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<i>The American Association for the Advancement of Science:</i>	
<i>Some Present Aspects of Chemistry in the United States:</i> PROFESSOR B. F. LOVELACE.	139
<i>An Ancient Skeleton discovered in Ecuador:</i>	
DR. MARSHALL H. SAVILLE.....	147
<i>Scientific Events:</i>	
<i>The Mulford Biological Exploration of the Amazon Basin; Educational Forestry; Lectures at the University of Michigan; Booklets of the American Association for the Advancement of Science.....</i>	148
<i>Scientific Notes and News.....</i>	150
<i>University and Educational News.....</i>	152
<i>Discussion and Correspondence:</i>	
<i>Another high-temperature Record for Growth and Endurance:</i> DR. D. T. MACDOUGAL AND EARL B. WORKING. <i>A Calculator for converting Gas Chain Voltage into Equivalent C_{H_2} or p_H Values:</i> DR. PAUL E. KLOPSTEG. <i>Mathematics in Spanish-speaking Countries:</i> PROFESSOR G. A. MILLER. <i>The Earliest Bees, Wasps and Ants:</i> PROFESSOR T. D. A. COCKERELL	152
<i>Special Articles:</i>	
<i>The Pneumatic Paradox in Acoustics:</i> PROFESSOR CARL BARUS.....	155
<i>The Kentucky Academy of Science:</i> ALFRED M. PETER	156

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SOME PRESENT ASPECTS OF CHEMISTRY IN THE UNITED STATES¹

It has often been observed that those living in the midst of great events sometimes fail to understand the far-reaching effects of the occurrences going on around them. During revolutionary times attention is so riveted upon the single occurrences which follow each other with bewildering rapidity that the participants often fail to view the succession of events as a whole and thus miss their full significance. Revolution is scarcely too strong a word to apply to the changes relating to chemistry which are taking place in this country. The very great impetus which the science of chemistry has experienced during recent years brings with it a series of problems vitally related to the science as a whole, to our educational institutions and to industry.

It seems appropriate that on this occasion we might with profit, to borrow a business expression, take stock of the present situation. I shall therefore endeavor to give a brief and partial analysis of the outstanding features of the existing conditions, which are more or less confused, and lay down a few broad principles which appear to offer a sound basis of future development.

The events of the past five years have exerted a profound influence not only upon chemistry but upon various other sciences represented by the American Association for the Advancement of Science. To meet the critical situation presented in 1914 and the more critical condition in 1917, the country called to its service the entire scientific resources at its command and nearly every branch of science contributed something, either directly or indirectly, to aid in the solution of the pressing problems presented. The geologist was called

¹ Address of the vice-president and chairman of Section C, of the American Association for the Advancement of Science, Chicago, December, 1920.

upon to reexplore the natural resources of the country and to find, if possible, within our own borders raw materials which we had formerly imported, and many important and unexpected discoveries were made. The physicist was presented with a host of problems, problems in light, in sound, in electricity, in wireless transmission, etc., and in the attempt to solve these problems contributed materially to the advancement of our cause and to the general welfare. The engineer, working in conjunction with the physicist and chemist, gave body and substance to the discoveries of the latter, and gave besides an example of the power of concentrated and intelligent effort to solve engineering difficulties of all kinds, which won the admiration of the world. The various branches of medical science, represented by the physician, the surgeon, the physiologist, the pharmacologist and others, all rendered a service of inestimable value, the memory of which will long be enshrined in the thought of the world. I refer not only to the direct service in mitigating immediate human suffering, but also, and more important even than that, to the advances in medical science which were made. And so we might call the roll of the sciences and each could respond with a record of achievement, of things actually accomplished for the welfare of our country and the world.

It is perhaps true that no branch of science was given the opportunity of rendering more conspicuous or more vital service than that of chemistry. It is scarcely too much to say that for a period of two years the whole orderly course of scientific research in chemistry was suspended. In 1917 the country was confronted with a very large number of practical chemical problems, some of them of an extremely complex and difficult nature, the prompt solution of which was imperatively demanded. These problems may be grouped under two general heads. Since foreign sources were to a large extent cut off as early as 1914, we were faced with the task of supplying the ordinary everyday needs of the community for the vast number of substances in the manufacture of which chemistry played an essential

