Report of a Survey Conference on Heterogeneous Catalysis. August 18-21, 1963. Hershey Pennsylvania (1964)

Pages
51

Size
6 x 9

ISBN
0309364248

Division of Chemistry and Chemical Technology; National Research Council

Report of a Survey Conference

on

HETEROGENEOUS CATALYSIS

August 18-21, 1963

Hershey, Pennsylvania

Sponsored by

Division of Chemistry and Chemical Technology
National Academy of Sciences—National Research Council

with financial support by the
National Science Foundation

Organizing Committee

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National Academy of Sciences—National Research Council
Washington, D. C.
1964

FOREWORD

In 1960, Drs. P. H. Emmett, A. G. Oblad, and J. Turkevich prepared a document entitled "A National Institute for Catalysis in the United States." In this document, they surveyed the historical background of heterogeneous catalysis and the present state of research into its fundamentals in the United States and in foreign countries. They reached the conclusion that basic research on this subject in the United States lagged very seriously behind national needs, and they proposed the establishment of a national institute of catalysis. They envisaged an independent laboratory to investigate basic aspects of heterogeneous catalysis and related matters.

This document was distributed to a number of interested individuals and organizations, and, in particular, to the National Academy of Sciences. The president of the Academy referred the proposal to the Division of Chemistry and Chemical Technology of the Academy—Research Council, where it came to the attention of the Executive Committee of the Division and of the Committee on Colloid and Surface Chemistry. As a result, Drs. Emmett, Oblad, and Turkevich were invited to discuss the proposal before the annual meeting of the Division on April 10, 1963. The Executive Committee then decided to convene a survey conference to examine three questions: (a) What is the present state of research in heterogeneous catalysis in the United States? (b) Is the present state of such research adequate to national needs? (c) If not, what should be done? If the answer to (b) was "no," the conference was to consider the proposal for a national institute as only one possible corrective measure.

The organizing committee scheduled the conference to be held August 18-21 at Hershey, Pennsylvania. In compiling the list of those to be invited to attend, the committee attempted to keep the conference small enough to allow for general discussion, and to select conferees as widely representative as possible of academic institutions, industrial laboratories, and government laboratories. In addition, it tried to assure the presence of individuals at various levels of the industrial and academic hierarchy. A very large fraction of those invited attended. The organizing committee also invited a number of governmental agencies to send representatives. A list of the participants is included at the end of this report.

The conference, which was held August 18-21, 1963, opened with an address by Dr. R. W. Cairns, chairman of the Division of Chemistry and Chemical Technology of the Academy—Research Council. An evening session was then devoted to consideration of the present status of research in heterogeneous catalysis. The conclusions appear in the section of this report entitled "The Present Status." Sessions on August 19 were devoted to the question of adequacy. Consideration of this aspect appears in the section entitled "The Inadequacy." On the following day, the conference convened as three committees to consider the proposals before the conference. Committee I, headed by Dr. A. Farkas, was to develop plans for a national institute. Committee II, under the chairmanship of Dr. M. Boudart, was to develop plans for distribution of research funds in existing academic institutions. Committee III, headed by Dr. V. Haensel, considered other possible remedial actions.

The merits of the various proposals were debated on the closing day of the conference. Following the debate, the conferees voted their preferences. The results of the voting are tabulated in Appendix G.

This report has been prepared and approved by the organizing committee, consisting of: P. H. Emmett, A. Farkas, V. Haensel, and R. L. Burwell, Jr. (chairman). "The Present Status" was written by Dr. A. Farkas; "Proposed Remedial Action" was written by Dr. V. Haensel; the Summary, Foreword, and "The Nature of the Inadequacy" were written by R. L. Burwell, Jr. The summaries of the actions of the committees were written by the respective committee chairmen. The committee had a verbatim transcript of the proceedings except for the meetings of Committees I and II.

The National Science Foundation provided financial support for the conference and for the publication of this report.

The organizing committee wishes to express its thanks to Dr. Edward Wichers, Executive Secretary of the Division of Chemistry and Chemical Technology, for invaluable assistance at all stages of this survey conference.

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SUMMARY

The Survey Conference on Catalysis considered three questions:

a) What is the present state of research in heterogeneous catalysis in the United States?

b) Is the present state of such research adequate to national needs?

c) If not, what should be done?

Under question a), reports established that in the United States: the annual wholesale value of products made directly by heterogeneous catalytic processes amounted to 21.4 billion dollars in 1962, out of a total of 130 billion dollars for all manufactured goods; 3 to 4 million dollars were spent on basic research in heterogeneous catalysis in 1962; during 1961-62 about 90 papers were published each year relating to fundamental aspects of heterogeneous catalysis (from sources about equally divided between academic and non-academic laboratories); and in recent years about eleven persons per year received doctoral degrees in this area, and about fourteen persons per year served as postdoctoral fellows, ten of whom were aliens who returned to the countries of their origin. It was further noted that very few young physical chemists working in heterogeneous catalysis had recently entered the academic profession, and that there was only one such person under forty-five years of age in the twenty-two leading universities.

The conference then approved the following resolution by majority vote: yes, 28; no, 3; abstain, 1.

> "The present total effective level of fundamental research in heterogeneous catalysis does not meet national needs. We believe that a major increase in the effective level of such research must be made if the United States is to maintain a satisfactory level of technological advance. We believe that the present general state of scientific knowledge is such that a properly concerted effort in this area would lead to important scientific advances which would substantially facilitate and stimulate the development of new or improved catalytic processes."

It was generally agreed that the inadequacy in heterogeneous catalysis stems from a general inadequacy in surface chemistry.

The conference considered several possible remedial actions and expressed itself as favoring:

> A national catalytic research institute. Such an institute would require a budget in the vicinity of 1 to 2 million dollars per annum. The vote on this measure was: yes, 23; no, 8; abstain, 1.
>
> An organization to distribute funds to support research in the fundamental aspects of heterogeneous catalysis in a limited number of university centers. The vote on this measure was also: yes, 23; no, 8; abstain, 1.
>
> The addition of a mission in heterogeneous catalysis to one of the existing national laboratories such as Oak Ridge National Laboratory. The vote on this measure was: yes, 17; no, 15.

In the discussion, the first two proposals were considered mutually exclusive, and the third was considered as additional to either of the first two.

Finally a vote was taken to determine first preference among the proposals. Proposal 1 received 16 votes; proposal 2 received 12.

THE PRESENT STATUS

The following reports were presented to the conference and discussed. (1) The Relation of Heterogeneous Catalysis to the Gross National Product, by Dr. A. G. Oblad; (2) American Publications in Heterogeneous Catalysis, by Dr. A. Farkas; (3) The Training of Doctoral and Post-Doctoral Students in Heterogeneous Catalysis, by Dr. R. L. Burwell, Jr.; (4) Institut de Recherche sur la Catalyse, Lyon, France, by Dr. R. L. Burwell, Jr.; and (5) Catalytic Research in Japan, by Dr. P. H. Emmett. The first, second, and fourth of these reports are presented as Appendixes.

Dr. Oblad discussed the relation between the value of chemical products dependent on catalysis and a justifiable budget for fundamental research on catalysis. He reported on a survey of those industries that depend wholly or mainly on catalysis, on the basis of which the wholesale value of the products manufactured by them in 1962 was estimated. The survey revealed that products of the petroleum industry, which uses a great variety of catalytic processes, are valued at 9 billion dollars. Other inorganic and organic chemicals produced by catalysis, including ammonia, nitric and sulfuric acids, various polymers, alcohols, aldehydes, phthalic anhydride, etc., are valued at 6 billion dollars. The rubber industry and synthetic textiles represent 2.4 billion dollars each. Fat hydrogenation and leather industry (enzyme catalysis) products are valued at 1.6 billion dollars each. The value of these products totals 23 billion dollars, or 21.4 billion dollars if the leather products are excluded. This total represents roughly 16 per cent of the 130 billion dollar wholesale value of all manufactured goods produced in the U. S. in 1962. This latter figure has to be related to the gross national product, which amounts to 580 billion dollars and includes various other services, government expenses, etc., in addition to the mentioned manufactured products.

