

The Dedication of the New Chemistry Building, University of Illinois

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THE DEDICATION OF THE NEW CHEMISTRY BUILD- ING, UNIVERSITY OF ILLINOIS

The new Chemistry Building of the University of Illinois was formally dedicated on the 19th of April. The exercises were held in the Auditorium and the program was as follows:

HONORABLE EDWARD F. DUNNE, GOVERNOR OF ILLINOIS, Presiding
SCRIPTURE READING AND PRAYER, REV. GEORGE P. HOSTER, D.D., Rector
of Emmanuel Episcopal Church, Champaign

MUSIC....."Illinois"

ADDRESS.....PRESIDENT EDMUND JAMES JAMES

ADDRESS, "THE TRAINING OF CHEMISTS," ALEXANDER SMITH, Professor of
Chemistry, Columbia University

ADDRESS, "RESEARCH AS A NATIONAL DUTY," WILLIS RODNEY WHITNEY,
Member of the U. S. Naval Board, Director of the Research
Laboratory of the General Electric Company

MUSIC....."America"

The addresses by President James, Professor Smith, and Dr. Whitney are printed in full below, and are followed by an illustrated description of the building, prepared especially for us by Dr. B. S. Hopkins of the Chemistry Department of the University.—[EDITOR.]

INTRODUCTORY ADDRESS

BY PRESIDENT EDMUND JAMES JAMES

The dedication of a great and expensive building, erected for university purposes, always raises the question whether a university is not spending an undue amount of its funds upon the mere piling up of brick and stone. The well-worn statement that a satisfactory college is a log with a man at one end and a boy at the other was the beginning, perhaps, of the serious criticisms made upon many of our American institutions that they were in the habit of spending too much money on brick and mortar, and too little on flesh and blood. You will remember that Johns Hopkins University started its beneficent and epoch-making work in the field of American education in a very inferior and in some respects, for its purposes, poorly adapted set of buildings, and that it has been pointed out many times as an illustration of how to do things worth while in the field of university education, as compared with some other institutions in the country which spend large sums of money upon the erection of great buildings and have comparatively little left for equipment, running expenses, and the payment of the salaries of the university professors.

There is undoubtedly a great deal of truth in the general view that we Americans run to large accumulations of brick and stone, instead of accumulations of brains, and I will confess that for many years I was not only a thorough believer in that view, but one of the sharpest critics of the tendency in many institutions to provide adequate and suitable buildings for university work.

I have changed my mind somewhat on this particular point since I have been responsible for recommendations as to university policy in this and other important matters. I have come to appreciate a side of the subject which did not appeal to me with very much force twenty-five years ago. In building up a great institution one has to have regard to the character of the people in whose service it is expected to function, and upon whom it must rely for its support.

For some twenty years, in three of the largest American universities, Pennsylvania, Chicago and Northwestern, I was intimately associated with the administrative work of departments, for whose support I was also expected to help win the contributions from private citizens. In other words, it was the worthy and beneficent benefactor whose interest I was expected to enlist, and whose money I was expected to persuade him to give for the support of the particular departments for which I was responsible. I found then that many men were willing to give money for buildings, who would not give money for their endowment; that many people would give money for collections, who would not give money to pay the salary of curators; and that many men who you might think would know better, were deeply influenced by the mere size of an institution, by the mere accumulation of brick and mortar in one great aggregate. I found that after all, the average man, that is the average successful business man, was impressed by mere bulk in a way which one would think he ought not to be if he had the brains which he must have had in order to accumulate the money which made it desirable for the university to cultivate his acquaintance.

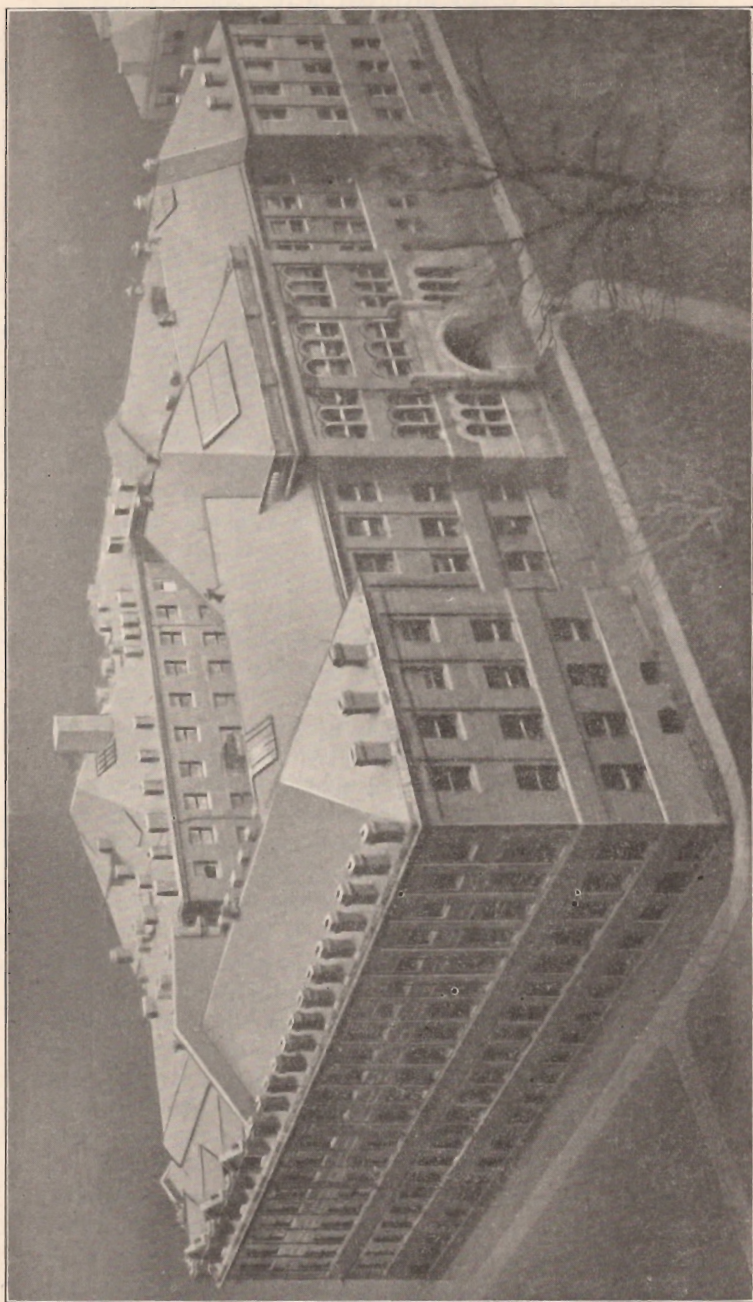
And since then I have noted that the great endowments have in some instances come from men who were impressed by the importance which their fellow-men attributed to the enterprise as evidenced by the buildings and plant which had been erected for its

conduct. When I became responsible for a certain portion of the policy involved in recommendations to the Legislature of Illinois, I saw another side of the same proposition.

We cannot expect the average man to appreciate the importance of certain phases of scientific work. In fact, it is very difficult for one academic man to appreciate fully the importance of the work which his fellow academician is carrying on in a, to him, remote field. I heard only yesterday a very distinguished member of this body remark that while Assyriology and Egyptology were undoubtedly very important subjects, yet certainly no one could claim for an instant that they ranked in importance with chemistry: moreover they had waited so long for development they might wait a while longer. And he was inclined, therefore, to feel that a university ought to be spending all its funds on chemistry, and postponing the time when it would be making collections of Egyptology and Assyriology. I called his attention to the fact that the building of the dam at Assuan had destroyed irremediably some of the very finest archeological remains of the ancient world, and that because the universities did not bestir themselves and collect these materials in time, they had lost the opportunity forever. I also called his attention to the fact that the great war was probably playing havoc with the great collections of Babylonian and Assyrian brickbats in the valley of the Tigris and Euphrates, whereas the knowledge of chemistry which we have not yet attained would be perfectly safe locked up in the bowels of nature for many generations to come if it were necessary, that is, if we couldn't get around to discovering it and unlocking it before.

Still more difficult is it for the average man who has not come in contact with academic things and university ways of doing things, who has little knowledge of human history and little perception of how one thing is tied to another, to understand in any thoroughly satisfactory way the importance of all these things which we academic men are urging upon the attention of the public.

Now chemistry is, of course, a rather concrete subject. Nearly every man, no matter what his education may have been, or whether he has any education at all, if he has simply read the newspapers or read the children's periodical literature, has some conception at any rate of what chemistry means and



THE CHEMISTRY BUILDING, UNIVERSITY OF ILLINOIS

some little idea of the importance of the subject in the history of human culture and the importance of developing it in the interests of human health and human welfare in general. And yet, I think, there is no doubt that the average man who has given his attention chiefly to Egyptology or Assyriology or to Latin and Greek, even though a cultivated and educated man, has little or no conception of the fundamental importance of the development of chemistry to the progress of human life.

Now, of course, the simplest way, the most direct way, and the proper way to induce this appreciation of the work of this great subject in the mind of the average man is to educate him directly upon the importance of chemistry; try to get some chemical ideas into his head; point out the relation of chemistry to the practical things that he himself is trying to do every day, etc., etc. But this is not always very easy to accomplish. I have found it to be so, as to the members of the faculties to which I have belonged and as to the members of my own family and acquaintances who were not connected with the universities; from a study of the remarks and views of the average man who comes to visit the University of Illinois, from the ranks of the advertising men, from farmers, from bankers, and men in general whose profession has not brought them necessarily in touch with academic methods and academic standards and academic ideals. I have come around quite strongly to the view that the most direct method of educating such people as to the importance of certain things is to let that importance be shown in some visible structure of steel and iron, of concrete and brick, which impresses his senses and may impress his imagination.