part, and these problems were far from being satisfactorily solved in 1917. The second group included the multitudinous problems which had to do directly with the prosecution of war. In order to meet the situation thus presented the critical nature of which could hardly be exaggerated, practically the entire research and manufacturing facilities of the country were drafted. The extent to which the research personnel of the country was drawn into some branch of industrial or war work was truly amazing. Never before had this country witnessed such intensive chemical effort. For the industrial chemist it did not as a rule call for any very radical change in the nature of his work. To him it meant, in the main, redoubled effort in the line he was accustomed to, or in related lines. But for the large number of university men who were able to give a portion or all their time, the change was more radical. In many cases they abandoned, for the time being, the researches upon which they were engaged and addressed themselves to the solution of certain definite problems, not chosen by themselves, but presented by the exigencies of war. These men came from various colleges and universities in all sections of the country and for nearly two years gave themselves over to an entirely new experience, viz., an intensive study of definite problems which were essentially industrial in nature, in that they were in most cases directed toward ultimate large scale operation. After working out a particular problem in the laboratory it then became necessary, with the cooperation of the engineer, to put the process being developed through the various stages leading finally to large scale production.

The very great chemical activity which characterized this period and particularly the conspicuous success which was attained by the chemist in the solution of many of the difficult problems presented to him have had important results in several directions.

1. The chemist finds himself in a more favorable position than he formerly held in the eyes of the general public. It was not so very long ago that to the average man in the street,

the terms chemist and drug-clerk were synonymous. The educated non-technical man however was better informed. Asked for a definition of a chemist, he would reply, Oh! he is a curious fellow who can look at a rock and tell you what it is made up of! When one considers the fundamental importance of the work of the chemist to the everyday life of every individual in the community, that his work enters into everything he wears, eats, drinks, reads, works with and plays with, it is really astonishing that the public at large has had so little appreciation of him. It must be remembered, however, that in the past few opportunities were afforded to the average citizen, and no encouragement, to learn what the chemist meant to him. It was not so very long ago that the most widely disseminated chemical information was that furnished by the Sunday supplements of certain newspapers. And it will be recalled that they appeared to be particularly fond of describing such experiments as the extraction of gold from sea water, and others of a similar type, generally giving a more or less grotesque idea of the chemist and his work.

The education of the public as to the importance of chemistry to the community began in the fall of 1914 when it suddenly discovered that it was dependent upon other countries for many things chemical which were necessary to its daily comfort and convenience. And the temporary lack of things to which all were accustomed, and for which they were told to wait upon the chemist, did much to raise the latter in the public estimation. And when the promised articles began gradually to appear, in increasing quantity and with steadily improving quality, the chemist was still further raised in public esteem.

The second lesson came with the war. The ordinary citizen came to realize, as he had never done before, that in modern warfare the most powerful weapons of offense and the most effective means of defense are literally the products of the laboratories of scientists. Thanks to the introduction of what came to be known as chemical warfare, the late war be-

came to a very large degree a contest between the chemists of the opposing countries. And a vivid knowledge of this fact was brought home to the people in a variety of ways.

Recognizing the fact that, under a republican form of government, the widest possible dissemination of popular but exact information concerning a particular science is a matter of fundamental importance to that science, the American Chemical Society several years ago authorized and provided for the establishment and maintenance of an official news service, known as the American Chemical Society News Service. The chief function of this service is to furnish, at frequent intervals, to all the important newspapers throughout the country for publication, short popular articles on chemical subjects. The space given by the newspapers to these articles, while not all that might be desired, is gratifying in that it evidences an interest, and let us hope it will prove an increasing interest, on the part of the people generally in a subject which is of such great importance to the general welfare.

2. A second and very much more important change which has been taking place during the past five years is a growing appreciation of the value of research on the part of those concerned with chemical industry. Some of the larger and more progressive concerns, whose policies are dominated by men of scientific training, have long followed a liberal policy in regard to research. They have been sufficiently far sighted to recognize the possibilities of research in the utilization of by-products, the development of new processes and the improvement of old ones. Their experience has amply justified the financial wisdom of such a policy. A larger number of concerns have maintained research departments of a more limited scope, their activities being confined to the more immediate and obvious problems of plant operation. Then we have had a very considerable number of chemical plants in which no research chemists at all were employed. There has been in the past a surprising number of plants which were operated, in effect, upon the idea that

it would not be profitable to try to discover anything new about the chemistry of the processes being carried on.

Very rapid changes have been taking place in this respect during the past few years. The demand for research chemists in the industries has been stimulated by a variety of causes: the desire, in many cases at the instance of government, to increase output and extend operations into new lines, the stimulus to new enterprises afforded by the general shortage of chemicals, and, perhaps most important of all, the conspicuous success which has attended the efforts to solve various important and difficult chemical problems. It is worthy of note in this connection that in a number of instances discoveries of very great practical importance to industry have been made by university professors to whom contact with industrial chemistry brought about by war conditions was an entirely new experience.