The average research expenditure is approximately two per cent of sales, which would amount to approximately 400 million dollars for all kinds of research in connection with the 20-23 billion dollar value of the industrial products dependent upon catalysis. Taking 10 per cent as the average value of the total research spent specifically on basic research, we obtain 40 million dollars, out of which it is estimated that 25 per cent ought to be spent on heterogeneous catalysis. The final figure thus amounts to 10 million dollars, whereas actually only three to four million dollars is spent annually on research on heterogeneous catalysis.

Dr. Farkas reported on his survey of publications dealing with fundamental aspects of heterogeneous catalysis in 1961 and 1962. The survey covered the following journals: Journal of the American Chemical Society, Journal of Chemical Physics, Journal of Physical Chemistry, Journal of Organic Chemistry, Journal of Catalysis, and also the Proceedings of the Second International Congress on Catalysis. The total number of papers in these journals was estimated on the basis of the author index and was related to the number of papers dealing specifically with heterogeneous catalysis. Work concerned with industrial catalysts, engineering aspects of catalysis, and also polymerization catalysis were disregarded.

The survey comprehended 8,896 papers covering 37,015 pages.

The total number of papers on heterogeneous catalysis was 176, representing 1.98 per cent of the total number of papers. Practically all the papers surveyed were by American authors, with the exception of a small number published in the Journal of Catalysis and the Proceedings of the Second International Congress on Catalysis.

The distribution of the 176 papers according to types of laboratories were as follows:

Academic	86
Industrial	75
Government	10
Foundation	5

The leading contributor of academic papers was Northwestern University with 26 papers. Johns Hopkins, University of Arkansas, M.I.T., and University of Pennsylvania together contributed 21 papers, while the rest of the 39 papers were written by scientists from twenty-eight other academic laboratories.

Of the industrial papers, 11 each were written by Gulf and Socony scientists, 10 by Esso, and a total of 15 by workers from Shell, General Electric, and Texaco; the rest of the 28 papers were contributed by twenty-two other industrial laboratories. The main contributors in the other two categories were Oak Ridge with 6 and Mellon Institute with 4.

Dr. Burwell reported on a survey of graduate students and post-doctorate workers in catalysis. A questionnaire sent to twenty-three faculty members—in chemistry, physics, and chemical engineering—inquired about the number of Ph.D.'s awarded between June 1958 and June 1963 in the area of fundamental aspects of heterogeneous catalysis, and the number of post-doctoral students in the same area during

the same interval. Numbers were also asked for U.S. residents including those who became U.S. residents and for those of foreign origin who returned to their native country. The results of this questionnaire were as follows:

	U.S.	Returned to Native Country	Total
Ph.D.'s	52	6	58
Post-Doctorate	18	51	69

This sample is believed essentially complete, and was substantiated by cross checking with the names appearing on the publication report of Dr. Farkas.

The discussion brought out that very few young physical chemists in the academic community are working in heterogeneous catalysis. There is only one physical chemist under the age of 45 working in this area in the twenty-two leading universities.

Dr. Burwell referred briefly to the research on catalysis carried out in the Iron Curtain countries. The September-October, 1962, issue of the Russian journal Kinetics and Catalysis is almost entirely devoted to papers from the Catalysis Institute of the Siberian branch of the Academy of Science. Of particular interest is a paper by Boreskov, which outlines the plans of the Institute. Another paper in the East German "Zeitschrift für Chemie" (Vol. 3. p. 121; 1963) describes what has been done in the Institute for Inorganic Catalysis of the German Academy of Science in East Berlin.

The French effort is concentrated in the Institute of Catalysis, affiliated with the University of Lyon, which does approximately 70 per cent of all of the research on catalysis that is done in France.

In Holland there are two major well-known laboratories concerned with catalysis, the State Mines Laboratory and the Shell Laboratory. There is also a new one at Eindhoven under Schuit.

Professor Emmett reported on catalytic research in Japan. There are three groups in Japan active in catalytic research. The first is at the Hokkaido University, where the Catalysis Institute is located. Personnel number 20 Ph.D.'s, with 3 to 5 post-doctorate scientists, and 10 graduate students. The second group is in the Tokyo area and includes 8 to 10 schools with approximately 40 professional or technical workers, and about 20 graduate students. The third category is the so-called provincial schools in the Tokyo area, which includes 7 universities with some 40 professional workers and 15 graduate

students. Thus the total of professional people working in catalysis is approximately 100 to 105, plus about 45 graduate students. An estimated 50 to 75 persons are working in Japanese industry on catalysis. A total of 1,000 chemists are thought to belong to the Catalysis Club of Japan, which includes everybody interested in catalysis.

THE NATURE OF THE INADEQUACY

The conference joined in a general discussion of the inadequacies of research in the fundamentals of heterogeneous catalysis. The following resolution was passed by a vote of: yes, 28; abstain, 1; no, 3. The detailed vote and statements of those not voting "yes" appear in the Appendix.

> "The present total effective level of fundamental research in heterogeneous catalysis does not meet national needs. We believe that a major increase in the effective level of such research must be made if the United States is to maintain a satisfactory level of technological advance. We believe that the present general state of scientific knowledge is such that a properly concerted effort in this area would lead to important scientific advances which would substantially facilitate and stimulate the development of new or improved catalytic processes."

Many different aspects of the inadequacy arose in the discussion. Clearly, the conferees varied somewhat in the importance they attached to the various aspects. An outline of views apparently shared generally was presented, and the items were individually approved, or modified by the conferees and then approved. What follows, then, represents a semi-formal concensus. The language is that of the organizing committee. Items in brackets were not formally approved but represented opinions expressed by a number of the conferees.

The importance of catalysis nationally rests primarily on the importance of heterogeneous catalytic processes to the American economy. The wholesale value of products resulting directly from heterogeneous catalytic processes is 21.6 billion dollars per annum, but only 3 to 4 million dollars are spent per annum on fundamental research in heterogeneous catalysis. It was strongly felt that this constitutes a prima-facie case as to the inadequacy of research in this area, particularly since the present level of theoretical understanding of heterogeneous catalysis is very poor.

Of about 90 papers a year published in this area, approximately half are from academic institutions. This figure represents papers aimed directly at the fundamentals of heterogeneous catalysis and at related areas of surface chemistry and physics. These 90 papers suggest an expenditure of about $400,000 in the universities for stipends

of students, materials, equipment, and summer salaries of faculty. This estimate is consistent with rather detailed knowledge about the relatively small number of faculty members directing research in the field. It was the consensus of the industrial research administrators attending the conference that the total industrial expenditure for research in catalysis was not likely to exceed $3,000,000. Note that overhead and capital charges are included in the industrial estimate but not in the university estimate.

[Several conferees experienced in fuel cell research were of the opinion that the present inadequate understanding of heterogeneous catalysis is a serious hindrance to the development of practical fuels cells. Other conferees expressed the opinion that the present level of catalytic research affected national prestige and the over-all defense effort unfavorably.]

The basic importance of heterogeneous catalysis is this. Of the myriads of thermodynamically possible reactions, only a rather small fraction can be achieved directly under any known condition. Heterogeneous catalysis adds a substantial number of reactions which can be run practically, but the number of possible reactions which cannot be effected practically by any known process is still a very large fraction of the thermodynamically possible. Heterogeneous catalysis provides the main hope for increasing the useful fraction.

