inadequately in the introductory chemistry course, and are of special interest at the chemistry-biology interface. The subject matter is thought to be challenging, current, and of lasting interest. A second category is concerned with material that terminal biology students may not get and yet will need. The topic <u>Organic</u>

Reaction Mechanisms falls within this classification. Material in this monograph would also be expected to be useful to those who had their organic chemistry eight and more years ago. In the third category we have selected some subjects that are perhaps not ripe for immediate writing but are almost ready. Such a topic is Information Storage and Retrieval in Molecular Systems. Perhaps it will be necessary to delay judgment on this subject. The remainder of this report consists of a discussion of the topics which we felt should be covered in each monograph, existing publications relevant to these topics, and a list of persons who would be eminently capable and (perhaps) sufficiently interested to author such monographs.

Interactions of Radiation and Matter. This subject might well be initiated with consideration of a simple system such as the photo reactions of chlorine. This, in turn, could lead through considerations of intermediate complexity to the reactions of light with the chlorophyll molecule. As chlorophyll is a relatively complex molecule for consideration in freshmen chemistry, and because detailed information on the chemical changes accompanying the reaction of chlorophyll with light remain obscure, this subject cannot have detailed coverage. Consideration should be given to reactions of light with aggregates and with conjugated systems. Photochemical oxidations and reductions are of interest both to the chemist and to the biologist and should be developed thoroughly. Photoisomerization reactions should be considered. Fluorescent and phosphorescent reactions offer intriguing possibilities for discussion both at the chemical and biochemical level. Another subject of great interest is bioluminescence, and the chemistry of this process is sufficiently defined to warrant thorough coverage.

The monograph by I. Simon, entitled Infrared Radiation (D. Van Nostrand), may be pertinent.

The group suggested the following individuals as possible authors in the area of interactions of radiation and matter.

M. Kamen, University of California at San Diego
J. Platt, University of Michigan
B. Kok, RIAS, Baltimore
M. Kasha, Florida State University
H. Zimmerman, University of Wisconsin
R. Clayton, Kettering Labs, Yellow Springs, Ohio
R. Hochstrasser, University of Pennsylvania

Geometry of Molecules. It was pointed out that Holden's monograph from the Physics Group covered a section of the material needed under this topic. Judith Bregman and Alan Holden also are writing a monograph in the physics series which will cover a substantial segment of the geometry of molecules. After considerable discussion, the group suggested the following tentative sequence for the presentation of material in this area of interest.

The geometry of bonds: This would include covalent bonds (e.g., the geometry of p^2, sp, p^3, sp^2, sp^3, sp^3d, and sp^3d^2 bonding) as well as ionic bonding in close-packed structures. Consideration also should be given to the geometry of hydrogen bonding; hydrogen bonding should be stressed because of its importance to the biologist. Hydrophobic bonding also is pertinent, particularly in biological membrane structures. A protein molecule could exemplify compounds with a variety of features to illustrate the types of bonding under consideration. The conformation of molecules is of primary importance and must be covered thoroughly as back ground for a proper understanding of catalytic activity in biological systems.

The sequence is not critical in the discussion of the following topics: Coordination compounds, clathrates, cis-transisomers, simple inorganic compounds, asymmetry, and optical activity. This should be followed by a consideration of the geometry of macromolecules, and the discussion should include the lattice structures encountered in inorganic compounds. Isotactic and atactic polymer molecules should be discussed. In relation to proteins, fibers, and rubbers, the helical and random-coil chain conformations should be developed in some detail.

One remarkable example of the influence of the geometry of molecules is in catalysis and the specificity of the catalytic action. Specificity is best illustrated by enzymes as biological catalysts. In addition, however, consideration should be given to isotactic polymer catalysis.

The group is aware of the existence of the following monographs pertinent to the subject of geometry of molecules: Ryschkewitz's monograph on bonding and structure (Reinhold); G. M. Barrow's monograph on the structure of molecules (Benjamin); W. Herz's monograph on the shape of carbon compounds (Benjamin); E. A. Wood, Crystals and Light (D. Van Nostrand).

Suggestions for authors in this area are:

Wm. Lipscomb, Harvard University
A. Rich, MIT
C. Price, University of Pennsylvania
H. Scheraga, Cornell University
E. Eliel, Notre Dame University
D. Koshland, University of California, Berkeley
R. Hill, Duke University
V. Boekelheide, University of Oregon

C. Dyerassi, Stanford University
I. Rappaport, University of California, Berkeley

Macromolecules. Both linear and cross-linked polymers should be considered, as well as their formation into films, fibers, gels, and aggregates. Consideration should be given to order and disorder in macromolecular structure. Both crystalline and amorphous macromolecules should be considered, and the organization of the polymers into linear, helical, random-coil and pleated-sheet conformations. Macromolecules with high cohesive force density and low cohesive force density should be discussed.