Whatever other influences may have contributed, the result is that the industries are calling more insistently and for greater numbers of thoroughly trained and experienced research chemists than ever before and in consequence the universities and colleges of the country, along with other research institutions, are confronted with several very serious problems. In the main the Ph.D. graduates in chemistry, after completing their training, go into one of three lines of work. Some of them go into college teaching and in the past this field has absorbed a very considerable proportion of them. Others whose liking for pure research has been the determining factor in their choice have gone either into government service or to research institutions, educational and others. This choice has usually entailed being content, at least for a period of years, with a smaller financial return for their work than might have been expected in other fields. The remainder have gone into industrial work. As a result of the rapidly increasing proportion going into the last named field, the colleges particularly are finding it difficult and, in many cases, impossible to secure the services of properly trained men.

Those connected with graduate institutions which are the source from which the colleges draw their teachers are in the best position to appreciate how serious the present condition is. Many times during the past twelve months the chemical department of the Johns Hopkins University has been compelled to reply to urgent calls for teachers that there were no men available. The seriousness of the situation is accentuated by the fact that, not only do the industries want the best and most promising men, but they are willing to pay larger salaries than the colleges and universities, with their limited endowments, can hope to pay and larger also than those obtaining in government research laboratories. The inducements offered by the industries are in fact frequently attractive enough to win over men all whose inclination is toward teaching and pure research.

There is another phase of the situation which is equally serious. Not only are the industries absorbing an undue proportion of young graduates, so much so that the universities and colleges find it impossible properly to fill various teaching and research positions, but in a good many cases they have invaded the research faculties in the universities themselves. To the university teacher the temptation to enter the industrial field is made very great by reason of the difficult economic situation in which he finds himself. The moderate increases in salary which have been recently granted by most of the institutions of the country have been entirely insufficient to offset the decreased purchasing power of the dollar and the economic position of the teacher, never particularly enviable, has been for the past three years considerably worse than formerly. The temptation to improve their economic positions has induced a number of men to abandon their university careers for industrial work, with consequent crippling of the research work of the institutions concerned. A perhaps larger number of university professors of chemistry have adopted a compromise. To supplement an inadequate income they have been devoting their summer vacations to industrial work, and in many

cases acting in an advisory capacity to their employers while they are carrying on their regular university work. The perils in such a situation from the standpoint of the university and the cause of pure science, some of them obvious and others not apparent, have been discussed several times and will be referred to a little later.

We come now to the consideration of another phase of the present situation. An active discussion has been going on for several years having to do with the general subject of the relation of the universities to the community. The particular part of this discussion with which we are concerned is that pertaining to the relation of the departments of chemistry in the university to the chemical industries.

However much some of us may be inclined to cling to our old ideals, I think most of us will agree that the idea long held of the university as a seat of learning for learning's sake is gradually giving place to a new conception of the university as a utilitarian institution. To appreciate the change that has already taken place one need only visit the class rooms of any large institution and see the handful of students taking Greek, for example, while in any subject having a direct practical utility, huge lecture rooms are filled to overflowing. Many colleges and universities have endeavored to uphold the old ideals and have continued to maintain the old chairs, and a few students continue to take these so-called cultural courses and always will so long as they are offered, but it remains true that the great majority of the students are interested mainly in those subjects which have a definite practical value. This is true of both graduate and undergraduate schools. And of necessity the departments dealing with subjects which are of practical value to the student in after life are receiving relatively greater, and increasingly greater, financial support from governing boards. Thus our higher institutions of learning, and particularly the graduate departments, are apparently tending to become, in fact, professional schools; that is, institutions in which men and

women receive specialized training which fits them for a particular kind of work. This development is perhaps not so much the result of the adoption of a definite policy by those in charge of such institutions, but rather comes from the demand on the part of the students themselves. The students want such courses and, if a particular university will not give them, they will go elsewhere. The very great popularity of chemistry in the colleges and universities throughout the country is not due to a widespread scholarly interest in the science itself, but arises from the facts that chemistry is fundamentally related to the welfare of the community and that a thorough knowledge of the subject opens the door to an attractive profession.

We have already pointed out that most of the graduate students in chemistry in the universities may be grouped under three heads:

1. Those looking forward to professorships of chemistry in colleges, in which their chief work will be the teaching of chemistry to undergraduates, with limited opportunities for research.

2. Those looking forward to careers of research in pure chemistry, either in universities or other research institutions.