Homogeneous catalysis also adds to the useful fraction. However, this is not ordinarily considered a special field of research. In principle, any two or more homogeneous reactions, suitably combined to regenerate a reactant, constitute homogeneous catalysis. Thus, as our understanding of homogeneous reactions has grown, homogeneous catalysis has tended to become merely a part of the ordinary study of homogeneous organic and inorganic reactions.

In heterogeneous catalysis, the catalyst is a surface species. In principle, heterogeneous catalysis is merely an aspect of surface chemistry. However, surface chemistry is so poorly developed, and the study of heterogeneous catalysis requires such a special set of techniques, that heterogeneous catalysis constitutes, in fact, a separate discipline, and it is likely to continue in this state for a substantial period of time.

There was a general feeling among the conferees that the development of heterogeneous catalysis is inextricably linked with that of surface chemistry in general, and that the inadequacy should be treated as one in surface chemistry.

Another aspect of heterogeneous catalysis that poses serious problems, and that, incidentally, separates it from homogeneous

catalysis, is its interdisciplinary nature. At present, the chemistry of the surfaces of solids and heterogeneous catalysis involves physical chemistry, organic chemistry, inorganic chemistry (particularly of coordination compounds), solid-state physics and metallurgy, and chemical engineering (with regard to mass and heat transfer). The present organization of research, particularly in the universities, is not such as to facilitate the interdisciplinary effort needed in surface chemistry. We see no likelihood that any present organization is likely to devote the necessary funds and effort required to maintain the necessary interdisciplinary effort for an adequate period of time.

[The conferees recognized that research in many areas, including solid-state physics, quantum mechanics, and inorganic coordination chemistry, would contribute to the future development of heterogeneous catalysis, even where the connection is not now evident. We have no way of estimating the expenditure for research of this nature, but, even when this research comes to fruition, workers in heterogeneous catalysis will be needed to apply the research findings to heterogeneous catalysis. A development in surface chemistry such as we envisage would, in many cases, be applicable to areas other than heterogeneous catalysis—corrosion, fuel cells, colloid chemistry, the ablation of nose cones in re-entering missiles, solid-state electronic devices, etc.]

The conferees further recognized that even the greatest effort can produce the desired result only if the general level of scientific background is adequate. It was stated as an example that no expenditure could have opened the way to the development of television in 1850. There was general agreement, however, that the necessary scientific background does exist for an important and widespread advance in surface chemistry and heterogeneous catalysis, and that it is not being exploited.

The technical development of new or improved catalytic processes is severely limited by inadequate understanding of the fundamentals of heterogeneous catalysis. Our understanding is insufficient to provide satisfactory guides to the empirical development of new and improved processes, and it can hardly contribute to the a priori selection of catalysts.

Although two or three petroleum companies have recently increased their basic research in heterogeneous catalysis, total industrial research in this area has declined generally for the last few years. Economic payoff from basic research requires ten to fifteen years, a longer period than the average tenure of a top manager. Even a moderately venturesome economist does not care to forecast more than five years ahead, and the fruits of research are two or three times as long in maturing. Outside the petroleum industry, few companies

have interests well-enough focused to support substantial basic research in heterogeneous catalysis. Thus, although there is and has been some excellent work on the fundamentals of heterogeneous catalysis in industrial laboratories, work in this area suffers from a lack of commitment to long-term support.

Analysis of the situation in universities is helped by putting it in historical perspective. Since about 1920 most academic workers in catalysis have been physical chemists. In the 1920's and 1930's, kinetics was a dominant area of physical chemical research. Heterogeneous catalysis came to be considered an aspect of kinetics, and shared, to some degree, its prosperity. Since about 1950, kinetics has had a smaller role in physical chemistry research. The new generation of academic physical chemists has been interested primarily in detailed examination of systems at the molecular level. They have worked necessarily with rather simple systems, and the emphasis has been on structure, not kinetics. Those working in kinetics have been concerned largely with the detailed examination of a single elementary step. Thus, the young physical chemist has not viewed heterogeneous catalysis as an area in which he could do the kind of work he wanted to do. In the top twenty-two American universities (the "top twelve" plus the "next ten" of Bernard Berelson's "Graduate Education in the United States," McGraw-Hill, 1960), there is only one physical chemist under forty-five working in heterogeneous catalysis—R. J. Kokes, at Johns Hopkins.

As an example of the present interests of the leading physical chemists, one may note that during the months of May, June, and July of this year, physical chemists from the top twenty-two universities published 12 papers in the Journal of the American Chemical Society, 17 in the Journal of Physical Chemistry, and 56 in the Journal of Chemical Physics. Furthermore, the authors of the papers in the last journal were on the average much younger than the authors in the first two journals. The number of papers dealing with kinetics was small.

This situation arises because the American university system permits the new faculty member to choose the area in which he wishes to work. He does not have to work for years as assistant to the professor, as in the continental system. We firmly support the indigenous system, and believe that the young physical chemists are doing important and distinguished work. This is the context in which our university research in heterogeneous catalysis must operate.

Academic physical chemists have abandoned other areas—for example, electrochemistry. However, this area has been taken over by analytical chemists and is receiving more attention than ever before. Kinetics is extensively studied by organic, inorganic, and biochemists and flourishes in these areas. Heterogeneous catalysis has not been appropriated by any other group of academic chemists.

Since 1900, a number of organic chemists in Europe have been working in the descriptive areas of heterogeneous catalysis. There have been few of these efforts in the United States. Howevei, a few American organic chemists are working in heterogeneous catalysis from the point of view of organic mechanisms. In addition, members of faculties of chemical engineering have been working in heterogeneous catalysis. Much of this work involved mass transfer in porous catalysts, but recently a small number of chemical engineering faculty has worked on other fundamental aspects of heterogeneous catalysis. The number of organic chemists and chemical engineers working in catalysis seems to be growing, but there is no sign that such growth will resolve the over-all problem of surface chemistry.

The basic problem areas of heterogeneous catalysis are:

a) the detailed surface structure of solids in general and of known catalysts in particular at the atomic level;

b) a quantum mechanical interpretation of the nature of surface orbitals and of the binding of adsorbed species;

c) the chemical identity of surface intermediates in catalytic reactions;

d) the nature of reactions of adsorbed intermediates and , in particular, the nature of the transition states in such reactions;

e) the need for greater knowledge about model homogeneous systems. The extensive work on model enzyme systems is clearly of considerable importance in understanding enzyme action.

There is some understanding of items a) and c), but items b) and d) are almost completely unexplored. We believe that the present general scientific background is sufficient to support major developments in understanding heterogeneous catalysis, and that it will permit an extended and more rational practical utilization of it. In the long run such a development would lead to the prediction of new catalytic reactions; a more immediate result would be the provision of theoretical bases for guiding the empirical development of new catalysts and catalytic processes.

One notes again that much of this program is really surface chemistry, and that the results of its development would be useful in many areas other than heterogeneous catalysis. One notes further that much of the work would need to be interdisciplinary in character.

Distinct advances must be made in all the items enumerated above if heterogeneous catalysis is to realize its potential contribution to the development of the economy. The present level of research in all these areas is clearly inadequate, and in some, almost non-existent.

PROPOSED REMEDIAL ACTION

After concluding that current research in catalysis is inadequate to the needs of the nation, the conference discussed and voted on four proposals for remedial action. Financing was not discussed because there was too little time to go into it thoroughly, and because it was felt basic policy decisions should come first. The first three proposals were discussed in committees and then presented to the conference for consideration. Summaries of the committees' reports to the conference and the subsequent discussions follow this outline of the conference's conclusions. Minutes of the committee meetings dealing with the most favored proposals are included in the Appendix. The fourth proposal was introduced from the floor.