The general properties of macromolecules should be considered in terms of viscosity, light scattering and other optical properties, absorption, elasticity, hardness, melting point, and strength.

A number of the naturally occurring macromolecules are of great interest to the chemist as well as to the biologist. Among these, consideration should be given to carbohydrate polymers, proteins, nucleic acids, and rubber. Among the synthetic polymers, discussion could be organized in terms of vinyl, polyester, polyether, and polyamide compounds. Among the inorganic materials, the polysilicates, the silicones, and boron nitride should be examind.

Suggested authors for the subject of macromolecules include:

E. Blout, Polaroid Corporation
C. Overberger, Polymer Institute, Polytechnic Institute of Brooklyn
H. Mark, Polytechnic Institute of Brooklyn
P. Flory, Mellon Institute
C. Tanford, Duke University
C. A. Thomas, Johns Hopkins University
J. Ferry, University of Wisconsin
C. Marvel, University of Arizona
T. Cairns, duPont Company
H. Spurlin, Hercules Powder Company
W.F.H.M. Mommaerts, University of California, Los Angeles
R. Kunin, Rohm and Haas Company
M. Stahmann, University of Wisconsin

Catalysis. Freshmen chemistry courses in general cover simple examples of acid and base catalysis and heterogeneous catalysis in some detail. Variations in catalytic activity can be illustrated in a meaningful way by mutarotation in the presence of the following agents: pyridine, phenol, and 2-hydroxypyridine. Another interesting series with increasing catalytic activity can be illustrated with Fe^{++}, chelated iron complexes, iron porphyrins and catalase to serve as enzyme models. Enzyme-substrate interactions should be discussed, and the utilization of the Michaelis-Menten constant should be described. In relation to acid-base catalysis, the importance of the acidity of surfaces, such as presented by the silica-alumina catalysts, should be covered. The importance of kinetic and geometric considerations in catalysis should be emphasized.

Although chain initiators are not catalysts in a strict sense, they should be discussed. Analogy can be drawn to the priming action of oligosaccharides in the formation of starch and other carbohydrate polymers.

Attention should be given to stereoselective catalysis in the polymerization processes. Examples could be cited from the activities of $TiCl_4$-$AlEt_3$ for olefins and Et_2Zn-H_2O for olegin oxides. Another example of stereospecific catalysis can be drawn from the pyridine nucleotides which act to remove specific hydrogens in dehydrogenation reactions with a variety of substrates.

The subject of active sites on enzyme molecules should be developed. Although there is limited information concerning the detailed configuration at active sites, there is considerable information on the amino acid composition at these sites. Frequently coenzymes serve at the active sites on enzyme molecules.

There should be a discussion of inhibitors of enzymatic reactions with a consideration of the types of inhibition observed and the information which can be derived from a study of inhibitors of high specificity. The activators of enzymatic reactions also should be discussed; coenzymes and specific metals may play this role. Many enzymes exhibit a high degree of substrate specificity, and often inhibitors show marked specificity for particular enzymes. Succinic dehydrogenase as blocked by malonate could serve as an example. Isozymes present another type of specificity of great biological interest.

Hydrogenase is a useful example of an enzyme, because of the simplicity of its substrate, H_2. Carbonic anhydrase likewise has the advantage that it catalyzes a relatively simple reaction. Among the enzymes catalyzing more complex reactions, anylase could serve as an effective example. Chymotrypsin can be blocked very specifically by combination with p-nitrophenylacetate. A very interesting discussion could be built around the insoluble trypsin complex prepared by Kathcalski; this presents an enzyme model of great theoretical importance.

The subject of the activity of lysozyme could be considered in some detail, as this is the first enzyme that has had its three-dimensional structure determined in a complex with an inhibitor. The tertiary structure in relation to catalytic activity could be illustrated with this enzymatic system.

The role of free radicals in polymerization processes should be considered in some detail.

The group suggested the following people who might serve as authors on a monograph on Catalysis:

C. Price, University of Pennsylvania
M. Bender, Northwestern University
T. Bruice, University of California, Irvine
D. Koshland, University of California, Berkeley
J. Wang, Yale University
R. Alberty, University of Wisconsin
R. Bock, University of Wisconsin
A. Streitweiser, University of California, Berkeley
P. Talalay, Johns Hopkins University
C. Anfinson, National Institutes of Health
M. Kaplan, Brandeis University
A. Katritzky, University of East Anglia

Electron Transfer Phenomena. There was considerable discussion of combustion, free energy, entropy, oxidation-reduction potentials, equilibria, and bond energies before the group finally decided that the sector of this subject which could logically be covered might be given the above title. One central theme under this subject might well be the unique responses of biological systems in electron transfer in terms of energy storage and utilization under relatively mild conditions of temperature and pressure. Respiration and photosynthesis can serve as examples of energy mobilization from reduced compounds and energy storage by reductive processes, respectively. The stepwise nature of biological electron transfer and the ability of organisms to couple the energy from specific steps to the production of ATP should be stressed.