3. Those expecting to become industrial chemists.

So long as the university had to do mainly with students of the first two groups, there was no particular difficulty in providing suitable instruction for them without in any way endangering the ideals of the university laboratory as a place set apart from commercial considerations and devoted, with singleness of eye, to the cause of the advancement of science for the common good. The course of instruction generally adopted by American universities required for its completion three or more years' work subsequent to the bachelor's degree. A part of this time was devoted by the student to acquiring a knowledge of the fundamental facts and principles of the science, after which he was required to spend one or more years in actual research under guidance.

The rapid increase in the number of stu-

dents falling under group 3, that is, those who come to the university with the idea of going into industry, raises, in addition to those problems already referred to, a number of others of equally vital importance to the universities and to the industries themselves.

1. Unless all signs fail, the demand for chemists for the industries is not a temporary one, but will continue and in all probability increase. The country has definitely set out to develop its chemical industries, the goal sought being nothing less than chemical independence. The realization, even if it is not altogether complete, or falls short of our present hopes, will call for a continuous supply of chemists. The enhanced popular interest in the subject may also be expected to produce an increased demand for chemists in college and university positions. It seems certain therefore that the graduate departments of chemistry (and undergraduate as well), already in many cases among the largest in their respective institutions, must look forward to a considerable increase in the number of students applying for instruction each year. This will entail problems of enlargement of buildings and other additions to material equipment, increase of teaching personnel, possible additions of new courses, etc. But these are questions which mainly concern boards of trustees and I will not discuss them here.

2. A group of problems are presented having to do with the content of the courses offered for graduate students. The graduate courses that have been given in the past were developed along broad theoretical lines without particular reference to the training of men for the industrial field. The attempt was made to give the student as broad an acquaintance as possible with the basic facts and principles of the science of chemistry and in addition a knowledge and experience of the methods of research.

Now, inasmuch as the industries are dependent upon the universities for the training of the chemists which they require each year in increasing numbers, it is only natural that they should concern themselves with the character of instruction given. And inasmuch as

one of the functions of the university is to train men for the industrial field it is only proper that those charged with the responsibility of this training should inquire whether or not the students are receiving the kind of instruction and experience that best fits them for their future work. The question therefore whether the chemical departments of the universities are giving the best kind of training to those who are to go into industrial work is entirely proper and the correct answer is of vital importance to the university, to the science of chemistry and to chemical industry.

Now there are a number of people among both teachers and employers of chemists, who believe that the present methods of university instruction could be materially changed to advantage so far as the future work of the industrial chemist and chemical industry are concerned and various suggestions have been put forward, most of them with the idea of making the work more "practical" in character. It is said that the present method and scope of university teaching make the Ph.D. graduate too theoretical and impractical; that when he goes into the plant he is at a loss because he has learned to think only in terms of small scale reactions and because he has no knowledge of engineering and therefore no appreciation of the mechanical difficulties that always appear when you go from the laboratory to large scale production. Hence it is concluded that the kind of chemist the industries need is one who is also an engineer. Hence the growth of a large number of institutions in the country in which a high-school graduate is put through a training embracing four or five years, taking various courses in mathematics, physics, engineering and chemistry, is given a bachelor's degree and sent into the industry. However valuable in a chemical plant men of this training may be, their outlook upon chemistry as a whole is entirely too limited to make them of any great value in the research laboratory. If our country is to realize its dream of chemical independence, our industries must have available and must employ large numbers of chemists of the highest quality, characterized by breadth

of chemical training, familiarity with chemical literature, enthusiasm for research and, above all, a thorough understanding of theoretical principles, which alone gives the investigator the ability to interpret observations and devise sound and effective methods of attack. The above qualities are essential to the research chemist, regardless of whether he is in an industrial or a university laboratory. For in the development of an industrial process, the first stage is in the laboratory and here the problem differs from a problem in "pure" research only in one particular, viz., that it is directed toward a definite commercial object. The same thoroughness should be sought, the same methods employed and precisely the same qualities on the part of the investigator are necessary.

Those of us therefore who are charged with the responsibility of university instruction in graduate chemistry should set our faces against the tendency in evidence around us to place the emphasis in teaching upon the practical, necessarily at the expense of the fundamentals.