I am quite sure that no farmer in Illinois, that no laboring man in Illinois, that no advertising man, or banker, or lawyer could view this great building which has been erected upon the campus of the University of Illinois in the interests of chemistry, even though he look at it merely from the outside, without unconsciously experiencing the feeling—you might almost say the conviction—"Why, that must be a mighty important subject on which the University of Illinois is willing to spend so much money!" And if he goes into the laboratory, though he doesn't understand what all these test tubes and all these pipes, etc., mean, but simply sees all the amount of

labor and effort and human capital that has gone into the enterprise, he is converted to the fact that that must be an important subject; and before he is convinced that it is not, somebody must establish the fact to his satisfaction that this investment of money has been a foolish one. In other words, the existence of such a building creates a *prima facie* case for the importance of the subject.

After all, friends, there is a certain symbolic significance in all of this. I am not, of course, arguing for the waste of money on great buildings. I am not arguing for spending money on buildings which ought to be spent on men. I agree entirely with the fundamental view which all of us hold. I am simply emphasizing the results which the investment of money in this form may produce upon the public mind, leading, in all probability, to a greater willingness to spend money for men and for equipment and for the real things for which the building is constructed, than would otherwise be the case. After all, a building is nothing but the body which is going to house the soul, and, speaking generally in a large way, the body is always constructed in advance of the soul, or at least with the development of the soul, and we can hardly expect any of those creations which combine body and soul to be developed without a body to a very great extent. You will remember that according to the Jewish conception of the world, even God Himself had to make the human body complete, ready to function, before, by breathing the breath of life into it, He created man.

And so I have stood in these later years of my life, for a worthy housing, in our great institutions of learning, of the subjects and departments for whose cultivation these institutions exist, looking at them as centers of teaching and research. Some of you have seen, for example, the Armory of which the University of Illinois has begun the erection over in our military field. I think it is not too much to say that the existence of this building, the mere sight of the building, the examination of the building, the mere going into the building has done more to convert the people who have actually come in contact with it to the necessity of more adequate appropriations for our military work than any speech I or anybody else could make. And I am quite sure that if we had upon the campus of the University of Illinois an ade-

quate library building, adequate to house five million books, as we hope to have in the course of time, the mere existence of that building, the mere impression which it would make upon the public mind, and I mean by that, the mind of the State, the minds of the taxpayers, the minds of the people who are contributing to the support of the institution, would be the most potent influence in getting an adequate fund for the purchase of books necessary to fill those shelves and the creation of a staff necessary to organize and develop such a library.

Friends, we are glad to have you here, rejoicing with us over the erection of this great structure, because it is going to be one of the most powerful agencies in helping us to secure for chemistry, for chemical investigation, for chemical teaching, for the spread abroad of chemical knowledge an ever greater influence.

There was always something symbolic and significant in laying the foundations and in completing the dedication of a great building for the uses to which it is to be devoted. The human being has, somehow or other, an unconscious feeling of the importance of the initial steps, and then the importance of the final steps, a sort of unconscious idea that a great structure of this sort represents in itself and shadows forth in itself the efforts of humanity directed toward higher things; and so, many tribes of men have made human sacrifices, have buried human beings alive under the corner stones of such buildings, have shed their blood in the final dedication, a symbol of what the great effort involved in erecting the building has signified.

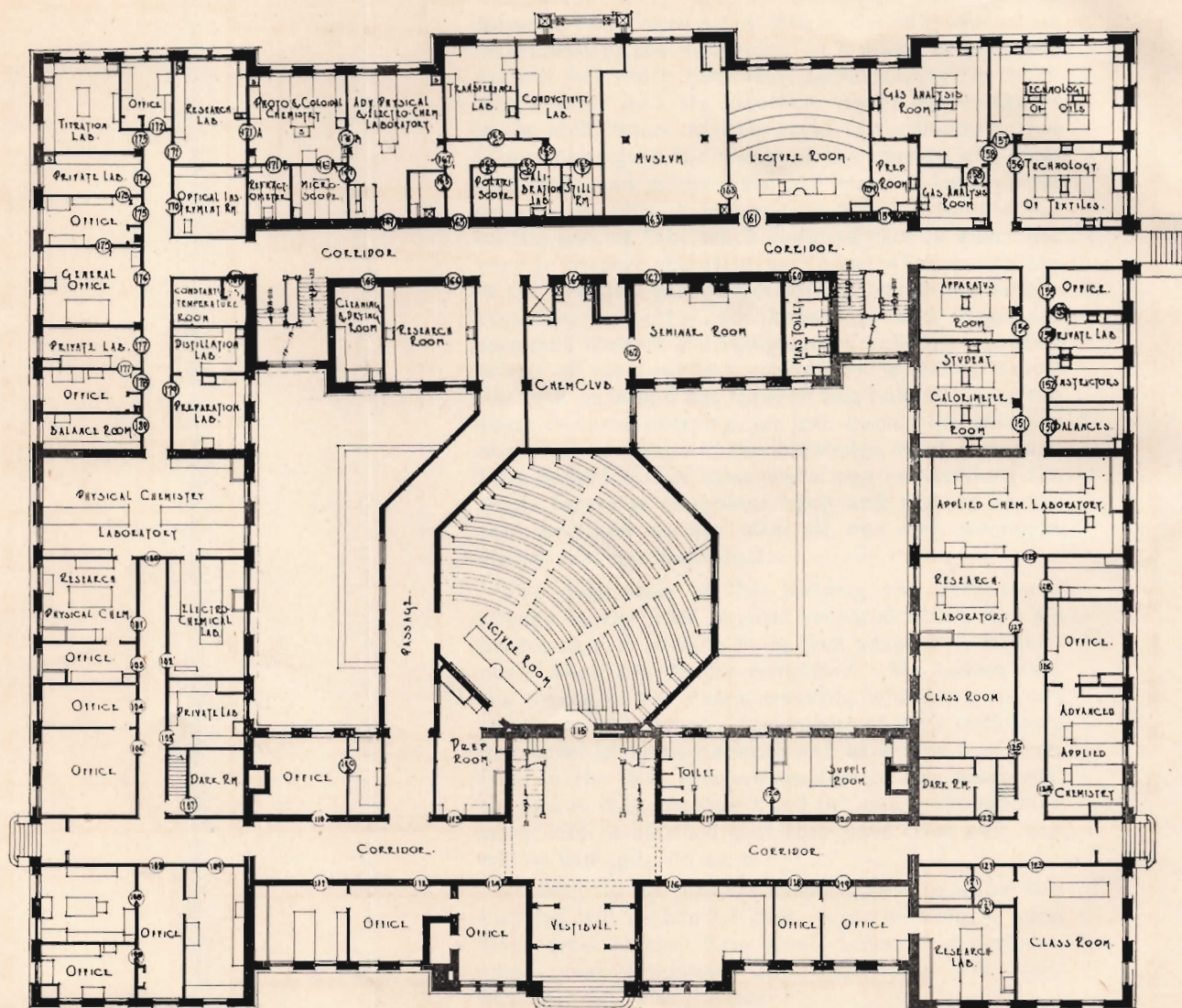
We have been at work on this building now for many years. In fact, the older portion of this building had no sooner been completed than the members of the chemical staff, themselves, set about planning for an enlargement of the structure, for an addition to it; and I believe that even now, before we have fairly dedicated this building, Professor Noyes and his associates are casting long and lingering glances at the open lot opposite the present building, with the hope that the University may get that against—I will not say, the time when we need more space for chemistry, for that is already here; these gentlemen have more than filled this building, and are pressing urgently for additional space—but against the time when funds may be available for actually beginning the erection of such a building. These chemical men have been at work for years planning for this structure, trying

to work out its details; and then if you stop to think of all the results of human toil and effort that have gone into the building itself, that every one of these devices utilized in the heating, in the lighting, in the ventilation, every one of these pipe combinations bringing compressed air, or gas, or the wire conduction of electricity; the discoveries as a result of long and anxious toil which have resulted in making the brick which enter into the structure itself; the evidences in the architecture and the style of the building, that into it have gone the results of the thought and creation of human beings since the dawn of history, one gets a real idea, a real notion of what infinite toil on the part of "the much enduring race of man" has gone to prepare this structure. And when one thinks of the countless generations through which the human race has elaborated the knowledge and experience necessary to erect and equip such a building, and then thinks of the countless generations of young people who will go in and out through this building in all the years to come, carrying out into human life in every direction the results of the knowledge which they may have gained within these walls, one realizes how the whole future is dependent upon and tied up to the past, and how we are, after all, one race, we might almost say, one individual.

The description of this building you have found already in the little circular prepared about it. We believe that it is going to be well adapted to its purposes when it is finally completed. We believe that the people of the commonwealth, who have erected this great building as a testimonial of their confidence and belief in human science and as evidence of their faith in the men who are trustees of this great gift, the men in the laboratories and the men in the teaching work, will be satisfied that they have done well, and will be willing to do more.

It seems to me that the chemical staff to whom this building will be handed over, ought to keep in mind three great things, three great duties, if you please, three great obligations: by which they will carry out their duties as trustees.

First of all, they should recognize that this is an agency of teaching, of getting hold of the young men and women of this commonwealth and other commonwealths and other countries who may come here to study, in such a way as to impress them with the



PLAN OF FIRST FLOOR—CHEMISTRY BUILDING, UNIVERSITY OF ILLINOIS

importance and with the value of the study of chemistry, and inspire them with the ambition to do their part in making this study effective and helpful to their day and generation.

In other words, that the members of this staff shall feel it incumbent upon them not to lop off their students as rapidly as possible, not to pride themselves on the number of students they drive away from the study of chemistry, or cut off from the possibility of studying it; but on the contrary, to pride themselves on the number of students whom they have taught to love chemistry, whom they have fired with an ambition to know more and ever more of the secrets locked up in this great field, and enlighten their minds to such an extent that they will appreciate in an ever larger way what chemistry has done and is doing and may do for the welfare of the human race.

Every member of the staff of this chemical department, it seems to me, ought to feel that it is his business first of all to be a teacher, a good teacher, a thoroughly efficient teacher, an inspiring teacher and guide and counsellor in this field of chemistry to the young people who may elect, or who may be forced into this important branch of study.