Redox potentials and equilibria can be introduced and covered in quantitative fashion. The application of these concepts and the analogy between biological systems and fuel cells can be discussed. The fuel cells also illustrate activation at surfaces and a variety of electrode phenomena. Consideration should be given to kinetics as well as the potentials involved.

The group suggested the following possible authors for the subject of Electron Transfer Phenomena:

H. A. Lardy, University of Wisconsin
A. Lehninger, Johns Hopkins University

J. Bockris, University of Pennsylvania
I. Klotz, Northwestern University
H. Beinert, University of Wisconsin
F. Basolo, Northwestern University
B. Kok, RIAS, Baltimore
R. Clayton, Kettering Labs, Yellow Springs, Ohio
Mildred Cohn, University of Pennsylvania

Chemical Evolution. This topic could be introduced by a discussion of the origin of the elements, a subject covered in Chemical and Engineering News quite effectively during the past year. Consideration should be given to stellar chemistry and the derivation of the elements from plasma. After considering the origin of the elements, the subject of primordial chemistry should be discussed. This would involve speculation regarding early chemistry on earth, as well as on other planets, which involved reactions in a reducing atmosphere containing H_2, CH_4, NH_3, and H_2O. From this point, the subject should be developed to indicate how such simple compounds yielded the complex organic materials of biological interest. The group considered that this subject was at a point in its development that would support a very challenging and interesting monograph for the beginning chemistry student. The Van Nostrand book by F. I. Boley on Plasma Physics may be helpful.

The group suggested the following authors for the treatment of chemical evolution.

M. Calvin, University of California, Berkeley
H. Urey, University of California, San Diego
S. Miller, University of California, San Diego
J. Oro, University of Houston
G. Gamow, University of Colorado
I. Adler, U. S. Geological Survey
H. Bethe, Cornell University
P. Morrison, Cornell University
E. Salpeter, Cornell University
E. Winkert, University of Indiana
E. Leete, Stanford University
T. A. Geissman, University of California, Los Angeles

Surfaces, Films and Membranes. As the title indicates, these would be treated in increasing complexity. The nature of adsorption and adhesion would be a starting point for the development of ideas on electrodes and electrical double layers. The development of semipermeable membranes and the nature of their formation as they function in osmotic pressure phenomena should be treated. This would lead into the development of concepts about the structure of biological membranes and their functioning in simple and active transport.

It may be possible to explore important unsolved problems concerned with biological membrane formation, maintenance, and functioning as influenced by factors such as radiation.

Possible authors:

- L. E. St. Pierre, General Electric Research Laboratories
- Katherine B. Blodgett, General Electric Research Laboratories
- D. Tosteson, Duke University
- M. C. Ledbetter, Harvard University
- J. Strominger, University of Wisconsin
- I. Epstein, University of California, Davis
- J. Bockris, University of Pennsylvania

Information Storage and Retrieval in Molecular Systems. Some members of the panel were of the opinion that it may be premature to write a monograph on this subject at present. However, the group wishes to suggest that the topic be held for future development as further experimental material becomes available.

Under this topic the transfer of information by nucleic acids could be discussed. Consideration would be given to the basic sequence in nucleic acids, and the nature of the genetic code would be explained. From this, one could develop the importance of transcription from DNA to RNA, followed by translation from RNA to protein.

The subject of gene regulation could be treated in reasonable detail. Particular attention should be paid to repression and "depression" (activation) of genetic information. Consideration also should be given to control by feedback.

Less well developed than the transcription and translation of genetic information is our knowledge concerning memory processes. This could be presented as an example of one of the challenging fields for further explanation. Current speculation warrants discussion, but relatively little concrete information is available regarding the storage and retrieval of information in the brain.

The sensing of odor and the mode of operation of sex attractants in insects constitute model systems of delicate sensing mechanisms. Sufficient information is emerging that it now may be possible to explain these reactions in terms of chemical structures.

The group suggested the following authors for discussion of information storage and retrieval in molecular systems:

J. D. Watson, Harvard University
S. Spiegelman, University of Illinois
J. Bonner, California Institute of Technology
G. Stent, University of California, Berkeley
H. Busch, Baylor University
A. Mirsky, Rockefeller Institute
C. Anfinson, National Institutes of Health
C. Williams, Harvard University
H. Röller, University of Wisconsin

Organic Reaction Mechanisms. This monograph would be especially designed to present the basic elements of mechanisms of organic reactions of interest in biological systems, with the relationship between the reactions and biological systems specifically delineated. Its purpose might be to bring some molecular basis to students in a terminal introductory biology course, or to bring some modern reaction mechanisms to the attention of biology teachers.