Conclusions of the Conference

1) Should a national institute for research in catalysis, in affiliation with a major university, be created? (i.e., recommendation of Committee I). Yes: 23 No: 8 Abstain: 1

2) Should several autonomous university centers for research in catalysis be supported? (i.e., recommendation of Committee II). Yes: 23 No: 8 Abstain: 1

3) Should an organization be formed to distribute funds for research to universities, research institutes, and industrial and governmental laboratories? (i.e., recommendation of Committee III). Yes: 7 No: 25

4) Should a mission in heterogeneous catalysis be added to one of the national laboratories? (This measure was to be considered as additional to, not a substitute for, the first or second proposal.) Yes: 17 No: 15

The formation of a national research institute was opposed by some as too authoritarian or too centralized. Others were worried about the difficulty of restricting faculty members with tenure to surface chemistry. Committee I, which had studied the proposal in detail, recommended that the institute be part of a university, and that all principal members of the institute have university appointments; this dispelled some fears. The feeling by many that only a new and

dramatic approach would attract attention to surface chemistry worked in favor of the proposal. This view was well expressed by Professor Germer:

> "I am a complete outsider, but I would like to give my general impression. I am quite confident if you spread money around in any fashion at all, it will be mildly useful, and if you do it very carefully, it might even be quite useful. But it seems to me that it is a weak and wishy-washy approach to it. There is the strong and bold approach, that is number one (the institute); and if you are confident enough and strong enough to make it, I think that is obviously the first choice. This can, of course, be a failure if the management is bad. With bad management, number one would be the worst choice. With good management, it will be the best choice. I am bold enough to make the choice for number one."

Opposition to the mere support of several university centers arose from doubts that more money and more uncoordinated activity would substantially alter the situation.

The creation of an organization to distribute research funds was opposed on the same grounds, that the real problem is not insufficient funds. Many felt strongly that this proposal was incompatible with the nature of universities, and they particularly disliked the idea of the board of directors of the funding agency soliciting and encouraging research projects proposed by the board.

The fourth proposal, to attach a mission in heterogeneous catalysis to one of the national laboratories, was opposed by those reluctant to accept any proposal in which government funds—and government control—might be a dominant factor.

When the first vote was taken, each conferee voted for as many proposals as he wished. In the second vote, each conferee indicated his first and second preferences only. In favor of:

	First	Second
1) a national institute for research in catalysis	16	6
2) multi-centers	12	7
3) funding organization	4	1
4) use of a national laboratory	0	13

The creation of a national institute for research in catalysis— as proposed by Messr. Emmett, Oblad, and Turkevich and modified by Committee I—received more support than any of the other proposals.

Summary of Recommendations to the Conference by Committee I

The committee found the proposal of Drs. Oblad, Emmett, and Turkevich for the establishment of an institute devoted to research into the fundamentals of heterogeneous catalysis well conceived and worthy of consideration. The following changes and guide lines for operation of the institute were recommended by the committee.

To insure the teaching aspects of the institute, the majority of the committee favored associating the institute with a university from which key staff members with faculty appointments would be drawn. The Institute for the Study of Metals in Chicago was preferred as a model for the organization of the institute.

A minority of the committee agreed that association with a university was desirable, but wanted a high degree of autonomy. They suggested hiring a number of senior full-time employees without faculty appointments. They thought it expedient to delay the initiation of the graduate program.

It will be necessary to have an outstanding director, one skillful in selecting staff and in maintaining the necessary cooperative effort without exerting undue pressure.

The original proposal stipulated twenty senior staff members. The committee felt such a large group would work more effectively if divided into five or six departments.

The selection of the university with which the institute is to be associated is of great importance. The committee thought it likely that several first-rate universities would be anxious to affiliate with the institute and to have it on their campuses.

The committee recommended that the institute concentrate on research in heterogeneous catalysis, and only study catalysis in other areas when it would advance the understanding of heterogeneous catalysis.

The availability in one location of modern instruments and techniques required for the study of heterogeneous catalysis, solids and surface reactions, is crucial.

Although the institute should make no special effort to develop patentable processes, any process or product of obvious economic value discovered in the course of fundamental studies should be covered by patent applications. The disposal of income from such patents should be in accordance with the policies of the university with which the institute is associated.

The feeling that the institute would have a positive effect on both the quality and quantity of catalysis research in other laboratories was almost unanimous among the members of the committee. Contact among the researchers at the institute and the availability of modern equipment would stimulate the staff and attract workers from related fields. Industrial research would be effected indirectly by the demonstration of new interest in catalysis and by the availability of new trained workers.

The director of the institute must scrupulously avoid overwhelming the staff with key researchers from industry.

Summary of Recommendations to the Conference by Committee II

About half the basic research in catalysis in the United States is carried out by a limited number of university scientists. Most are isolated. They are plagued by insufficient support for a continuing effort. They are unable to hire technicians and other professional help to increase the breadth and depth of their work. In many instances, this marginal situation keeps them from attacking the various problems of catalysis with the modern tools of optical, X-ray, and resonance spectroscopy, electron diffraction and microscopy that attract the majority of bright graduate students to other fields.

As a result, many university scientists vitally interested in catalysis are devoting more and more time to peripheral areas. The number of students exposed to the problems of catalysis and trained in their solution is not commensurate with the increasing needs of growing universities or the requirements of pure and applied research in industry.

To remedy this situation, special grants should be awarded on a continuing basis to a limited number of university centers:

1) to strengthen existing research facilities by emphasizing continuity of work;

2) to develop existing facilities and encourage the establishment of interdepartmental research units where several staff members of various disciplines can attack the problems of catalysis;

3) to increase the number and quality of doctoral students in catalysis who, besides doing original work, will develop an appreciation for the problems and techniques of others engaged in the same endeavor in the same location;

4) to foster multi-sided exchanges of information, viewpoints, and techniques among catalysis laboratories in industry, university, government, and other institutions through post-doctoral fellowships, visiting professorships, and leaves of absence.

This recommendation involves raising funds, administering the program, disseminating information, and educating management bodies in industry, university, and government about the purposes, activities, and needs of catalysis research.

Responsibilities for the decentralized university research programs could undoubtedly be most effectively exercised by a central administrative body, i.e., a National Institute of Catalysis.

Summary of Recommendations to the Conference by Committee III

Before discussing ways in which the inadequacy of research in catalysis might be overcome, the committee defined the reasons for the inadequacy.

A. At the university level:

1. Established workers in the field suffer more from lack of man power than from insufficient support; the reverse is true for the younger workers.

2. Auxiliary workers and technicians are difficult to obtain under the existing academic system.

3. The bringing together of various disciplines is not an easy task.

B. At the industrial and research institute level:

1. Most industrial research lacks continuity. The reasons are pressure from development projects, impatience with long-term research, and variable management attitude toward basic research.

2. It is difficult to bring together various disciplines.

3. Lack of tax credit for basic research discourages development.

An agency fully cognizant of the problems could become a focal point for help along the lines discussed above. It would differ from

the usual donor agencies by seeking the proper research personnel among the various disciplines. Such personnel may be located at universities, research institutes, industrial or government laboratories. Particular emphasis would be placed on promoting work by younger personnel.

The following resolution was passed by the subcommittee:

> Establish a funding agency to increase the extent of fundamental research in heterogeneous catalysis at established universities, colleges, government agencies, and industrial and institutional laboratories.
>
> This is an active agency, with power to propose areas of research as well as to receive proposals for research projects.
>
> Prudent financial responsibility will be exercised by the funding agency in making grants and monitoring contract activities. There will be no restrictions on publications, and the results should be made public.