In the second place, it is certainly a great and fundamental function of the staff of such a great laboratory as this to be enlisted with a truly religious fervor in making their contributions to an ever-wider knowledge of chemistry; fired with the ambition to add each year some little increment or other to our knowledge in this field, to our control over nature, which comes from a knowledge, a thorough-going knowledge of this field. Every member of this staff should feel that it is incumbent upon him to be an investigator, a research worker, and if he ever feels that he neither has the brains nor the ambition to do something in that line, he ought to resign his position on the staff and select some other career, for certainly no man who isn't fully imbued with his fundamental responsibility in this respect has any business being a trustee of this enormous agency for the benefit of the public. If he is not doing this, he is a false trustee, he is betraying the interests of the people who have vested this power in him.

A third very important matter, which every member of this staff, and the staff as a whole, ought to keep in mind is that you should let your light shine.

In other words, you should let the world know something about what you are doing through the publication of the results of your investigations and by a conscious and direct effort to educate the public as a whole upon what the chemical laboratory and chemical investigation and chemical teaching have in them for the common welfare. I should call this work extension work in the large sense, and I think every member of this staff ought to be interested in it. I don't mean that every member of the staff should go out and give courses in chemistry in high schools, or go out and lecture to the general public upon the value of chemistry, though some men on the staff certainly ought to be able to do this in an acceptable way; and the history of how some of the greatest chemists of the world have come to be through the inspiration of these general extension lecture courses, that is, courses given by eminent chemists to people who could not be expected to understand their lectures unless they were couched in non-technical and plain terms, demonstrates the importance of the work.

I feel, my friends, that we do not realize how ignorant the common man is as to what is going on in these great universities. He is very apt to look upon them with indifference, or regard them as mysterious centers of thought and work which he doesn't understand, and which have little connection with him or his interests.

The question has often been raised in meetings of professors and administrators in our state universities, as to the function of research and investigation in a state university.

I should say that function was exactly the same as in any private university, and it is far more insistent and far more necessary for the welfare of the institution than even in the case of the private universities. I have always maintained that in the long run the community will support the state universities in a large and liberal way much more because of what they are doing for the advance of science, than what they are doing in the work of teaching.

My friends and colleagues of the chemical staff of the University of Illinois:—We are expecting from you the adequate performance of this threefold function of effective and inspiring teaching, valuable investigation, and diffusion of the results of this work, first among scientific men through your scientific periodicals, and then among the great mass of the community

by newspaper and magazine articles, popular addresses, etc.

I wish you Godspeed in your future work in this magnificent structure, and I think I can promise you for the Board of Trustees, and, if I understand the people of this state rightly, for them and their children, the heartiest support in this great undertaking that is now committed to your charge.

THE TRAINING OF CHEMISTS

By ALEXANDER SMITH

The address on research, which follows mine, deals with that aim of the chemist which always receives the most enthusiastic recognition. But thorough *training* is indispensable before original work can begin. A genius, without adequate training, seems to know by instinct what information he needs and where to find it. He devises new methods when those which he has learned fail. He reaches the goal, in spite of all handicaps. Better training would have saved him some needless loss of time, but often would not have improved the final result. Geniuses, however, are few and far between. The advancement of the science would be fitful, if it depended upon them alone. The greater part of the additions to chemical knowledge are made by men with an aptitude for the science, it is true, but with nothing approaching genius of the higher order. With them, the thoroughness of the previous training is, therefore, a very potent factor. At the other extreme, in the case of the chemist who does mainly routine analyses, who corresponds to the draftsman as distinct from the architect, the training he received must determine largely the value of his results. In all the intermediate cases, where intelligent study of an individual situation is demanded, and new adaptations to special purposes are required, training in the principles of the science and previous exercises in applying them to new cases, with the alertness and mental adaptability which such training produces, are the chief factors in success. The training of chemists is, therefore, a matter well worthy of careful study.

It is not my purpose to discuss the subject as a whole. I desire rather to emphasize four points which, after nearly thirty years' experience as a teacher, I am inclined to think are of vital importance, yet receive too little consideration, and indeed are often entirely ignored.

OVERLAPPING COURSES

Take, for example, the treatment of the freshman who, on entering a college or university, offers chemistry for admission. In the vast majority of cases he is placed in the same class with those who have never studied the subject before. All agree that the result is unsatisfactory, but many attribute this result to the wrong cause. They say that the chemistry of the High School is valueless, and that their pupils would be better off without it. The actual fact is that, to such pupils, the introductory parts of the course seem trivial and boring. They become indifferent. Later, when matter suited to more mature minds comes up, they do not observe the change. Soon they fall behind the beginners, and finally they barely pass in the course, if they pass at all. The result is not the fault of the student or of the High School, however—it is an inevitable result of ignoring the most familiar features of human psychology. Administer the admission requirement with reasonable strictness, place those credited with chemistry in a class or section *by themselves*, make them feel from the start that they are getting something that is new to them, and they will respond accordingly. Of course, elementary matters cannot be omitted. No two members of the class come from the same school, their training is very diverse, and there is hardly one fact, no matter how simple, which is known to every one. The elements must be reviewed at the same time that new matters are introduced. But a pace much more rapid than that of the beginners can be maintained. In Chicago, my experience showed that this class secured in two quarters a much better knowledge of chemistry than a class of beginners could obtain, under the same conditions, in three quarters.

If the school course is valueless, why give admission credit for it? If it represents a real advance into the science, as experience shows that it does, why ignore it? Why not accept it, and start at the higher level? Overlapping of courses is all too common in chemical training, and it often begins by duplicating all the work of the High School, and not taking it for granted and proceeding beyond it.

Overlapping affects many of the later courses in every university. The instructor in qualitative analysis, instead of ascertaining exactly what is taught in the inorganic course preceding it, and confining him-

self to the briefest possible references to what he has a right to assume as known, too often spends many hours repeating such parts of the elementary facts and such elementary principles as are required in his work. I have known of instructors in quantitative analysis who ignored all the content of the previous instruction—both facts and theory—and reduced the subject to a series of mechanical processes, which could have been performed equally well (or equally badly) by a beginner. The students respond quickly to this situation, just as in other circumstances they would respond to demands on their previous training, and soon work with due lack of intelligence. Thus not only may the previous training remain unused, where continuous and most effective use could have been made of it and much might have been added, but, being unused, it is soon forgotten. At the end of two or three years of work, the pupil may actually know less of the science than he did at the end of the first year. Even if each course overlaps only about half of the preceding course, the inevitable result is that the pupil gains in four years only what, with better coördinated instruction, he could have secured in two years.

Curiously enough, the opposite fault affects much of our organic chemistry. Here the books, instead of striving to link the subject intimately with inorganic chemistry, and thus aiming at continuity, too often give the subject as far as possible the appearance of a different science. Unfortunately many instructors follow the same lead. I have known cases where a law of chemistry was hardly ever mentioned, an experiment was never shown, a substance was almost never exhibited, and the only chemical material in evidence was pulverized gypsum in streaks and curves on a black background. There are notable exceptions, of course, but too much so-called organic chemistry is nothing but a riot of symbols and "bonds." Some overlapping is necessary here, to offset the real differences in the nature of many of the reactions and of many of the experimental methods. The course might well be made essentially a part of the elementary general chemistry, and less like a separate science.

In respect to loss of time by overlapping, the university, with its numerous instructors, is at a disadvantage when compared with the college. In the latter, three or four years of chemistry are all given under the immediate direction of one man, and con-

tinuous work and rapid progress by the pupil are more likely to be secured.

STANDARD COURSES

In different institutions in which the training in chemistry serves the very same purposes, there is too little agreement in regard to the weight, the content, and the quality of the regular courses. In many universities and colleges, the course in inorganic chemistry based on High School chemistry is standardized, and demands two or three classroom periods and six hours of laboratory work weekly for twenty-four to twenty-eight weeks. But the graduates of one large university tell me that their course in this subject is inferior in quality and extent to the average High School course, and that previous work in the science is neither required for admission to it nor recognized in any way when existent. Courses of all kinds, intermediate between these extremes, are common. Now, the establishment of a more uniform standard is most desirable for many reasons. Migration from one school to another is rapidly increasing. Schools of medicine are requiring previous college work, but the boy who has had about half a course each in inorganic chemistry and in qualitative analysis or organic chemistry can neither be admitted, nor can he be directed to any course in which his peculiar deficiencies can be made up. The student who decides to move to a school of engineering often finds that he has been provided with a similarly extensive, but superficial, preparation which leaves him a misfit. When the student attempts graduate work in another institution, he encounters the same handicap. Naturally, a slight course in inorganic chemistry can be followed only by a course in mechanical qualitative analysis, such as prevailed forty years ago, and any attempts in each successive course to develop a grasp of the modern aspects of the science must be given up. A separate and distinct course in physical chemistry, taken later, can never solve the problem. In such a course only a few illustrations can be given, whereas continuous application of the same principles in study and in the laboratory during the whole training is necessary to success. The student keeps the different courses in separate, water-tight compartments in his mind, and only a genius will make the thorough-going applications and connections that are required to weld the whole into a science. Modern chemistry simply teems with ap-

plications of physical chemistry. This is the case both in the laboratory and in the factory, both in the biochemistry and physiology of the school of medicine and in the courses required of the student in chemistry and chemical engineering. The institutions of learning must respond to the obvious demand. We are not training students to use four or six years hence even the chemistry of to-day, much less the chemistry of 1880 or 1890. We are training them to understand the chemistry and biochemistry of the future and to apply and expand the science as it will be several years hence. All that we know for certain about that chemistry is that it will be less capable of mechanical, unintelligent use than the chemistry of the past, and that ability to apply theoretical conceptions will be more desirable, nay, more indispensable than ever. Standardizing our elementary courses, both as to extent and as to character is an essential part of preparedness to meet the demands of the future.