The material might include the following subjects:

1. Addition and elimination reactions by cationic, anionic, free radical and "concerted" processes, with simple examples related to biologically important systems.
2. Substitution at saturated carbon atoms and alkylation mechanisms.
3. Oxidation and reduction, including free-radical autooxidation of hydrocarbons, alcohols to aldehydes and ketones (chemical and catalytic), and aldehydes to acids.
4. The formation of acetals and esters, with intermediates and transition states.
5. Enolization and aldol condensation, including kinetics and equilibrium.
6. Photoisomerization and photodimerization.
7. Some free radical reactions (if not already adequately covered in {1} and {3}).

Possible authors are indicated below:

M. Bender, Northwestern University
F. Westheimer, Harvard University
A. Loewy, Haverford College
J. Benfy, Earlham College
A. C. Giese, Stanford University
L. Anderson, University of Wisconsin
E. R. Thornton, University of Pennsylvania

N. J. Leonard, University of Illinois
D. Y. Curtin, University of Illinois
Wm. Shive, University of Texas
E. C. Taylor, Princeton University
M. Reinicke, Texas Christian University
A. Hassner, University of Colorado
A group from Johns Hopkins University

Report of the Working Group on the Physics Chemistry Interface:

Macroscopic and Statistical Thermodynamics

Leonard K. Nash, Chairman (Department of Chemistry, Harvard University)
Hans Bremermann (Department of Mathematics, University of California, Berkeley)
Newman A. Hall (Executive Director, Commission on Engineering Education)
Frederick Reif (Department of Physics, University of California, Berkeley)
Fred M. Snell (Department of Biophysics, School of Medicine, State University of New York, Buffalo)

The working group on thermodynamics concerned itself mainly with ways in which interdisciplinary activities could be effective in the currently-evolving context of undergraduate courses in chemistry and physics. At the junior-senior level, for instance, it seems both reasonable and probable that the present pattern will continue. That is, there will be a number of special courses proceeding independently in applying the basic principles of thermodynamics to the important problems in various fields of chemistry and physics. There was complete agreement that a substantial amount of thermodynamics can and should be taught in introductory chemistry and physics courses taken by students in their first two college years.

For the freshman chemistry course there already exists some half-dozen treatments of classical thermodynamics, and this subject appears likely to become a standard part of that course. The situation in physics has not been as promising. The first reasonably comprehensive account of classical and statistical thermodynamics intended for use in the introductory physics course is just now being constructed at Berkeley. There is need for much more exploratory work on the development of thermodynamics in this way. A sound appraisal of possibilities can be achieved only if a variety of approaches are worked out and tested. It was felt that the normal stimuli of commercial publishing would suffice to generate these alternative approaches.

The group was strongly of the opinion that two features would have to be common to all of the successful approaches. First, the association of macroscopic and statistical thermodynamics should be stressed from the very outset. Secondly, the major emphasis should fall on the effective presentation of fundamental principles. The committee was unanimous in concluding that the possibilities for interdisciplinary usefulness would not be promoted by the haphazard introduction of a great deal of material illustrating the applications of thermodynamics to other disciplines. It is not diversity of application that will yield a solid foundation upon which other disciplines can be built, but rather a primary concern with the fundamental principles that underlie all kinds of applications. However, without appreciably diluting the presentation of principles, one could greatly increase the interest and effectiveness of introductory thermodynamics by the use of problems, demonstrations, and laboratory experiments illustrating the diversified applications of this subject to other disciplines. By cutting across disciplinary boundaries, these would stress the enormous practical utility of what may seem to be very abstract principles, and should promote an understanding of how those principles can be brought to bear in actual experiments. If they are to be effective, the problems, which might be rather long and elaborate, must deal with real situations occurring in interesting contexts. New demonstration experiments could conceivably be made from traditional laboratory experiments that, as such, are far from satisfactory. What is a rather routine laboratory experiment might, if suitably worked up, become a rewarding demonstration, and its interest and significance actually could be much enhanced if the application were drawn from a discipline other than that of the course in which it appears.

Although the creation of problems, laboratory experiments, and especially demonstration lectures is a highly individual matter, the commissions involved could perform a useful service by assembling a compendium of descriptions of appropriate problems, demonstrations, and laboratory material. The final product of such an effort could take a form similar to the publication "Novel Experiments in Physics," produced by a committee of the American Association of Physics Teachers. Another method of compiling such material would be by examination of existing textbooks and laboratory manuals.

The sort of interdisciplinary activity suggested for introductory courses does not seem to us to be appropriate for junior- and senior-level courses. However, one potentially worthwhile activity at this level might be pointed toward the development of a series of monographs devoted to such topics of interdisciplinary and/or general interest as the association of entropy and information, rate processes and irreversible thermodynamics, measurement of temperature, or techniques of solution thermodynamics.