Suggestions for initial policies included:

1. giving special attention to needs of young investigators in heterogeneous catalysis, from both academic and industrial origins.

2. providing for specific means of stimulating interest in catalysis at all levels of education, including encouragement of education of junior partners on projects.

3. emphasizing continuity of support of active investigators.

4. considering means of making the investigator's work more effective.

5. encouraging the exchange of information in catalysis.

> The funding agency shall be composed of scientifically qualified representatives from academic, industrial, and government institutions. The membership is on a three-year staggered rotating basis. The need for such an agency is to be periodically reviewed by the National Academy of Sciences—National Research Council.

A research center attached to a national laboratory was also discussed by Committee III, but was not recommended to the conference. Dr. Halpern subsequently proposed from the floor of the conference that: "there be established a research center to do research on heterogeneous catalysis within the framework of one of the existing government research institutions. Such possible institutions are the AEC laboratories, the National Bureau of Standards, and the Bureau of Mines." This was the fourth proposal voted on by the conference.

Summary of Discussions of Proposals by the Conference

1. The bulk of the discussion about a national institute for research in catalysis centered on the compatibility of an institute and the university to which it is attached in matters of faculty appointments, tenure, etc., and the compatibility of a research program desired by the institute board and principles of academic freedom. Conflicts are extremely difficult to resolve, and the proponents of the institute felt they should be played by ear.

2. Most of the discussion about the proposal for several autonomous centers revolved around the relationship between these centers and a national institute. The concept of the autonomous centers was modified to subordinate the centers to the governing body of an institute. It was stressed, however, that each center was to remain autonomous. The two proposals tended to merge, with varying degrees of autonomy and location differentiating them. There was not enough time to clarify a plan. Details remained hazy.

3. Discussion about the funding organization centered on the means of funding. Government funds, as in the other proposals, were the only ones suggested. The extent of support was discussed, and support of as many working investigators as possible, including industrial and research institute workers, was stated to be the objective.

4. The proposal to make use of a national laboratory was discussed in terms of switching emphasis to heterogeneous catalysis. The fine work in radiation chemistry was cited as an example of a new project. The training of graduate students at government laboratories, as is now done at a number of locations, was emphasized.

APPENDIXES

APPENDIX A

STATEMENTS BY THOSE NOT VOTING YES ON THE ADEQUACY RESOLUTION

W. K. Hall

"Generally speaking, I believe the current effective level of research in catalysis is commensurate with the national need. Furthermore, I am inclined to doubt that a concerted effort is any more likely to lead to major developments in the field than the more individualistic approach now being followed. While more fundamental research in catalysis would be highly desirable, it is probably not vital to the national interest. I really cannot evaluate the possible impact of an increased annual outlay of $2,000,000 for this purpose on the rate of growth of the gross national product, but I do not feel that a substantial expected effect was established by the data presented."

D. S. MacIver with the concurrence of V. Haensel

"I believe that more or better basic research in the fundamentals of heterogeneous catalysis could well be of benefit to the United States, but I am not convinced that the national need is so acute that a concerted effort by some agency, governmental or otherwise, is required. The data presented at the Survey Conference was, in my opinion, insufficient to resolve this latter point. Furthermore, if such a concerted effort were indeed necessary, I do not believe that a National Institute for Catalysis or, alternately, several university centers of catalysis research would properly represent that segment of the economy which has the greatest practical reason for concern with catalysis, namely, American industry."

P. B. Weisz

"Inasmuch as there exists no objective measure for 'the present total effective level of fundamental research,' nor for the magnitude of the 'national needs,' neither an assertion nor a denial of a statement that one 'meet' the other is deemed to be meaningful. We therefore

find ourselves unable to cast a 'yes' or a 'no' vote concerning the opinion as proposed.

"This does not detract from our concurrence with the substance of the concluding sentence of that opinion: We believe that an intensified effort in the area of fundamental research in catalysis, beyond the present level, would result in a substantial advancement of the technology of conversion and utilization of our natural resources, and thus importantly advance the national economy."

APPENDIX B

THE RELATION OF HETEROGENEOUS CATALYSIS TO THE GROSS NATIONAL PRODUCT

by
Alex G. Oblad

To give a more factual basis to the belief that basic research in heterogeneous catalysis is seriously inadequate in the United States, a comparison of the amount of research now going on with that which can be justified is of interest. Accordingly a survey and summary of the industries depending directly, in an important way, on catalytic technology has been made. The following are the results of this survey for the year 1962.

Field	Sales per Year in Billion Dollar Wholesale Value
Petroleum products	9.0
Chemical products	6.0
Rubber products	2.4
Synthetic textiles	2.4
Fat hydrogenation products	1.6
Leather products	1.6
	23.0

The petroleum products made directly by catalytic methods are gasoline, diesel fuels, kerosene, fuel oils, and lube oils. Petroleum products are also involved in a major way with negative catalysis, i.e., inhibitors. Most of the principal petroleum products are treated with inhibitors to stabilize them towards aging.

The chemical industry, like the petroleum industry, is largely based on catalytic technology. Some of the large production items are ammonia, nitric acid, sulfuric acid, alcohols, aldehydes, butadiene, benzene, toluene, xylene, hydrogen, and the various polymers.

The synthetic rubber and the synthetic textile industries depend on catalytic processes in a multiplicity of steps and processes. Likewise, fat hydrogenation to produce margarine and other edible fats is a large industry using catalysis.

The pharmaceutical industry and the dye industry have important products produced by catalysis, but no attempt was made to estimate these.

In looking at the imposing total of $23 billion dollars, it should be borne in mind that the total value of manufactured goods in the United States in 1962 was about $130 billion. Thus, catalytic technology is directly involved in producing about 18 per cent of the goods manufactured in the U.S.A. When one realizes that the total of goods and services in the U.S.A. was $550 billion in 1962 (the gross national product), and all contingent and based on the $130 billion of manufactured goods, it becomes immediately apparent that catalytic technology is of extreme importance to our over-all economy.

Industry has a number of rules-of-thumb regarding research and development, one of which is the relationship between research and development expenditures and gross sales. This relationship varies from industry to industry, being lowest in the textile industry (0.2% of sales) and highest in the aircraft and missile industry (18.7% of sales). However, in order to arrive at a reasonable estimate of research and development for our "catalytic technology industry," let us assume a very conservative percentage of sales which is down towards the bottom of the list. On this basis let us take 2 per cent of the gross sales value, the total in the table. We then arrive at a research and development volume of $460 million per year to cover both basic and applied research in this vast area of production.

We must now divide this research and development effort between basic and applied research. A reasonable distribution based on practices of the past is 10 per cent basic and 90 per cent applied research and development. Taking $46 million as the volume of basic research in the areas pertinent to the process and products involved, we must make a further breakdown regarding the distribution of the $46 million among the several scientific disciplines involved in producing the $23 billion of materials. Our best guess regarding this is that about 25 per cent of the basic research should be devoted to catalysis, the major item in the process technology. This results in a hypothetical research budget of about $11.5 million for fundamental work in catalysis. To compare with this, we have estimated that the total annual budget in 1962 for basic research in catalysis was in the range of $2 to $3 million dollars. Thus, there is a disparity of a factor of 4 between an amount that could very reasonably be justified on the basis of the sales volume of products from catalytic technology and the annual amount of extant basic research in heterogeneous catalysis.

Those of you present at this meeting may take issue with some of the estimates used in arriving at a final dollar volume for basic research in catalysis. However, taking the sales volumes as a starting point, please make your own estimates for the breakdown. I think the most conservative of you will agree that our program of basic research in catalysis in this country is quite inadequate.