In this connection, a word is in place in regard to the training of candidates for the degree of Doctor of Philosophy, a class of students which is rapidly increasing in numbers and importance. Their training in the fundamental branches of chemistry is at present very various and unequal in quality, even when sufficient in quantity. They can take advanced courses, but piling knowledge on a shaky foundation is unwise. The advanced principles can perhaps be used, albeit mechanically, when, as given, they happen exactly to fit the problem. But when they have to be adapted to a different situation, only a chemist who has an absolutely sound understanding of the fundamental elements of the science can make the adaptation with certainty. We are all familiar with published researches which were in reality futile and valueless because fundamental principles were overlooked or were not correctly brought into relation to the observations.

One remedy is to require graduate students to attend the elementary classes. This, however, is only a half-measure. Review courses in general chemistry, analytical chemistry, and organic chemistry, in which these subjects are examined in retrospect, can be given so as to occupy less time, and yet achieve the object much more effectively. Emphasis can be laid on application of modern views, the oddities which pervade most courses in chemistry can be discussed, a broader and more critical scrutiny of the principles

can be undertaken. Of especial importance is the fact that the classification of the content of chemistry can itself be discussed, although with beginners the classification can only be *used*. Also, the reasons for preferring certain definitions and certain conceptions can be considered, and less advantageous or even erroneous statements commonly encountered can be brought out as they could not be in a class for beginners. We learn much more by a study of wordings that are open to criticism than by simply memorizing uncritically faultless ways of stating the same things. Thus, the preparation of the graduate student can be standardized also, at least in respect to its most essential features.

AN ALTERNATIVE TO LECTURING

In a lecture one states the facts or explanations clearly and, *for the moment*, the attentive student understands perfectly. But, is it our object to train him to understand statements made by others—does ability to do that constitute a knowledge of chemistry, and play an important part in making a chemist? Is a watchmaker a person who recognizes a watch when he sees it, who knows what makes it run, and when it is running well, or is he a man who can make and repair a watch? Is not a chemist one who can himself make correct statements about chemical topics, and can himself put together the necessary facts and ideas, and himself reach a sound chemical conclusion? Listening to a lecture keeps the student in a *receptive* attitude of mind, whereas the attitude we desire to cultivate in him is the precise opposite of this. The student should begin by himself acquiring the ability to state simple ideas correctly, and later himself practice putting facts and ideas together and reaching conclusions. The conclusions are not new, but going through the operation of reaching them for himself is new to the student. No one would explain to a group of people who were not musicians how the piano is played, and perform a few lecture experiments on the piano, and then be foolish enough to expect the audience to be able at once to play the same pieces themselves. Of course not, because we all know that every kind of mechanical dexterity has to be acquired by practice and by the formation of habits, nervous and muscular. But we do not all realize that mental operations are also *largely mechanical*. For the most part they are made up of half-unconscious responses, each

of which is an idea previously acquired by practice, and only the selection of the units of which the whole mental operation consists, and the arranging of them in due order, are the results of actual thought and conscious reasoning. After explaining some point to the class, such as the reasons in terms of the ion-product constant for the precipitation of calcium oxalate, one might assume that they all understood the explanation, and perhaps they all do. But ask them individually to *state* briefly the reason for the precipitation, and some will make remarks that have no bearing on the subject, some will make partly incorrect statements, many will make statements that are correct so far as they go, but are incomplete. Only one student in thirty will give a correct and complete answer. Many of the others undoubtedly understand the matter perfectly, but unless they have an opportunity themselves to put the answer together, the impression will be slight and fleeting. It is the exercise of going through the reasoning and the wording of the answer, for oneself, that alone can make the impression a permanent one and fix the explanation in the mind.

Evidently, the pupil would better study the subject in the book, taking much or little time according as his powers of acquisition are slow or fast, until he can state each important point in his own words. Then the classroom work can be confined to testing the preparation, discussing difficulties, showing illustrative experiments, and asking questions about the cases illustrated. Before printing was invented, oral instruction was necessary. It seems to me that a good many university men have not yet realized that the printing press is now available. It is right that we should know the history of our profession, but not necessary to adhere to all the practices of antiquity. We all know walking was invented before the locomotive, but none of us walked to Urbana to this meeting. Was that thoroughly consistent?

I am not proposing to abolish lecturing. In courses taken by students who already know how to study, that is, in the more advanced courses, lectures are of great value. They give a general view of the territory as a whole, they distinguish the more important from the less important items, and they enable the student to conduct his *own private study* of the subject with intelligence. I am referring mainly to the elementary course for freshmen, where not one member of the class in twenty has ever studied in the true sense, or

has any knowledge of how to study. It is a part of the benefit he gets from the course that he learns how to study and acquires the necessary habits. Listening to lectures, in such a case, if the lectures are well constructed, only deludes him into thinking that he has fully grasped the subject, and *prevents* him from studying. Additional class exercises given by assistants and subordinate instructors do not help the situation materially. Often the assistants do not keep in close touch with the mode of presentation of the lecturer. Always the students feel that, since assistants handle this work, it must be less important, and so it suffers in effectiveness. After trying both plans, it will be found that incomparably better results are obtained by giving two or more sections, of thirty to forty students each, to a competent instructor, and letting him conduct the whole work of each section. The lessons are assigned in advance, and due preparation is insisted upon.

There are other disadvantages of the lecture method for freshmen. The lecturer must adjust his speed to that of the slower, if not the very slowest members of the class, although many of its members could follow equally well if the pace were tripled. With the slower students spending more time in preparation, and this and the other variable factors thus relegated to the home study, the class becomes more uniform, and either twice as much ground can be covered in the hour, or the ground can be covered twice as thoroughly, according to the nature of the topic.

That the student has thus acquired a more thorough foundation in chemistry, and that he has learned how to study, are both of great advantage when the next course is taken. When the lecture method has been used, the students have still to be taught the necessity for continuous study and how to do it, and progress in the next course is slow. Then also, the fleeting impressions, detained temporarily by a few days of violent but superficial study just before the examination, have almost entirely evaporated, and overlapping and repetition of all the necessary facts and principles is an absolute necessity. For this reason, also, much time is lost. Efficiency demands that something of permanent value be accomplished *each year*, and there is every reason against postponing the application of efficient methods to the second year.

Again, questioning shows at once which points have been understood by all, and which points have re-

mained unclear, and the time is spent on the latter. Also, the recollection of past topics, when the need of applying them arises, can be tested, misunderstandings can be recognized and removed, and lapses of memory can be remedied. The method finds out infallibly what is needed, and how much in each case is needed, and permits the doing of precisely what is necessary. The process involves continual measurement of the existing results. A *lecturer* can only guess at what is needed, and how much of it, and must necessarily be more or less in error on every occasion. The method advocated has for the chemist the attraction of being quantitative and, with practice, the experimental error becomes negligible.

Still again, since the lectures are systematic and orderly, while the laboratory work is necessarily more or less topical, the pupil thinks the lectures are the kernel of the course. Yet, in point of fact, the real contact with the subject takes place in the laboratory, and it is better therefore to make the student feel that the laboratory work is the principal feature of the course, and that the classroom work is simply a discussion and adjustment of what has been learned in the laboratory and at home. Individual observation, and reasoning from observation, can thus receive that strong emphasis which they deserve, but in a lecture can never receive. Naturally, every week each student must begin with the experiments for that week, since he cannot otherwise prepare himself for the class meetings.

Finally, many chemists admit that they learned little chemistry from the first lecture course, but insist that the personality and point of view of the lecturer—not only in matters chemical, but in respects quite remote from that science—exercised a profound influence upon their own point of view and their subsequent attitude towards life. In reply, it need only be pointed out that, in the free interchange of thought which is a necessary part of the method suggested, the opportunity for the personality of the instructor to assert itself is even freer than it ever can be in a lecture, and that the digressions, if they are such, since they will usually be suggested by reactions shown by the students themselves, will be much more likely to strike some target effectively and forcefully than will the random shots of a lecturer, who knows only what is in his own mind, and nothing of what is in the mind of the listener.

IMPROVED LABORATORY FACILITIES

The mechanical equipment of a chemical laboratory is an important efficiency factor in the training of chemists. There is perhaps no department in the college or university where the ratio of results achieved to time spent is so small. This is particularly true of the quantitative and organic laboratories, although it is conspicuous in all branches of the science.

For example, the evaporation of a solution on a steam bath may take five or six hours. The temperature of the liquid may never greatly exceed 90° . A vigorous attempt is made to train the student to carry on several operations simultaneously, but four or five months elapse before he learns to do this effectively. A plate covered with shot and heated with steam under pressure, one at each working place, will easily give a temperature of 130° . The time required for the evaporation will become a mere fraction of that required with an ordinary steam bath, and the saving of time will begin on the first day, instead of being postponed until months of training have brought about the same result by another method. The cost of fuel will also be less. When the dissolved substance is a very soluble one, the vapor pressure of the solvent becomes rapidly smaller as evaporation proceeds, and soon the steam escaping from a bath gives to the air a partial pressure of water vapor equal to the vapor pressure of the solution, and evaporation ceases. With the steam confined in the plate, so that saturation of the air is avoided, the evaporation will proceed much further without interruption. A tube connected with a vacuum system provided on all desks will remove the vapor, and will facilitate further evaporation beyond this point to a surprising degree. Desk ventilation is, of course, required when the steam plate is used.

Ventilation at each working place, as it has been installed in the new laboratory here, also permits much saving of time. Hoods take the student away from his desk and reduce the number of operations he can carry on simultaneously. Hoods become dirty and unsightly, because no one student can be held responsible for their condition. They also furnish the students with an excuse for leaving their desks, and conversing about football, when they should be at work. In case a hood is really required, which seldom happens, a folding hood can be drawn from the

supply room, and erected over the desk ventilator.