In the opinion of this group, one of the most important areas for interdisciplinary cooperation is the coordination across departmental lines of instruction on both the introductory and advanced levels. Instructors in junior-senior courses should make every effort to keep themselves informed about the presentation of thermodynamics in the freshman-sophomore courses so that they may build as much as possible on this antecedent work rather than starting all over again. An optimal coordination in this respect could be promoted by the creation and dissemination of information of three distinct, but related, kinds.

(a) A syllabus, directed toward upperclass instructors, showing exactly what is being taught about thermodynamics during the first two years, together with an estimate of the solidity of such presentations. Such a syllabus should permit an accurate appraisal of what need not be taught in junior-senior courses.

(b) A syllabus directed toward underclass instructors, indicating which principles of macroscopic and statistical thermodynamics, and which kinds of treatments of them, are most essential for later work in the several disciplines.

(c) A statement, directed again toward underclass instructors, spelling out the reasons for teaching thermodynamics in the different disciplines. (E. g., is thermodynamics an essential tool of research or merely an instrument for unifying the presentation of other topics?)

Three methods of assembling the above information were thought of by the group.

(a) On a national basis, the commissions involved (CCP and ACCC) are in a position to collect appropriate information from a number of physics and chemistry departments and to compile and disseminate the type of syllabi and statements mentioned above.

(b) A more detailed and immediately useful exchange of information could take place between the appropriate departments within each institution. However, some form of public statement or encouragement from the commissions would greatly facilitate such local interdisciplinary cooperation.

(c) Merely by assembling and examining a group of representative texts used in teaching thermodynamics in different fields, it should be possible to identify the essential thermodynamics principles and the goals of teaching thermodynamics in the different disciplines (items {b} and {c} above). Members of the working group expressed some interest themselves in carrying through such an operation. A careful examination of such a group of texts should permit isolation of the modes of presentation, applications, etc., which are characteristic of the various disciplines.

It was felt that the above suggestions represent the most fruitful approach to interdisciplinary cooperation in thermodynamics at the present time. Later, it may prove desirable to undertake further activities along lines indicated by the results of carrying out these suggestions.

Report of the Working Group on Quantum Mechanics

Ferd E. Williams, Chairman (Department of Physics, University of Delaware)

Daniel G. Aldrich (Chancellor, University of California, Irvine; representing Agricultural Science)

A. Gib DeBusk (Department of Biological Sciences, Florida State University)

Arthur Martin (Department of Zoology, University of Washington)

George C. Pimentel (Department of Chemistry, University of California, Berkeley)

G. Milton Wing (Department of Mathematics, University of Colorado)

The members of the group agreed upon the importance of quantum mechanics in the general education of the scientist and engineer, and the desirability of introducing some quantum mechanical ideas at the freshman level. This material would be descriptive and somewhat intuitive. It is felt that an introduction to the concepts of quantum mechanics is essential for the modern approach to general chemistry based on the chemical bond.

The group concluded further that there is a significant common core of quantum mechanics which is needed for junior- and senior-level work in the sciences and engineering. The importance of this common core is clearly evident for the disciplines of biology, chemistry and physics, and is also believed evident for geology. Therefore, the common core of quantum mechanics should be made available during the latter part of the sophomore year. It appropriately would be as rigorous as the available time and prerequisites allow. One year of calculus and one year of classical physics are prerequisites, and work in differential equations is corequisite. The representatives of all the disciplines stressed the emphasis of fundamentals, with some applications for illustrative purposes.

It was agreed that the interdisciplinary core of quantum mechanics presented at the sophomore level should include the following items.

(1) Development of the need for quantum mechanics by consideration of experimental observations not explainable by classical mechanics.

(2) Consideration of measurements, observables, and uncertainty.

(3) Definition of the state function to describe a quantum mechanical system, and postulation of a linear operator for each dynamical variable.

(4) Development of both the time-dependent and time-independent Schrödinger equations.

(5) Detailed consideration of the hydrogen atom, as illustrative of a soluble one-electron problem.

(6) Consideration of approximate methods, including perturbation theory applied to the interaction of radiation with matter, and the one-electron approximation (using product functions) applied to the many-electron atom and to the hydrogen molecule.

(7) If time permits, consideration of a system by both operator and matrix methods; for example, the harmonic oscillator.

Some recently-developed materials for instruction in quantum mechanics at the sophomore level were available at the conference and were considered. Although in some ways they were more ambitious in coverage and level of sophistication than our suggestions, we found them relatively inadequate as far as interdisciplinary aspects are concerned.