APPENDIX C

AMERICAN PUBLICATIONS IN HETEROGENEOUS CATALYSIS, 1961 AND 1962

by
A. Farkas

This survey covers articles published during 1961 and 1962 in the Journal of the American Chemical Society, Journal of Chemical Physics, Journal of Physical Chemistry, Journal of Organic Chemistry; the 1962 volume of the Journal of Catalysis; and the Proceedings of the Second International Congress on Catalysis, published in 1961.

We have included in our survey all papers on catalysis that had as their main objective the elucidation of the mechanism of heterogeneous catalysis, the mode of catalyst action, the study of chemisorption, or the physical and physicochemical characterization of catalysts from a fundamental point of view. The papers dealing with purely industrial catalysts, their evaluation, influence of mass transfer, etc. were omitted from the survey.

Only solid catalysts purposely added to the system are considered heterogeneous catalysts. Thus, in homogeneous systems, because of the presence of two phases, the formation of solids or liquid phases, were not included. We have omitted a number of border-line cases such as liquid-phase oxidations catalyzed by solids, alkylations, acylations, carbonylation, oxo reaction involving solid complexes, and also all polymerization reactions. Papers dealing with the techniques, analytical methods, procedures, and papers prepared by foreign scientists were also omitted.

The survey was made primarily on the basis of the author index of each journal. In case of doubt as to the nature of the paper, the contents were checked.

We counted the papers concerned with fundamental aspects of catalysis, but the total number of papers was estimated by multiplying the number of index pages by the average number of papers per page. In arriving at the average number of papers per page, the entries on several index pages were counted, and allowance was made for the book reviews.

Our first table shows that the total number of pages in each journal ranges from 550 to almost 10,000, and all the journals together total more than 37,000 pages. The number of papers in each of the first four journals varies from about 1,300 to about 2,900, but there are many fewer in the Journal of Catalysis and the Proceedings of the Second Congress, which contain 57 and 143 papers respectively. The total number of papers in all these publications is 8,896, and they cover 37,015 pages, averaging 4.16 pages per paper.

TABLE 1

Publications Surveyed

Journal	Volume	Year	Total Number Pages	Total Number Papers
J. Org. Chem.	26 27	1961 1962	9977	2982
J. A. C. S.	83 84	1961 1962	9941	2512
J. Phys. Chem.	65 66	1961 1962	4994	1359
J. Chem. Phys.	35 36 37	1961 1962 1962	8799	1843
J. Catalysis	1	1962	550	57
Second Int. Congr. Catalysis		1961	2754	143
Grand Total			37015	8896
Average Number of Pages per Paper				4.16

Our second tabulation shows the number of fundamental catalytic papers in relation to the total number of papers in each of the publications, and their percentage. If we look at the ACS and Institute of Physics journals we find that the percentage varies from 0.3 per cent (J. Org. Chem.) to 4.78 per cent (J. Phys. Chem.). In the other two publications, of course, the percentage is very much larger: 40.35

per cent for the Journal of Catalysis and 26.87 per cent for the Proceedings. The rest of the papers in the two last-named publications deal mostly with fundamental aspects of catalysis, but were authored by foreign scientists.

TABLE 2

Number of Papers on Fundamental Aspects of Catalysis

Journal	Total Number of Papers	Number of Papers on Catalysis	Percentage
J. Org. Chem.	2982	9	0.30
J. A. C. S.	2512	27	1.07
J. Phys. Chem.	1359	65	4.78
J. Chem. Phys.	1843	15	0.81
J. Catalysis	57	23	40.35
Second Int. Congr. Catalysis	143	37	26.87
Total	8896	176	1.98

The total number of fundamental papers in these journals is 176 out of 8,896, amounting to 1.98 per cent, or roughly 1/50, of all papers.

Our third table breaks down the papers according to types of institutions to which their authors are affiliated—academic, industrial, government, and foundation laboratories. The latter category includes the Mellon Institute and the Stanford Research Institute. As you see from this table, academic and industrial laboratories are responsible for approximately 90 per cent of the papers published on fundamental aspects of catalysis, roughly 49 per cent being contributed by academic laboratories.

Our fourth table shows the breakdown of the academic institutions according to location. Northwestern University leads with 26 papers, followed by Johns-Hopkins with 8; Arkansas, 5; MIT and Pennsylvania, 4 each. Thus, these five institutions account for 47 out of 86 papers listed in this category, or 54.7 per cent. The rest of the papers (39) were contributed by the following 28 academic institutions: Alfred, Brown, Chicago, Chicago Medical School, Caltech, Columbia, Delaware, Georgia Tech, Grinnell, Illinois, Indiana, Iowa State, Kansas

State, Lehigh, Marquette, Minnesota, NYU, Pittsburgh, Princeton, Purdue, Rice, St. Joseph, Tennessee, Texas, Tufts, U.C.L.A., Virginia, and Washington.

TABLE 3

Number of Catalysis Papers Contributed by Different Types of Laboratories

Journal	Academic	Industrial	Government	Foundation	Total
J. Org. Chem.	7	2			9
J. A. C. S.	23	3	1		27
J. Phys. Chem.	27	29	6	3	65
J. Chem. Phys.	8	7			15
J. Catalysis	5	16	1	1	23
Second Int. Congr. Catalysis	16	18	2	1	37
Total	86	75	10	5	176
Percentage	48.9	42.6	5.7	2.8	100.0

TABLE 4

Contribution of Academic Laboratories

Academic Institution	Number of Papers	Percentage of Total
Northwestern	26	30.2
Johns Hopkins	8	9.3
Arkansas	5	5.8
M. I. T.	4	4.7
Pennsylvania	4	4.7
28 Others*	39	45.3
Total	86	100.0

*Alfred, Brown, Chicago, Chicago Medical, Caltech, Columbia, Delaware, Georgia Tech, Grinnell, Illinois, Indiana, Iowa State, Kansas State, Lehigh, Marquette, Minnesota, N.Y.U., Pittsburgh, Princeton, Purdue, Rice, St. Joseph, Tennessee, Texas, Tufts, U.C.L.A., Virginia, Washington.

Table 5 shows a similar breakdown for the industrial laboratories. Eleven papers each were produced by Gulf and Socony. Esso was responsible for 10; Shell, General Electric, and Texaco each for 5. Thus the six named industrial laboratories contributed 47 of the 75 papers, which amounted to 62.6 per cent. Twenty-two other industrial laboratories contributed the rest of the 28 papers. These laboratories are the following: Abbott, Atlantic, Bell, Calresearch, Corning, Cyanamid, du Pont, Ford, General Dynamics, Houdry, Kellogg, Linde, Monsanto, Phillips, Rohm & Haas, Sinclair, Sohio, Standard of Indiana, Union Oil, U.O.P., Union Carbide, and Westinghouse.

TABLE 5

Contributions of Industrial Laboratories

Industrial Laboratory	Number of Papers	Percentage of Total
Gulf	11	14.6
Socony	11	14.6
Esso	10	13.3
Shell	5	6.7
General Electric	5	6.7
Texaco	5	6.7
22 Others*	28	37.4
Total	75	100.0

*Abbott, Atlantic, Bell, Calresearch, Corning, Cyanamid, du Pont, Ford, General Dynamics, Houdry, Kellogg, Linde, Monsanto, Phillips, Rohm & Haas, Sinclair, Sohio, St. of Indiana, Union Carbide, Union Oil, U.O.P., Westinghouse.

The final table, number 6, shows the contributions of the foundations and government laboratories. As you see, there are only two, Mellon and Stanford, under the foundation category; and four, Oak Ridge, AEC, Bureau of Mines, and Signal Corps, in the government category. I might mention that the two Oak Ridge papers were written in collaboration with the University of Tennessee.