The traditional arrangement of chemicals on a side shelf is also open to many objections. Anywhere from ten to a thousand times as much of the chemical may be taken as the operation really requires, so that reckless habits are acquired and much material is wasted. When the class is following a program, and working on the same experiments, the same chemical is needed by several students at the same moment, and delays occur. For the same reason, certain bottles are quickly emptied. When one of the bottles is empty, it is not the business of any student to have it filled, and so another convenient excuse for conversation is provided. The side shelf furnishes opportunities for conversation far more plentifully than it does chemicals. With a little initial work by the instructor, a list of the amounts of each chemical and solution required for the term's work can be prepared, and each student can be provided with a kit of chemicals which he keeps in his desk. Professors Freas and Beans, at Columbia University, tried this plan first on a class in qualitative analysis, and the instructor added between twenty and twenty-five per cent to the work of the course in order that the time thus saved might be utilized. The saving in the total quantity of chemicals consumed pays the expense of making up the kits, and the twenty to twenty-five per cent additional training is all clear profit. Every student is entitled to the set of chemicals appropriate to his course. If he wishes to use more than the allowance, which should be ample, he can obtain them from the supply room and have them charged in his bill for breakage. Thus those who prefer to be extravagant pay personally for the privilege, and the appropriations at the disposal of the department are conserved and permit the offering of better facilities to all. For example, in one term of a course in organic chemistry, one student used less than \$8 worth of chemicals, while the largest amount used was over \$28 for the performance of the same work. It was evident from this that \$12 worth of chemicals was ample, and that all students using more had been dissipating the resources of the department, and should hereafter be required to pay for the excess.

In a large laboratory, there are times of the day when the number of students trying to replace broken articles or to obtain other supplies at the stock room, becomes great, and loss of time is the inevitable result. No

institution of learning can afford to multiply skilled attendants, when they are needed only during a rush hour in the afternoon. On the other hand, the use of unskilled help leads to mistakes, involving loss of money by the department and loss of time by the student. The provision of more than one supply room is an expensive remedy, and does not always prevent crowding. Instead of waiting twenty minutes or more for his turn, the student can in one minute write out his demand on the telautograph, and then return to his desk and go on with his work. A receiving clerk stamps the card in a calculagraph clock at the time the order comes in, and again when the boy returns (after delivering the article) and presents the same card signed by the student. The time required for filling the order need never exceed seven minutes; if it does, the cause of the delay is investigated. Of course, a stock of supplies equal to all ordinary demands must be available, and in the larger laboratories this stock represents an investment of at least \$60,000 to \$80,000.

In all laboratories, much glass apparatus is returned in dirty condition. Since it will not be accepted in this condition by another student, it cannot be received. It is thrown away and the student's account is charged with its value. Installing dish washing machinery will save the greater part of this expense and reduce materially the number of new articles to be ordered, received, unpacked, checked, and stored. In our own experience the substitution of a charge for washing, in place of a charge for the whole cost of the apparatus thrown away because of being dirty, as it had been made the year before, reduced the breakage bills for an equal number of students by nearly \$1200. During the year the apparatus of instructors and the apparatus used in lectures can be washed at one central place more economically than by scattered, unsupervised labor. Then, too, in many courses, cleaning apparatus takes up much of the time of the student. A graduate student, who is paying tuition, room rent, board and other living expenses, and who is sacrificing his earning power to obtain further education, can save time which has a high money value to him by sending his apparatus to the supply room for cleaning.

Ring stands and burners are usually painted with asphalt paint. This gives an exceptionally porous covering, especially fitted to permit access of laboratory gases and to hold moisture. One investigator

finds that when more than two coats of paint have been applied, rusting is not retarded, but accelerated. The sand blast will take off every trace of the paint with astonishing ease, and thus, with a single coat of new paint, of a properly chosen kind, every article placed in the outfit will look as good as new. Ill-kept apparatus fosters careless work, while nice-looking apparatus guides the student, without his being conscious of its influence, into clean-cut and satisfactory manipulation.

The sand-blast reminds us that a mechanic and a work-shop are necessary features of a large laboratory. One recent research by an eminent chemist indicated that he made an electroscope out of a tomato can tied to an empty Lydia E. Pinkham medicine box by means of tan-colored shoe laces of the latest model. A more efficient and durable instrument could have been made with the help of a mechanic, and much of the time the professor and student spent in trying to work with this aggregation would have been saved. It is more economical to purchase standard apparatus, but, when modified forms are required, when repairs are needed, and when new apparatus is devised for research, the mechanic, readily accessible in the building, is a necessity.

Another problem of the laboratory is to utilize the desk space during a larger proportion of the time. If many of the desks are to be used during only two afternoons in the week, and are to remain idle during four-fifths of the working hours, one cannot provide a desk for each student, with all the overhead cost for the building and plumbing which that implies. In some courses, three or four cupboards, each capable of holding the whole outfit, can be provided under each working space, and three or four students can be accommodated. But in many cases, as in quantitative analysis and organic chemistry, the outfit is extensive, and often only one student can use the desk. Yet the space is not really utilized. Most of the apparatus is placed on the bottom of the cupboard and on the single shelf above—with the smaller articles in the drawers—and much empty space is provided above the apparatus, in order that articles at the back may be taken out without disturbing those in front. Cannot some way be devised of saving this space, and at the same time making it unnecessary for the student to get down on his hands and knees on the floor to explore the dark recesses of the desk?

A desk designed by Dr. Fales seems to solve this problem (Fig. I). The door is without hinges, and is pulled straight forward. Attached to it is a set of shelves and racks of the same width as the door, and extending to the back of the cupboard. These are planned so as to provide a place for each item in the outfit. This rack moves on a small wheel in the center of the foot of the door, and is supported behind by a wheel running in a brass-lined groove. Thus, when the front panel (or door) is pulled out, the whole rack comes out into the light, each side can be examined at a glance, and any article on it can be taken out in an instant. The outfit, placed in the box in which it is drawn from the supply room, occupies 10,000 cubic inches. When set out in the rack, it

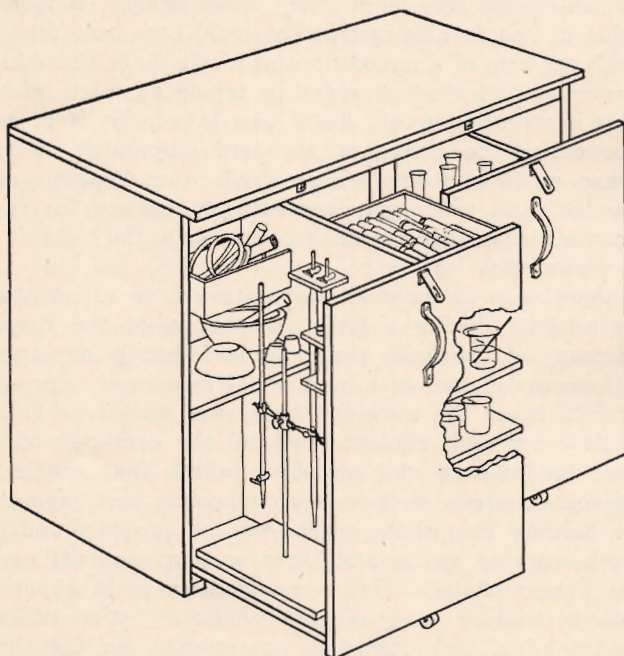


FIG. I

occupies 24,000 cubic inches. When placed in the ordinary desk with its cupboard and drawers, it occupies 44,000 cubic inches. Since in the rack-cupboard it thus occupies only about half the space commonly required, two outfits for two different students can go where one went before. In addition, actual measurement shows that the student can take out any needed article or chemical in one-third of the time re-

quired with the common arrangement and, instead of taking three to four minutes (by measurement with a stop-watch) to ascertain that he does *not* have a chemical asked for by the instructor, he reaches the same conclusion with greater certainty in six seconds. The effort to pull out an ordinary laboratory drawer, *when empty*, requires, by measurement, a force of 4 to 12 pounds. That necessary to draw forth the rack, with its complete load of apparatus and chemicals (weight 40 lbs.), is only 2 pounds. And finally, the construction of the desk costs no more than does that of the usual desk with two drawers and a cupboard.

There are teachers of chemistry who feel that mechanical devices for making laboratory work more efficient are beneath their notice. But, after all, the laboratory is essentially a study, in which materials take the place of books, and manipulation and thinking take the place of reading and thinking. A book is arranged mechanically for convenient and rapid use, whether it is to be read straight through or employed for reference. Why should not similar attention be given to the mechanical arrangement of the laboratory? Of course, the publisher and printer arrange the book—not the author. But the architect does not know enough about chemical work to devise anything helpful—and we are lucky when he does not knock out part of our plans by persuading the authorities that they will put the building out of harmony with the other structures on the campus. Hence, the chemist must himself tackle the problem in detail.

Then again, if the laboratory operations occupy long periods of time, the intervals between the points at which thought by the student is required, or the practice of certain manipulations is demanded, are so prolonged that the pupil forgets to think when the time comes, and bungles the manipulation because his mind has long since wandered to some other subject. Thought and physical activity are more effective when there is a more or less continuous demand for them, and so every abbreviation of the periods of waiting and of the interruptions, caused by looking for some article or going to a hood, increases the efficiency of the work as a form of study. It also, of course, permits more work to be done, and, therefore, more subjects for thought and more manipulations to be introduced, and so gives more mental training and greater technical skill.

The magnificent addition to the laboratory, the opening of which we are now celebrating, has been made at a most opportune time. A German statistician has discovered that the ratio of chemists to population in four countries is represented by the numbers: Switzerland 300, Germany 250, France 7, Great Britain 6. The corresponding number for the United States is probably nearer to the two last numbers than to the number for Switzerland. The general run of people in this country, even educated and intelligent people, have hitherto been almost entirely unaware of the important rôle which chemistry plays in the industries. When you tell them that many railroads employ fifteen or twenty chemists each, they stare in astonishment, and cannot imagine what there is for a chemist to do in such a connection. But the discussion raised by the war has suddenly drawn chemistry out of its modest retirement, placed it in the limelight, and advertised it as nothing else could have done. The number of students in chemistry, always a rapidly growing factor, has this year taken a great leap forward. The University of Illinois is fortunate in having completed a building for chemistry so carefully planned and so magnificently equipped. It is fortunate also in the splendid spirit which has characterized its work in chemistry, and in the remarkable number of investigations of the highest order which have been, and are being carried on in its laboratory. The State of Illinois is to be most heartily congratulated both on the performance of its University, along chemical lines, in the past and, with the space and the facilities which the new laboratory offers, upon its promise of even greater things in the future.