It was recognized that there are challenges in the satisfactory presentation of the proposed interdisciplinary core of quantum mechanics at the sophomore level in the time which could be made available. We feel, however, that this is not an insurmountable problem. We recommend that further, more detailed studies be made to develop scientifically correct and pedagogically suitable presentations for specific sections of the proposed material. In Appendix A are listed topics for further study, with suggested contributors. In order to clarify our proposed approach, we have included Appendix B, which outlines an example of possible material for the interdisciplinary core of quantum mechanics at the sophomore level. This is obviously not the only way the material can be approached at this level.

Beyond the quantum mechanics described above for the sophomore level, the group felt that the topics, as well as the level of sophistication of analysis, diverge for biology, chemistry, and physics. The interests of biologists would more nearly go along with the chemists who are concerned with valence theory, liquid field theory, and molecular orbital calculations, for example. On the other hand, the interests of physicists in the fields of solid state and high energy physics include relativistic quantum mechanics, scattering theory, and second quantization.

We are pleased to acknowledge the contributions and helpful observations of Leonard Eisenbud, Alan Holden, E. Leonard Jossem, Norman Pearlman, Melba Phillips, and Fred Reif during our deliberations.

APPENDIX A

Topics for Further Study	Recommended Contributors
1. Theory of measurement on quantum mechanical systems.	F. Reif, E. Wigner
2. Methodology of development of postulates of quantum mechanics.	L. Eisenbud, R. Karplus
3. Pedagogical development of the Schrödinger equation.	E. Kerner, P. Morrison
4. Interaction of radiation with matter.	H. Bethe, J. Platt
5. Hydrogen molecule and the covalent bond.	C.A. Coulsen, J. Linnett

APPENDIX B

Outline of Possible Quantum Mechanics Course at Sophomore Level
(Approximately one quarter {12 weeks}, possibly a full semester.)

I. Introduction.
   A. Black body radiation, photoelectric effect, Compton scattering.
   B. Electron diffraction, Stern-Gerlach experiment, atomic spectra.

II. Postulates and Principles of Quantum Mechanics.
   A. Measurements and observations; uncertainty principle.
   B. Separation of state function; linear operators for dynamical variables.
   C. Superposition principle; interference and polarization.

III. Wave Equations.
   A. Time-dependent Schrödinger equation.
   B. Time-independent Schrödinger equation.
   C. Application to hydrogen atom.

IV. Approximate Methods.
   A. Perturbation theory.
   B. Application of time-dependent theory to interaction of radiation with matter.
   C. Approximate many-particle wave functions in terms of one-particle functions.
   D. Indistinguishability of identical particles and the exclusion principle.
   E. Application to many-electron atom; periodic table.
   F. Application to covalent bond, and to the hydrogen molecule

Report of the Committee on Interdisciplinary Experimental Science

F. B. Humphrey, Chairman (Department of Electrical Engineering, California Institute of Technology)
W. B. Cook (Executive Secretary, Advisory Council on College Chemistry)
W.W. Hambleton (Department of Geology, University of Kansas)
J. W. Harbaugh (Department of Geology, Stanford University)
O. T. Hayward (Department of Geology, Baylor University)
L. K. Nash (Department of Chemistry, Harvard University)
G. Weinreich (Department of Physics, University of Michigan)

I. INTRODUCTION

The primary problem related to interdisciplinary teaching activity is one of transference and transference mechanisms. For instance, the geology student often sees no relevance to his field in the introductory physics and chemistry courses because they restrict themselves to the discussion of situations in which conditions are carefully specified and limited; while the physics or chemistry student can easily lose sight of the real world and its uncertainties and orders of magnitude. Accordingly, these several disciplines can profit by development of materials of an interdisciplinary character that are designed to bridge the discontinuity. The most fruitful areas for preparation of such materials include design of laboratory experiments, and problems and examples for classroom use within the scope of introductory courses.

Considerable overlap in fundamental interest exists among the various disciplines, admittedly hidden by differences in emphasis and nomenclature. It would be more efficient in terms of the student's time and would perhaps increase the interest level of the subject matter if these overlaps could be recognized and utilized. Obviously course material in, say, physics could be modified to include geological examples, etc. Some of the considerations to follow will be applicable to such modifications; but our main concern is with the less obvious role that the laboratory might play in promoting interdisciplinary interest. For the sake of example, the particular interaction between geology, physics, and chemistry will be considered in detail.

A laboratory section of a course attempts by design to accomplish one or more of the following objectives:

1. To originate questions pertinent to future lectures,
2. To act as a private demonstration of lecture material,
3. To establish proficiency in experimental procedures peculiar to a particular discipline,
4. To illustrate the general scientific approach.