TABLE 6

Contributions of Government and Foundation Laboratories

Laboratory	Number of Papers	Percentage of Total
(A) Government		
Oak Ridge	6	60
Three others*	4	40
Total	10	100
(B) Foundation		
Mellon	4	80
Stanford	1	20
Total	5	100

*Atomic Energy Com., Bureau of Mines, Signal Corps.

APPENDIX D

DESCRIPTION OF A FRENCH INSTITUTE FOR RESEARCH IN CATALYSIS

The Institut de Recherches sur la Catalyse is located in a building recently constructed for it in Villeurbanne (Rhône), a suburb of Lyon. Some of its support comes from the university, some from the Centre National de la Recherche Scientifique (CNRS), and some from industry.

There are two professors, Prettre and Teichner, both of them salaried by the university. Prettre is the director. There are two associate professors (maitres de recherche) provided by CNRS, and twelve assistant professors (charges de recherche), ten of them paid by CNRS and two of them by the university.

There are 30 to 35 technicians, among them ten mechanics, glassblowers, etc. The university pays for a few, CNRS, the rest.

There are 60 doctoral students, all of whom have the degree of ingénieur chimiste, which is similar to an M.S. Of these, 50 per cent are supported by CNRS, the rest by industry—including government-owned industry. The industry-supported student works on a problem of interest to his sponsor, and is obligated, by contract, to work five years for his sponsor after receiving his doctorate.

CNRS has given the institute an equipment grant of one million new francs each year since 1958. The institute is very well equipped, but feels somewhat strapped for running expenses. It gets 400,000 new francs per year from CNRS, which is too little; it is supplemented by about 100,000 new francs from industry. In particular, industry provides an overhead of 2,000 new francs for each student sponsored.

We owe our thanks to Professor M. Prettre for most kindly supplying information on his institute.

APPENDIX E

DELIBERATIONS OF COMMITTEE I

The committee to discuss a catalysis institute consisted of Drs. Chitwood, Danforth, Eischens, Hansen, Hansford, Hofer, Hulbert, Keough, McKee, Oblad, and Siegel. Dr. A. Farkas acted as chairman.

The objective of this committee was to answer questions of the following type.

> What would be the effect of the proposed action (establishing a national institute of catalysis) upon the amount and the quality of the work done in fundamental aspects of catalysis?
>
> What would the effect be on the training of new workers?
>
> Would the proposed action stimulate interdisciplinary research?
>
> What would be the effect of the proposed action upon basic research in industry?
>
> What would be the optimum form of the proposed national institute of catalysis?

The committee was to consider the proposal for a national institute by Drs. Oblad, Emmett, and Turkevich, but was not bound by any details of their proposal. The committee was at liberty to recast the proposal for a national institute in any way it thought best.

The chairman emphasized the importance of defining accurately the scope and objectives of research by the catalysis institute, including the teaching aspects of the institute. The question was also brought up as to whether the institute, as proposed, would coordinate research efforts carried out inside and outside the institute (see p. 5, para. 2, of the original proposal).

First, Dr. Oblad reviewed briefly the proposal, entitled "A National Institute for Catalysis in the U.S." The proposed institute's association with a university was discussed in detail. It was generally agreed that the granting of degrees based on work performed at the institute would be practically impossible unless the institute were part of an established university. The discussion of this point brought out that various problems arise from this type of association, and the relation of the Mellon Institute and the University of Pittsburgh was cited as an example. Views were divided as to whether the teaching activities should be part of the institute's activities from its inception, or whether the initial activities of the institute should be restricted to research, teaching to be taken up at a later stage.

After extensive discussion, the majority favored an institute modeled after the Institute for the Study of Metals in Chicago, in which the key staff members carry faculty appointments.

A minority held that while the association with a university is highly desirable, the institute should retain a high degree of autonomy, and possibly have a number of senior full-time employees without faculty appointments.

It was agreed that if the institute were associated with a university, then tenure, salary, employment conditions, policy on consulting and patents, etc. would have to be in accord with the conditions prevailing at the associated university.

Another problem in an academic institution arises from the need for cooperation among staff members. It is a basic concept of the institute to direct interdisciplinary effort toward solving problems in basic catalysis. This necessitates close consultation and cooperation among various staff members and the selection of a common objective, at least for part of the effort. Academic researchers are used to freedom in selecting and pursuing a research objective and may object to any cooperative effort. However, it was brought out in the discussion that the personnel of the institute would be selected in such a manner that a cooperation of this type would be possible without jeopardizing individual creative effort. It was also thought that the establishment of the institute itself might create the team spirit necessary for a concerted action. A certain part of the researchers' effort could be spent on their individual problems following their own approach.

Organization of the Institute

In order to ensure the basic objective of the institute, it will be necessary to have an outstanding director who will skillfully select

the staff and make sure, without exerting undue pressure, that the cooperative and concerted effort of the institute is maintained. It was pointed out that the examples of institutes mentioned on page 6 of the proposal are laboratories, whose members are not on the faculty of the university with which the laboratories appear to be affiliated. Dr. Oblad assured the committee that the mentioned laboratories were selected as examples in a more or less arbitrary manner and were not meant to set the pattern of the proposed Institute of Catalysis.

It was agreed that sufficient control over the program of the individual senior researchers would be effected by their selection and by the extent of funds authorized for their research work. Of course, there is always a remote possibility that a staff member originally interested in catalysis would lose interest and turn to research unrelated to catalysis. In this case, the person could not be discharged if he had tenure; his activity could be considerably limited by allotting him only a minimum budget.

The original proposal provided for 20 permanent senior members on the staff of the institute. It was thought that such a large number of individual researchers might be unwieldy for a concerted effort, and that probably they should be grouped in five or six departments.

Dr. Oblad assured the committee that no over-all coordinating activity of the institute was contemplated and outlined the proposed establishment of the institute as follows:

First, an advisory board would be established with prominent scientific leaders as members. The members of the board would be interested in catalysis but need not be active in "catalytic" chemistry. The advisory board would define the broad objectives of the institute and select its location. The board would also spell out the proper way for achieving this objective and select the director. The director would then in turn select the personnel with the approval of the advisory board.

Dr. Hansen pointed out that this procedure would be unsatisfactory from the point of view of the university with which the institute would be associated. As a rule, the university makes the selection and announces the appointment of its faculty members. The obvious way out of this dilemma would be the selection of senior personnel by the director and concurrence of the university authorities in his selection.

A considerable amount of discussion was devoted to the selection of the university with which to associate. The consensus was that

while some famous and well-known universities may set stiff conditions for the association, other universities may welcome and actually bid for it. The latter class of university would, of course, include smaller and lesser known universities; but it is very likely that some first-rate university, for one reason or another, will be anxious to have the institute of catalysis located on, and associated with, their campus. The selection of the proper university for the indicated association will be one of the most important, and probably most arduous, tasks of the advisory board of the institute.

According to the original concept, the institute should be financed by industry, government, and private funds in approximately equal proportion so that none of the organizations providing funds would have an undue influence on policies and objectives.

The ideal situation would be to secure the necessary endowment, approximately 50 million dollars, from a single source—an impressive but not entirely unlikely objective. Several members of the committee, considering the great involvement of the government in fundamental research, thought the government or its agencies the most likely source for the necessary funds. In a general way, it was thought that the more agencies involved in providing the funds, the more restrictions on the operation of the institute. An individual donor or group of donors might donate the funds so that the building could be named after a person selected by the donor or donors.

Scope of the Institute

The study of the fundamentals of catalysis cuts through so many disciplines and areas of general chemistry that very strict definitions of the scope of the institute might be undesirable. However, it was agreed that heterogeneous catalysis needs special study since other closely related areas, including homogeneous catalysis, enzyme chemistry, and polymerization, appear to have received sufficient attention. Therefore, it seems desirable to focus the attention of the institute on heterogeneous catalysis without completely excluding any area of catalysis or peripheral disciplines which may elucidate heterogeneous catalysis.