COLUMBIA UNIVERSITY, NEW YORK CITY

RESEARCH AS A NATIONAL DUTY

By WILLIS RODNEY WHITNEY

The object of this paper is to emphasize the importance of material research and to lay stress on its necessity to any people who are ever to become a leading nation or a world power.

I have called it material research because I wanted to exclude immaterial research. I class under this head pure thought as distinct from thought mixed with matter. It is worth while making this distinction because it is not always recognized. It is very natural for us to feel we can think new things into being. Chemistry has advanced only in propor-

tion to the handling of chemical substances by someone. When the study of our science was largely mental speculation, and the products and reagents largely immaterial, like fire and phlogiston, we advanced but slowly. Ages of immaterial research for the philosopher's stone led only to disappointment. Successful results in modern times came from *following* Nature, learning by asking and experimenting, reasoning just enough from one stage of acquired knowledge to ask the next question of materials.

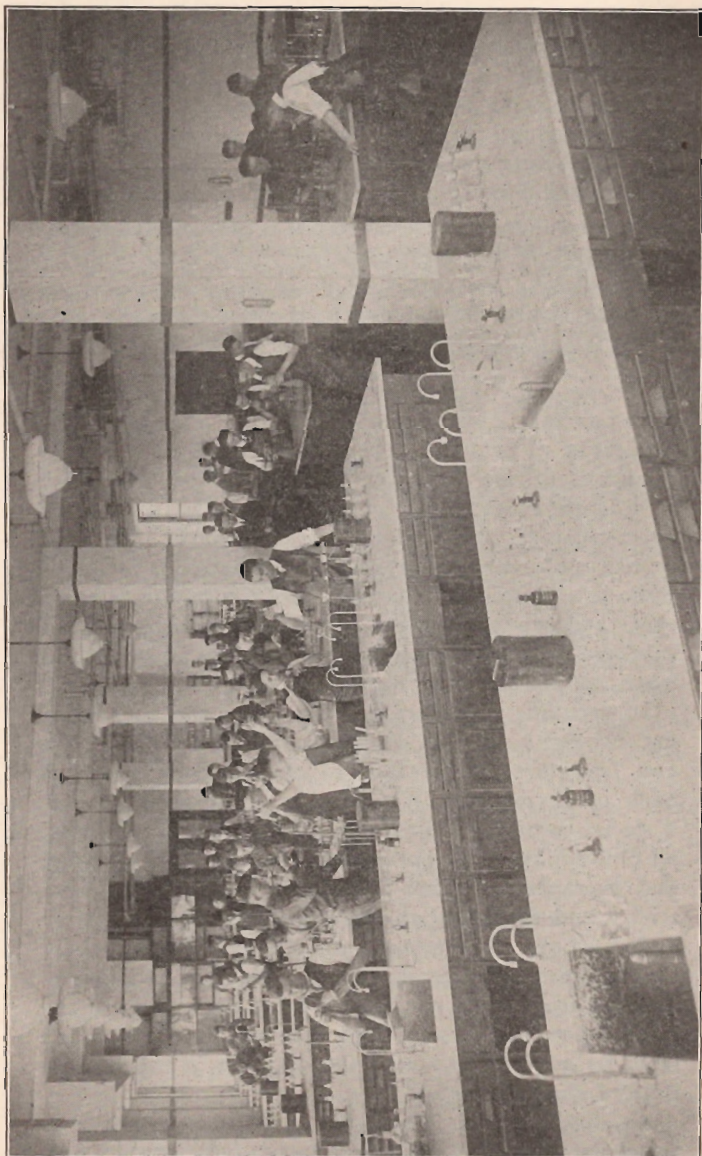
Professor Trowbridge, of Harvard, once said:

"Before Galvani's time men were lost in philosophical speculations in regard to subtle fluids; *after* his experiments their thoughts were directed to the conditions of matter *immediately* about them. Benjamin Franklin brought electricity down to earth from the clouds, while Galvani's experiments brought men's minds down from the heights where they were lost, having no tangible transformations to study."

We are now being shown, by systems of national development, how important is the study of the properties of matter. There is no need to raise the questions of the war, nor of the relative originality of different races, nor to compare the gifts to scientific knowledge of the various world powers. We shall go only so far as to point out that in national processes there is a certain peculiar and useful attitude towards exact and new knowledge. I want to convince you, if I can, that in the uses of science we ourselves have much to learn, and in the matter of research we are still children.

In speaking of research, I do not mean to confine my thoughts to the chemists and their knowledge and literature, but rather to that science which is back of chemistry. We may call it natural science, if we are careful. It includes, for my present purposes, all philosophy based on measurable facts. Psychology and therapeutics come under this head; so do electricity and medicine, anatomy and physics, chemistry and biology. These are inquisitive sciences, where the answers come from asking questions of Nature. If I can leave with you even a faint impression of the importance of *new* knowledge, the strength to be gained from its acquirement, and the pleasure in the process itself, I shall feel repaid.

As distinct from your Illinois attitude, research is *sometimes* looked upon as a remote, postponable, and especially exacting undertaking, well-suited for martyrs of science and unreasoning optimists, and not at all for teachers. The historical methods of teaching have still lingering in them some of these signs. Even in



A CLASS IN QUALITATIVE ANALYSIS IN THE INORGANIC LABORATORY, UNIVERSITY OF ILLINOIS

our day it is sometimes said that a teacher should not be an investigator. It will take a long time to efface that idea completely, but it will be as surely forgotten as the fact that most of our older colleges were once religious centers. It is important to realize that the need, facilities and *possibilities* of research are all about us, retarded only by the inertia that is in us.

Every chemist, even in his freshman days, handles the identical substances with which all material advances will be made. Because he cannot always handle them in the ways of the advanced industry, he is led to imagine that research is closed to him. Yet so much useful pioneer work in all fields has been done with simple material equipment coupled with good mental equipment, that it almost seems as though this was the rule. The telegraph and telephone started with a few little pieces of wire wound by hand with paper insulation. The basic work on heredity was carried out by an Austrian monk with a few garden peas. The steam engine came from the kitchen fire, and wireless from the tricks of a little spark gap. There was, however, the same general kind of mind behind each one of these discoveries—the mind of the inquisitive thinker.

ADVANCED TRAINING NECESSARY FOR SCIENTIFIC SERVICE

Exactly the opposite belief is also quite common—that great advances are made by sudden flashes of thought through the mind of some lucky and presumably *unoccupied* individual. If this were so, there would be little need for the high degree of training which is necessary for almost any scientific service in our day. We may find a simple illustration of this point in organic chemistry. We know that the artificial production of important chemical compounds, such as indigo and rubber, has been accomplished. But how many of us realize the training that was necessary and the research that had to be done before success could be claimed. The Badische Company spent seventeen years completing the indigo work after the *first* synthesis, and expended about \$5,000,000 before a pound was put on the market. I might say that without at least fifty years of work by thousands of research chemists, neither problem could have been solved.

In my study I have a photograph of about thirty young research men grouped about Wöhler. This is the chemist of Göttingen who first discovered that an

organic compound could be produced in a laboratory. It was he also who made the first metallic aluminum. The picture was taken in 1856, about as early as decent photographs were possible. Every year since 1856, that Göttingen laboratory, among others, has been training chemists in research. They have gone into fields of infinite chemical variety. Each man has been a center in some distant place, and around this center there has often been built some kind of growing chemical structure. Many became teachers, and their students in turn became experimenters and teachers. Many followed industrial chemistry and extended the field of the ever-increasing army of chemists. In my particular photograph is one man who in 1866 became the Professor Goessman of the Rensselaer Polytechnic Institute and was later professor at Amherst and very prominent for years in the Massachusetts State Board of Agriculture.

Since 1856 the same seeking for knowledge by renewed groups of such men has been continually going on in many foreign laboratories. It is only slowly being taken up in our country. Is it not time that we awakened to the fact that, as research chemists, we are still in our infancy? If we are ever to be a leading country in industrial chemistry, research is absolutely necessary. If such research is done elsewhere, then the major part of the advantage will lie elsewhere also.

Scientific research, or research in the natural sciences and in the industries, might be defined as the pioneer work of the *developed* country. In this light it is easy to see that our turn has come. Not long ago our pioneer work was of another kind. It was opening up the undeveloped land. It was actively and well done. But the work must change because our requirements have altered.

Carl Helfferich, Director of the Deutsche Bank and now Secretary of the Treasury of Germany, writing before the war, said:

"All economic labor aims at making external nature contribute to the needs of man. It is as true of the primitive gathering of roots and berries as of the production of cyanamide or calcium nitrate. The enormous progress of modern economic technique is due to the splendid development of the natural sciences and the systematic application of scientific knowledge to economic labor. Physics, chemistry and electricity have outvied each other in their influence upon economic technique."

Speaking of the scientists, he says:

"Our hermit poets and thinkers converted themselves more and more during the past century into practical creative workers,

and an enormous expansion of activity has resulted from the progress of the pure and applied natural sciences."

American chemists have had German chemists pointed to as examples almost long enough, but there is some value in concrete examples, and I cannot refrain from comparing our own impoverished condition in the matter of fixed nitrogen to that of Germany.

Excepting one or two minor attempts, we Americans have made almost no study of the fixation of atmospheric nitrogen. I want you to realize the varied and expensive researches, mostly carried on abroad, which were required to reach the present position of the nitrogen question. There were in Germany and, by German capital, in Scandinavia, several direct oxidation processes, carried through the experimental to the practical commercial stage. The Schoenherr process is one of these, the Birkeland and Eyde process another. The direct combination of nitrogen and hydrogen to form ammonia has been successfully developed in the German Haber process, and the cyanamide process, with all its products from carbide to ammonium nitrate, was developed in Germany. There they used not only the peculiar reactions of calcium carbide with nitrogen, but the production of the nitrogen from liquid air, the reaction between water and cyanamide to form ammonia, and then an oxidation process for obtaining the nitric acid. The oxidation of ammonia to nitric acid by such methods as the Ostwald process has been studied by many investigators since 1830, and several different schemes are now in use abroad.