An emphasis on the accomplishment of objectives 1 and 2 has required that the experimental section of beginning courses be closely coordinated with a particular lecture series, and hence has restricted the usefulness of the laboratory. If the lectures were to be modified to include demonstrations to such an extent that the insistence on this close coordination could be relaxed, it would be possible to use the lab primarily to illustrate the scientific approach on an interdisciplinary level. The third objective would still require special considerations, but the necessity of a large amount of specific proficiency in beginning students is questionable.

II. PROPOSAL

The ultimate aim of the program here outlined is the generation in introductory science courses of the spirit of independent research. It is believed that the most effective method of development of this attitude is through the experimental or "problem-oriented" approach, in which the student is presented with a comprehensive exposition of a problem, and is permitted considerable time and freedom for its solution. The discipline thus becomes subservient to the problem, and the nature of the problem dictates the disciplinary emphasis of the solution.

Such an experimental science laboratory would necessarily be self-sufficient, offering a broad choice of large problems or challenge-oriented experiments. The experiments themselves could be interdisciplinary in that, for instance, a physical principle could be illustrated in a geological context, perhaps using chemical techniques.

One possible realization of such a laboratory would be the creation of a written collection of interdisciplinary experimental problems, each one outlined in sufficient detail so that its interdisciplinary implications would be clearly understood by one proficient in either discipline. From such a file, each instructor could select those best suited to his purpose, student population, and facilities. This approach is radically different from current practice in most introductory science courses. It is anticipated that a course developed around the experimental approach would require a smaller total number of problems, but that the interdisciplinary transference would be far greater than in conventional laboratory programs in the various disciplines.

The following is a list of six examples of the type of subject which we believe to be susceptible to the approach we are proposing. In each case, the topic is of much more than passing importance in more than one discipline. In each case, an experimental investigation is possible which begins on a completely elementary level and proceeds toward more sophisticated and complicated aspects. (We use the word "experimental" in a wide sense which may include, as part of the project, an appreciable amount of library research.) In each case, the procedure to be followed can vary over a wide range to suit the needs, interests, inclinations, and abilities of individual students and teachers.

1. Crystals
   External geometry of crystals; internal geometry of crystals; imperfections and substitutions; ion exchange; whiskers; crystal growth; semiconductors.

2. Forces
   Gravity measurements; Archimedes' principle and isostasy; centrifugal and Coriolis effects; gyroscopic phenomena.

3. Phases
   Phase equilibria, phase transformations; solid-solid transitions; magnetic transitions; dependence upon temperature, pressure, and applied fields; multicomponent systems; eutectics; interface phenomena.

4. Waves
   Elastic waves; water waves and other interface waves; reflection, refraction, mode conversion; diffraction and other effects of finite wavelength.

5. Solutions
   Chemistry and physics of water; ionic equilibria; complex ions and chelation; non-aqueous liquid solutions; solid solutions.

6. Radioactivity
   Half-life; decay series; energy release; elemental origins and balance; age dating.

III. IMPLEMENTATION

In order to develop the requisite file of problems, the following procedure is recommended for the geology-chemistry-physics interaction being considered here. A similar implementation for other areas would be expected.

It is proposed that the Panel on Interdisciplinary Cooperation, a division of the Council on Education in the Geological Sciences, assume initial responsibility for development of interdisciplinary topics. The panel would be composed of physicists, chemists, and geologists. The first major step would be to investigate available literature that bears on the project. This includes general textbooks of physics, geology, and chemistry, paperback monographs on specific topics, and relatively newly-developed secondary-school science literature. A tabulation of this material arranged topically would be prepared in order to help the panel in planning and steering the project. The panel would then select those topics most amenable to interdisciplinary treatment and recruit prospective authors (see Appendix). Finally, funds would be requested from the National Science Foundation to support the development of such a collection of "problem brochures" which would be published and made generally available.

APPENDIX

(a) Resource Persons from Chemistry

Crystals:

R. C. Brasted, University of Minnesota
F. A. Cotton, Massachusetts Institute of Technologv
J. A. Campbell, Harvey Mudd College
D. H. Templeton, University of California at Berkeley
J. V. Quagliano, Florida State University

Phases:

L. K. Nash, Harvard University
K. J. Mvsels, University of Southern California
Per-Olbv Löwdin, University of Florida
H. T. Hall, Brigham Young University
S. A. Rice, University of Chicago
D. E. Carritt, Massachusetts Institute of Technology
Leo Brewer, University of California at Berkeley
J. L. Margrave, Rice University

Solutions:

Eric Hutchinson, Stanford University
Henry Taube, Stanford University
H. H. Sisler, University of Florida
Henry Eyring, University of Utah
W. J. Argersinger, University of Kansas
K. N. Trueblood, University of California at Los Angeles
J. A. Ibers, Northwestern University