This does not in any sense mean that university laboratories should avoid attacking problems the solution of which is of importance to industry. On the contrary, one of the happy developments of the past few years has grown out of the opportunity which has been afforded to large numbers of university professors to get in close contact with some of the problems of commercial chemistry. Many of these problems, of fundamental and far reaching importance to the industries, have been taken into the university laboratory and the professor brings to their study his ripe knowledge and experience, his patience and resourcefulness which, combined with the material facilities at his command, offer the promise of sure progress in their solution. Already substantial contributions along a number of lines have been made and we may confidently look forward to greater achievements in the future. The universities may very properly take advantage of the opportunities thus presented to render a high service to the community. But there are also dangers

inherent in the situation. While rendering this service, we must sedulously avoid sacrificing the ideals of pure science. We must keep out of our university laboratories the spirit of commercialism and not allow our interest in these problems of applied chemistry to lessen our interest in the large number of even more fundamental questions which happen to be of less immediate practical importance.

In the foregoing discussion we have partly anticipated the answer to a question which has been frequently discussed in recent years. I refer to the matter of cooperation between the universities and the industries. How can the university laboratory render the most valuable service to chemical industry? How can industry cooperate with the university to the end that the interests of both may be best served? It must be clear that these interests are mutual; more particularly, that any plan which enables the university more effectively to perform its function of advancing scientific knowledge and training chemists will be beneficial to industry and anything which interferes with or in any way hampers the university laboratory in the performance of these primary functions must ultimately be harmful to industry.

Recognizing the importance of this question and fully conscious of the wisdom of properly guiding the movement already under way looking toward a closer relation between the universities and the industries, the American Chemical Society, under the recent presidency of Dr. Stieglitz, authorized the appointment of a committee to study and report upon the subject. The committee consists of leading educators and representatives of industry and I believe is still engaged in studying the question in the effort to formulate a plan by which the desired ends may be accomplished without injury to the university.

The opening paragraph of a tentative report made by the committee reads as follows:

The most important contribution which the universities can make to the development of industry in this country is to supply the industries with sufficient numbers of men thoroughly and

broadly trained in the principles of chemistry. All other considerations must be subservient to this fundamental purpose.

This is a thoroughly sound principle and if it is accepted fully and made a guiding policy by both the university faculties and the industries it will constitute a touchstone by means of which the quality of any specific proposal may be tested. It must be clearly understood that if men are to be "thoroughly and broadly trained in the principles of chemistry" emphasis must be laid upon a good many things of which we can not *at present* point out any very direct practical application to industry. The fact is, however, that the number of these abstract questions emphasized by university teachers that have no bearing upon the problems of commercial chemistry is not nearly so large as the practical man believes. In other words, chemical industry lags considerably behind chemical science. The discovery on the part of industry that it has not been utilizing the chemical knowledge which has been available all along, carefully recorded in the literature, is really one of the outstanding events of the last five years. This is the explanation of the greatly increased demand for trained chemists. Their chief efforts will be directed, not so much toward original research, but rather toward applying what is already recorded to the practical problems of the plant.

The second paragraph of the report deals with "the strong tendency at the present to draw men, who have been particularly effective in research work, away from the universities by the payment of salaries far in excess of the salaries paid the same men in a university." In view of the considerable number of younger men of great promise who have in consequence been induced to abandon their university careers, the report goes on to say that "it seems evident that unless a very considerable increase in the salaries of teachers of chemistry can be secured, the next generation of chemists is likely to be trained by a set of mediocre men. Such a result would be disastrous to our industries and every possible effort should be made to meet this danger."

As to the various specific proposals for cooperation that have been put forward they should all be tested by the touchstone mentioned, and if this is conscientiously done it seems to me that no very great difficulty will be experienced in reaching wise decisions. There would seem to be no possible objection to the endowment of fellowships in the universities, similar to the duPont fellowships, which leave the student and the instructor entirely free in the choice of the subject of research and which carry no restrictions in the matter of publication of the results.

Fellowships designed to promote the solution of problems for the benefit of a particular industry, it seems to me, may be safely accepted by the university, but it should be clearly understood: (1) That the subject of investigation should be of fundamental importance to the industry as a whole; (2) that the instructor and student must be left entirely free in deciding upon the method and scope of the investigation; (3) that there must be no secrecy attached to the work; and (4) that the results should be published for the benefit of the industry as a whole within a reasonable time.

It seems to me that other kinds of fellowships proposed, of a private character, for example, a fellowship endowed by a single firm for its exclusive use, either for a limited or indefinite period, would be attended with grave dangers to the university. Aside from other considerations of equally vital importance, one of the most invaluable and inspiring features of the university research laboratory, viz., the entire freedom from restrictions which prevails, would be lost by the introduction of a system of private fellowships. Each worker, while he is interested mainly in his own particular subject, needs the inspiration which comes from contact with his fellow workers, and to deny him the privilege of learning what those around him are doing is to take from him a thing of inestimable value and for which there is no substitute.

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