At the time most of this research work was under way it was not at all clear what use was to be made of it. Much of it was *purely academic* research, but it was clear that without the knowledge itself, certainly no use at all would be made of it.

I do not want you to look at research as an old, established utility. I want you to see it as I do: a powerful factor proved by the advance of the industrial welfare of the foremost countries, and a world-experiment of less than a century's trial, but something still unappreciated in America. It is true that the earliest man and many of the lower animals accomplished ends by research, but I refer now to research in the natural sciences and to the research which in our day is necessary to our desired activities. These sciences are already very highly developed, and advanced education is demanded by them. For ex-

ample, if I wish to cure physical ills, I cannot expect to do it by reciting ancient incantations, nor by using roots and herbs, as was once customary. I must first familiarize myself with an accumulation of previous experience. I must study anatomy, physiology, chemistry, bacteriology, etc. This is a relatively recent world-condition. Conditions are similar in all the applied sciences. The accumulated knowledge in any field is already very considerable, and to get into the firing line of useful work one must go up past the baggage train of knowledge and experience. There is something in the blood which makes an American naturally hate preliminaries. It will be a great day when we see how important preliminaries are. The hospital surgeon well knows how much more willing the young interne is to actually handle cases, if it is only to administer the ether or the iodine, which any nurse can do, than he is to study the theory of ether as an anesthetic, or of iodine as an antiseptic, which perhaps no nurse could understand. The young student of mechanics thinks he could have devised the steam turbine if it had not been done before his day, but when he comes to study the problem as it has actually been developed, he finds the same old kinetic theories, differentials and integrations which he spurned as too theoretical when he sought a short road to engineering.

AMERICAN PROGRESS PROPORTIONAL TO PREPARATION
BY RESEARCH

I want you to realize that in America we are going ahead in the future at a rate dependent *entirely* upon our preparation. Laboratories are a relatively modern thing. In most of the sciences they are a development within the lives of men now living. I want you to see that we must be foremost in systematic, organized research, or we shall be distanced by other countries which already well recognize the value of *new* knowledge.

When so much of our material welfare, the condition and extent of our manufactures, the quality of our agricultural efforts, and the health of our people, depend upon the rate of our acquirement of *new* knowledge, there ought to be much greater effort made along the lines of research than is at present the case. We call knowledge power, but we need to see that *new knowledge* is the second power of power.

I would rather be a little Moses than a big Jeremiah. I would much rather point a way to a promised land, however remote, than talk about our lamentable conditions. But we Americans are not sufficiently imbued with the spirit of active and efficient service. We are a preliminary experiment on the possibility of operating a competitive nation in a democratic manner, but we don't care enough about it. We have about as little interest in the wonder and elasticity of nature, the laws of materials (except where they affect our stomachs and our health) as had Darwin's starving Patagonians. With us the spirit of the hive is confined to the bees. Germans and Japanese make better scholars than we do, and a Chinese laundryman sticks longer to his daily job and talks less about it. We are living in the Garden of the Gods, but we are still eating grass.

Is there no significance in the fact that many American colleges are better known through their foot work than their head work? Is it not significant that the Y. M. C. A.'s dotting our land are as strong in bowling alleys as in education, and that most of our religious training goes to the heathen? Is it a sign of health that so large a portion of our newspapers are paid to feed us with results of useless experiments between prize fighters? I think the stadium should be the accessory of the laboratory, not the temple of the oracle; and that in reality a research laboratory is more compatible with the object of a university than is the more common training table. I do not mean to be too insistent as a critic or too pressing as an advocate, but I hate to see my own country such a trailer as it now is. I hope the conditions are changing, but I know they are not changing fast enough. Probably Moses and Jeremiah were both right.

All service is based on knowledge, and knowledge is an ever augmenting thing which almost anyone may increase. If the stock is *eternally* useful, as it is, how great must be the value of the *indestructible* increments which *anyone* may produce. I do not think due reverence is given to new knowledge. I want to illustrate.

SERVICE OF RESEARCH

Sometime, somewhere, centuries ago, the slag of a fireside appeared transparent; someone tried to learn more about it, and so ultimately, glass was made. Research is still under way on that very material, and countless numbers of men have slowly added to the knowledge. Glass has kept the cold

from the house. It has let in the light. It has renewed our eyes as they have worn out. Through telescope and microscope it has shown us the greatest and the smallest things of the universe. It has bottled our drinks and held our lights. Every year still adds new service, just in proportion as experiments add new knowledge. To-day we hear of a new glass permeable to ultraviolet light, glass opaque to X-rays, and glass for cooking utensils. Not one of these little increments will ever be lost, but will continue in use, so how highly should we value them? Why did we delay so long in coming thus far, and how far or fast may we still go?

Research is preparation. It is preparing in one decade for the problems and the necessary work of the next. There are various kinds of preparedness. We are hearing a great deal about one of them nowadays—immediate preparedness for national defense. But there is a more far-sighted preparedness that no one has adequately described and of which the building of new laboratories is a token. This type is the very best kind of preparedness for national defense, if begun in time. The continued study of the secrets of nature, the uncovering of buried treasures which always seem buried just deeply enough to develop the diggers—these are the criteria of a strengthening nation.

Research presents a way, and the only certain one, of insuring peace, of preparing successfully for defense, and of being successful in war. It is the lasting, undeviating factor which has always dominated. This may sound bold and entirely inconsistent in itself. It is all true. Can we learn to see it? From the military expert to the anthropologist, thinking men recognize that for over 100,000 years war has been almost continuous on the earth. The inventors of chipped flint successfully fought those inferiors who had *not experimented* with flint. There were then no better arms. These also got their game even when it was scarce and other means failed, and so they continued to survive. This little and early example of survival was repeated a great many times before our present complex world conditions were reached, and will as surely continue to be repeated. The fundamentals were always the same. A 42 cm. gun is only a better flint. Trinitrotoluol is only a more modern sling. Arms and ammunition have changed, but just so have also changed the myriads of other important acces-

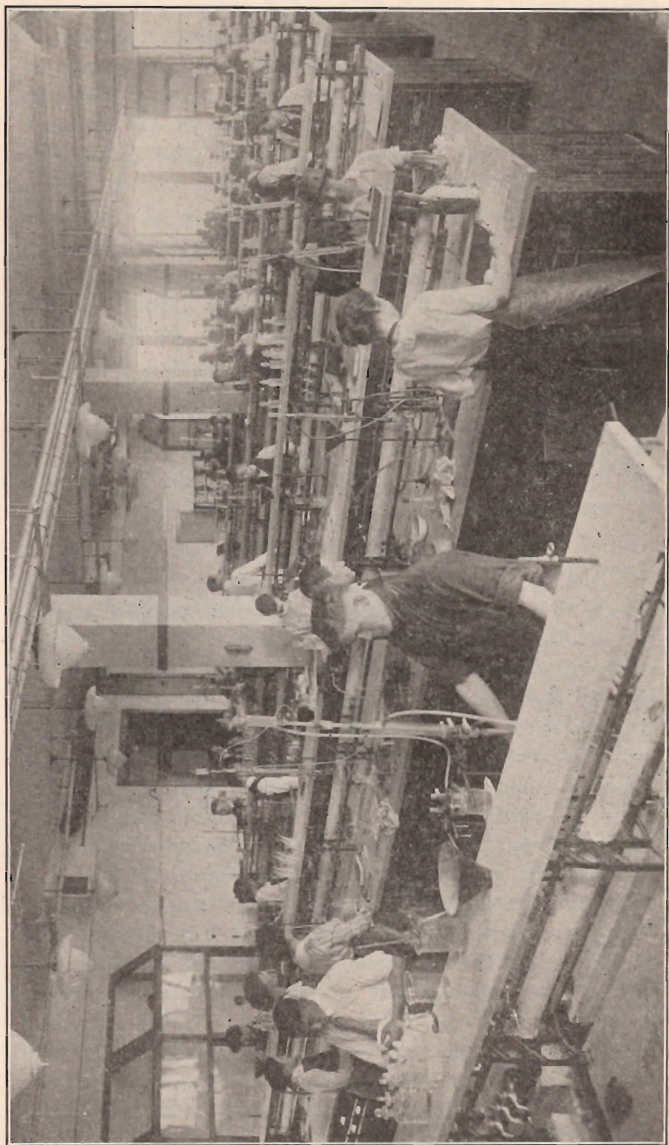
sories to survival. This is the important point. Good guns go with good clothes, and niter is good for fertilizers and for guncotton. The signs that we are improving in our civilization will also indicate that we are growing in our powers of national defense, but this should come rather as a consequence than as an object. The world has always been improving, and the real growth and development has come to those nations which have been responsible for the original research work and not for the mere storage or conservation of the knowledge.

The first or fundamental discovery in any series is not the only important one, so I am going to take an extreme view and say, it is only the continuation of research which is of any considerable importance to us. The fundamental discoveries may be like seeds, but the values are like growing plants. An acorn may correspond to the work of a Henry or a Faraday, but the great and growing tree of electrical or chemical work corresponds more nearly to the living state of the oak species. We are much more interested in what is to come than in what has already been accomplished.

PROBLEMS FOR RESEARCH

I realize that I ought to illustrate this appeal for research by concrete examples of chemical things to study. I know the feeling of the chemist who is mentally compressed by the mass of investigation work which has already been done and by the known facts which seem already to cover entirely all possibilities; but I know, too, that the future will make use of knowledge for which we now have *no vocabulary* and no powers for comprehension, and so could not possibly *anticipate*. If, then, I try to illustrate the search for new knowledge, you may be sure my illustrations will be inadequate.