(b) Resource Persons from Geology

P. Bickford, University of Kansas
R. M. Garrels, Northwestern University
P. M. Hurley, Massachusetts Institute of Technology
K. B. Krauskopf, Stanford University
D. B. McIntyre, Pomona College
S. N. Davis, Stanford University
R. P. Sharp, California Institute of Technolo[illegible]
Ray Bisque, Colorado School of Mines
G. Rapp, University of Minnesota
W. W. Hambleton, University of Kansas
B. F. Howell, Pennsylvania State University
J. A. S. Adams, Rice University

V. J. Hurst, University of Georgia
J. C. Jamieson, University of Chicago
C. L. Drake, Columbia University
G. A. Thompson, Stanford University
W. D. Keller, University of Missouri
Ned Ostenso, University of Wisconsin
A. L. Howland, Northwestern University
P. E. Potter, Indiana University

PARTICIPANTS

Conference on Interdisciplinary Activities
Seattle, Washington
June 28 to July 2, 1965

Agriculture

Chancellor Daniel G. Aldrich
University of California, Irvine
Irvine, California 92650

Biology

Professor Hans Bremermann
Department of Mathematics
University of California, Berkeley
Berkeley, California 94720

Professor R. H. Burris
Department of Biochemistry
University of Wisconsin
Madison, Wisconsin 53706

Professor A. Gib DeBusk
Department of Biological Sciences
Florida State University
Tallahassee, Florida 32306

Professor Arthur Martin
Department of Zoology
University of Washington
Seattle, Washington 98105

Professor Brian McCarthy
Department of Microbiology
University of Washington
Seattle, Washington 98105

Professor Aubrey W. Naylor
Department of Botany
Duke University
Durham, North Carolina 27706

Professor Marcus Rhodes
Department of Botany
Indiana University
Bloomington, Indiana 47405

Professor Fred M. Snell
Chairman, Department of Biophysics
School of Medicine
State University of New York
Buffalo, New York 14214

Chemistry

Professor Konrad E. Bloch
Department of Chemistry
Harvard University
Cambridge, Massachusetts 02138

Professor William B. Cook
Executive Secretary
Advisory Council on College Chemistry
Stanford University
Stanford, California 94305

Professor Leonard K. Nash
Department of Chemistry
Harvard University
Cambridge, Massachusetts 02138

Professor Charles C. Price
Department of Chemistry
University of Pennsylvania
Philadelphia, Pennsylvania 19104

Professor George C. Pimentel
Department of Chemistry
University of California, Berkeley
Berkeley, California 94720

Engineering

Dr. Newman A. Hall
Executive Director
Commission on Engineering Education
1785 Massachusetts Avenue, N. W.
Washington, D. C. 20036

Professor Floyd B. Humphrey
Department of Electrical Engineering
California Institute of Technology
Pasadena, California 91109

Geography

Professor Richard Morrill
Department of Geography
University of Washington
Seattle, Washington 98105

Geology

Dr. William W. Hambleton
American Geological Institute
Department of Geology
University of Kansas
Lawrence, Kansas 66045

Professor J. Harbaugh
Department of Geology
Stanford University
Stanford, California 94305

Professor O. T. Hayward
Department of Geology
Baylor University
Waco, Texas 76703

Mathematics

Professor G. Milton Wing
Department of Mathematics
University of Colorado
Boulder, Colorado 80304

Physics

Professor Judith Bregman
Department of Physics
Polytechnic Institute of Brooklyn
Brooklyn, New York 11201

Professor Frederick Reif
Department of Physics
University of California, Berkeley
Berkeley, California 94720

Professor Gabriel Weinreich
Department of Physics
University of Michigan
Ann Arbor, Michigan 48104

Professor Ferd E. Williams
Department of Physics
University of Delaware
Newark, Delaware 19711

SPONSORING COMMISSIONS

Commission on Undergraduate Education in the Biological Sciences
Ted F. Andrews, Executive Director
The George Washington University
Washington, D. C. 20006

Advisory Council on College Chemistry
William B. Cook, Executive Secretary
Department of Chemistry
Stanford University
Stanford, California 94305

Commission on College Physics
John M. Fowler, Executive Secretary
Physics and Astronomy Building
The University of Michigan
Ann Arbor, Michigan 48104

COOPERATING COMMISSIONS

Committee on Educational Policy in Agriculture
R.E. Geyer, Executive Secretary
National Academy of Sciences - National Research Council
2102 Constitution Avenue
Washington, D.C. 20418

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Newman A. Hall, Executive Director
1785 Massachusetts Avenue, N.W.
Washington, D.C. 20036

Commission on College Geography
John F. Lounsbury, Project Director
Eastern Michigan University
Ypsilanti, Michigan

Geological Education Orientation Study (GEO-Study)
O. T. Hayward, Director
Department of Geology
Baylor University
Waco, Texas

Committee on the Undergraduate Program in Mathematics
Robert H. McDowell, Executive Director
P.O. Box 1024
Berkeley, California 94701