The availability of modern instruments and techniques for the study of heterogeneous catalysis, solids and surface reactions, in one single location was thought of great importance in accomplishing the objective of the institute.

Patents

In accordance with the proposal, the institute would not work towards patentable processes nor would it take out patents, as a rule. However, if and when, in the course of fundamental studies a process or product of obvious economic value is developed, the institute would take out patent protection. While the provisions for the disposal of income from such patents as outlined on page 9, section 5, last paragraph of the proposal, appear equitable, it was decided that the patent policy should correspond with practice at the associated university.

Effects of the Institute on Research

Opinion was practically unanimous that the institute would increase the quantity and quality of fundamental catalysis research.

First, through cooperation and daily contacts, the scientific staff will deepen its interest and insight into catalytic problems. The availability of modern equipment and techniques will intensify their research effort, too.

Second, the establishment of the institute will attract new workers from peripheral fields.

Third, the training effort of the institute will familiarize more workers with the techniques and problems of catalysis, even before the formal graduate program is initiated.

The establishment of the institute will also raise the level of the industrial research by focusing interest in catalysis and by providing trained workers.

It was noted that it would be unfortunate if staffing the institute were at the expense of industry and the senior positions were filled by key industrial researchers. The director of the institute will need to recruit skillfully, patiently, and tactfully so as not to generate ill will.

APPENDIX F

DELIBERATIONS OF COMMITTEE III

Committee III was charged with exploring remedies for the inadequacies of research in catalysis not discussed in committees I and II.

The committee spent considerable time deliberating the various conditions under which catalytic research is carried out. Established academic investigators generally have more money than they can spend; their main problem is obtaining man-power to work on projects. In this respect, heterogeneous catalysis suffers a great deal from competition with "more glamorous" fields of research. The established workers in catalysis in universities also feel that the university system makes the hiring of technicians for supporting work very difficult. Special arrangements have been worked out in only a few cases.

Younger workers in catalysis do not, as a rule, have sufficient financial support. In many instances there are more students than money to support them, largely because the donor agencies are reluctant to allocate money until a man has proven himself.

Industrial research in catalysis suffers in general from lack of continuity. This may be due to pressure from other development projects, impatience with long-term research, and variable management attitudes toward basic research. A number of committee members supported the thesis that a substantial improvement would result if fundamental research in industrial laboratories could be conducted on a tax credit basis.

The main difficulty in heterogeneous catalysis research appears to be in bringing together persons from different disciplines and in creating enthusiasm and proper communications. Each discipline requires the efforts of a top-notch man in his field. As a rule, such men do not respond well to pressures from other disciplines to provide the answer for a specific problem. The situation is equally true in industry and in universities.

These problems are not the only ones facing heterogeneous catalysis, just the ones mentioned most frequently. The committee felt

that most of these difficulties should be alleviated by any new approach. Again recognizing that a national institute of catalysis or a multi-center system presents a possible solution, but not for this particular committee, the committee conceived of an agency, composed of people well versed in the needs of heterogeneous catalysis. It would serve as a focal point for efforts to alleviate the existing difficulties. This agency would not seek to build new buildings nor to create an inflexible system inhibiting changes in disciplines or directions of the work.

The ideal agency would have at its disposal funds from an unknown source, and these funds would be dispersed to individuals whose efforts in heterogeneous catalysis appeared to provide the best approach to the finished product. The question is immediately asked, "Why interfere with the existing funding agencies, such as PRF, NSF, and many others?" The main objection to the existing agencies is the shot-gun effect when funds are given not on the basis of the work needed, but on the basis of a proposal submitted by an investigator. It is not surprising that such proposals draw immediate and violent ire from the academic people, who resent being told what to do. This is not the object of such an agency, and much of the spirit of this discussion was lost in semantics. On the other hand, to some members of Committee III, it appeared strange that the same people who abhorred the idea of an agency sponsoring certain general fields of research approved the idea of an institute of catalysis to tell them what to do if the different disciplines are to be reconciled or coordinated.

The over-all result of the discussion by Committee III was a resolution reading as follows:

> Establish a funding agency to increase the extent of fundamental research in heterogeneous catalysis at established universities, colleges, government agencies, and industrial and institutional laboratories.
>
> This is to be an active agency, with power to propose areas of research as well as to receive proposals for research projects.
>
> Prudent financial responsibility will be exercised by the funding agency in making grants and monitoring contract activities. There will be no restrictions on publications, and the results should be made public.

Suggestions for initial policies include:

1. giving special attention to needs of young investigators in heterogeneous catalysis, from both academic and industrial origins.

2. providing for specific means of stimulating interest in catalysis at all levels of education, including encouragement of education of junior partners on projects.

3. emphasizing continuity of support of active investigators.

4. considering means of making the investigator's work more effective.

5. encouraging the exchange of information in catalysis.

The funding agency shall be composed of scientifically qualified representatives from academic, industrial, and government institutions. The membership is on a three-year staggered rotating basis. The need for an agency is to be periodically reviewed by the National Academy of Sciences—National Research Council.

In subsequent discussion of the proposal, a number of other suggestions were made. Dr. Halpern suggested using existing government facilities for catalysis research. As pointed out in a number of supporting statements, such a proposal does make some sense, because man-power and equipment and buildings are available, or may be available, for such work. The proposal has a number of disadvantages. For example: (1) Continuity is not assured. (2) Government support is not assured. (3) It may be difficult to create the proper interest and enthusiasm. (4) Many desired disciplines may be lacking. Such a proposal could be an adjunct to the proposals from Committees I, II, and III.

APPENDIX G

VOTES CAST BY MEMBERS OF CONFERENCE

	Resolution: Inadequacy of Research	(1) National Institute	(2) Multi-Centers	(3) Funding Organization	(4) Addition to National Laboratory	Preference
Boudart	yes	no	yes	no	no	2
Burwell	yes	yes	no	no	yes	1,4
Carberry	yes	yes	yes	no	yes	2,1,4
Chitwood	yes	yes	yes	no	yes	1,4,2
Ciapetta	yes	yes	yes	no	no	1,2
Danforth	yes	yes	abstain	no	yes	1,4
Eischens	yes	yes	no	no	yes	1,4
Farkas	yes	yes	no	no	yes	1,4
Emmett	yes	yes	yes	no	no	1,2
Germer	yes	yes	yes	no	yes	1,4,2
Greensfelder	yes	abstain	yes	yes	no	3,2
Haensel	no	no	no	yes	yes	3,4
Hall	no	no	yes	yes	no	2,3
Halpern	yes	yes	no	no	yes	1,4
Hansen	yes	yes	no	no	yes	1,4
Hansford	yes	yes	yes	no	yes	2,1,4
Hirschler	yes	yes	yes	no	yes	2,1,4
Hofer	yes	yes	no	no	yes	1,4
Hulburt	yes	yes	yes	no	no	1,2
Keough	yes	yes	yes	no	no	1,2
MacIver	no	no	yes	yes	no	3,2
McKee	yes	yes	yes	no	no	1,2
Oblad	yes	yes	no	no	no	1
Parlin	yes	no	yes	no	no	2
Parravano	yes	no	yes	yes	no	2,3
Peri	yes	yes	yes	no	yes	2,1,4
Pines	yes	yes	yes	no	no	2,1
Reid	yes	no	yes	yes	no	3,2
Siegel	yes	no	yes	no	yes	2,4
Smith	yes	yes	yes	no	yes	2,4,1
Taylor	yes	yes	yes	no	yes	1,4,2
Weisz	abstain	yes	yes	yes	no	2,1,3

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