In the first place, I cannot be reckless enough. This I learn from looking backward. I would not have dared suggest that a dozen good men should study the little hydrogen generator of the freshman laboratory, to see what was in it. If I had, I suppose I should have suggested a research on pipe organs, because of the singing hydrogen flame, or on bombs, because of the explosions. But someone tried synthetic ammonia, others Zeppelins, and others the cutting and welding of iron. When I see in our own factory the three score men now using oxyhydrogen all day for this latter use, I am impressed with the eternal proximity of new and useful knowledge. A very few years ago, two or three



THE ORGANIC LABORATORY, UNIVERSITY OF ILLINOIS

times as many men would have been necessary to do this work in the old, more difficult and less satisfactory manner.

The most natural suggestions for research are those simple ones referring to chemical elements. There are still plenty of "unknowns" among the elements, and of one thing we may be sure, there are certainly no two alike. Any chemist who wants to add to chemical knowledge need not go beyond the list of elements for his subject. The properties he discloses will every one of them be sometime a help to his science and of service to his country. As far as possible also, his country will reward him with patents if he asks them.

We ought to begin at the points where others left off, and continue the research of the chemical elements. One reason why this appeals to me is that I have seen so many recent applications of entirely new knowledge of elements in my own work. I merely mention tungsten, molybdenum, boron, argon, silicon, magnesium, titanium, thallium, vanadium and chromium, which, because of properties not known until recently, are nevertheless already doing commercial service in our restricted electrical field. Surely we know still far too little about these elements, but we know less about many others.

If now, the chemist, still neglecting the infinite compounds and narrowed in his researches to the elements, and then perhaps to the metals, and finally to a single element, still asks, "What shall I do?" I would refer him to the isotopes of his element. Our American Richards, supporting the researches resulting from the studies of radioactivity, has shown that there are two leads. They are somewhat different, but cannot be separated easily. Of course someone ought to separate all isotopes, and then there is plenty of room for research on the single isotope.

One of the great needs of the country which reflects on us chemists and calls for immediate research, is that for American potash. There is no supply in sight which is nearly comparable with the German deposits, and our fertilizer and other industries will certainly suffer because of this difference. We have plenty of feldspar calling for a simple process for removing the potash it contains. We have oceans of sea-water carrying plenty of potash. We don't know how to extract it. Don't say it can't be done, for it is being done by miles of seaweed. Why should we

confine ourselves to trying to take it away from the seaweed, instead of learning what the seaweed knows about getting it from the water? You may look supercilious, but until a large number of chemists have studied semipermeable membranes, there will always be this lack of understanding of those simple reactions of living matter going on around us. There will always seem to me a possibility of doing such physical and chemical things more nearly as we may wish to do them, when we know how they operate.

When nothing new is being done by us it will be a sure token of our decay. When we stop increasing our experimental activities or fall for a considerable time behind the activities of other countries, we may expect to see our light become merely a memory, like that of Greece or Rome. Thus far we Americans have not reached a fair average as investigators in natural sciences, and yet we have incomparably superior conditions for the growth of research. I cannot look beyond the period when research shall cease in a country and still imagine that country a power in the world.

There are no sharp lines to be drawn through research to separate pure from applied, scientific from practical, useful from useless. If one attempts to divide past research in such a manner, he finds that time entirely rubs out his lines of demarcation. At this particular time, however, one may imagine a more or less zigzag zone which serves to divide research in a commonly accepted way. I will illustrate. In a manufactory the price of a new product should include the cost of research. No matter how complicated the system, this is always true. Otherwise the industry would ultimately commit suicide. In practice it is common to apportion to particular products the cost of their separate development, and to fix the price so that within a reasonable time, or by a reasonable volume of sales, the so-called development cost may be wiped out. Thereafter the product may be sold on the basis of the continuing cost of actual production. While this system is extensive, it does not cover the cost of many of those original researches which may have been absolutely necessary. The argon tungsten lamp, in its development cost, did not carry the expenses of Rayleigh and Ramsay's work, and there will probably always be such classification of research work necessary.

"UNPAID RESEARCH" NEEDS APPRECIATION

Under such a classification, the part of research I am most interested in promoting is what we may call the *unpaid* kind, not because it is cheapest, but because it is the most valuable. It is most neglected, most poorly understood, most in need of appreciative support in America.

The separate industries do not need encouragement in research nearly so much as the nation needs it. The industries can be depended on to estimate its value to them, for they take annual inventories. But a country which keeps no books, seems to have to depend on accident for its most valuable research work.

It seems to me that many of our American colleges have been shortsighted in this respect. This may be explained by the rapidly increasing demand in our growing industries for analytical chemists and chemical engineers, who could at once meet the existing industrial requirements. This demand has kept the chemical departments of our colleges and technical schools very busy with the elementary and analytical side of chemistry and left little room for the synthetical or experimental side. It has also naturally tended toward the development of highly efficient organizations, equipments and corps of instructors for the preparation of the one type of chemist, but this very success seems frequently to make impracticable the training of men for research. The conscientious American professor has usually devoted his life to bringing his students up to a certain promising stage of interest in science and experiment, only to see them scatter before they have had any experience in questioning Nature, or have tried any unbeaten path of chemical byway.

While I am greatly interested in what might be done for science by technical research laboratories in the industries, I am sure that the university must be the important factor in guiding the pioneer work if we are to be a sufficiently advancing nation.

Let me recall recent words of President Wilson:

"I know I reflect your feeling and the feeling of all our citizens when I say the only thing I am afraid of is not being ready to perform our duty. I am afraid of the danger of shame. I am afraid of the danger of inadequacy. I am afraid of the danger of not being able to express the correct character of the country with tremendous might and effectiveness whenever we are called upon to act in the field of the world's affairs."

These words ring true. The American spirit is characterized by them. But think further a moment. They refer to a fear based upon an entirely corrigible

defect. The cure is in our hands. The time when we are called upon to act in the field of the world's affairs is *now*; but it was yesterday, and it will be tomorrow. I maintain that no nation can effectively act in that field at odd or selected moments. It is either doing it much of the time, or it is likely to be unable to do it any of the time.

GENERAL ELECTRIC COMPANY, SCHENECTADY, N. Y.

DESCRIPTION OF THE CHEMICAL LABORATORY OF THE UNIVERSITY OF ILLINOIS¹

By B. S. HOPKINS

In 1901 the legislature of the State of Illinois appropriated \$100,000 for the erection of a chemical laboratory upon the campus of the University of Illinois. With this sum available, plans were drawn for a building which it was expected would provide for the needs of the department for a period of twenty-five years. The smallness of the appropriation made it necessary to select a style of construction which entailed considerable risk from fire. It is built of red brick with Bedford limestone trimmings. It consists of three stories and basement, and is shaped like the letter "E," with a frontage of 230 feet and a depth of 116 feet along the wings. The middle rear portion contains the lecture room and the wings were largely given over to routine laboratories. The plans for this building were principally the work of the late Professor A. W. Palmer, to whose wise foresight and untiring energy this building stands as a fitting memorial.

The growth of the department of chemistry was much more rapid than was expected and it became evident that more room was needed before half of the twenty-five year period of usefulness had passed. Plans were formulated for the erection of an addition to the original building in such a manner that the completed building would form a hollow square, with the lecture amphitheatre in the center. The style of architecture conforms in essential features with that used in the old building but the new part is built entirely of fire-proof material. The dimensions of the complete building are 230 feet by 202 feet, and there are available 164,288 square feet (3.77 acres) of work-

¹ In compiling the data for this article the author has received the kindly assistance of members of the chemical staff, the supervising architect's office, and the contractors; he is under special obligation to Professor W. A. Noyes, Professor E. W. Washburn, and Dr. D. F. McFarland of the chemical faculty, Mr. E. R. Math, Superintendent of Construction, and the general contracting firm of Freeman and Brooks.

ing space. Plans for the new building are the result of the coöperation of the Supervising Architect's office with the heads of divisions of the department of chemistry under the able leadership of Professor W. A. Noyes, Director of the Laboratory. By this coöperative development of the plans, the special needs of each line of work are provided for, while the building as a whole possesses uniformity of design without needless duplication of equipment.

The new building joins the old at the extremities of the rear wings, where fire walls make it possible to shut off either side completely. The fire walls project above the roof and may be seen in the accompanying cut of the building. The liberal use of white enamel brick in the court makes the inner rooms light and attractive. Passage between the old and the new portions of the building may be effected through the wings or by a corridor which connects the center portions upon the first and second floors. Although the new part of the building covers a smaller area than the old, it furnishes a larger working space for the reason that five entire floors are available for laboratory purposes. The general plan of space distribution places the research laboratories, offices, library and museum in the new building while the routine laboratories are chiefly in the old building. It is expected that considerable remodeling of the old part will be done during the coming summer in accordance with this plan. The offices of the director of the laboratory and of the division of applied chemistry remain in the old part near the main entrance on the west front.

The building is a part of the quadrangle of university buildings and is conveniently located with respect to the College of Liberal Arts and Sciences, the College of Commerce and Business Administration, the College of Engineering, the College of Agriculture, and the Graduate School, from all of which the department of chemistry draws students. The main entrance is in the center of the west front, which faces the quadrangle. Two smaller entrances are located upon both the north and the south sides of the building, while in the center of the east front is located the service door, which is conveniently placed with respect to the main stockroom, the elevator and the shipping rooms.

THE NEW BUILDING

The framework of the new building is of structural

steel, the major partitions and walls are brick, the minor partitions of pyrobar and the floors are composed of alternate rows of hollow tile and joists of reinforced concrete. The concrete covers the hollow tile to a depth of two inches, thus producing a continuous T-effect, giving strength and lightness. Upon the concrete, electric conduits for the wiring system are laid and a top layer of concrete covers the conduits. The final layer upon the floor is a coat of "rezilite mastic" which is about an eighth of an inch thick. This last layer is acid-proof and gives considerable resiliency to the floors without making them soft enough to yield to heavy pressure. Some of the floors in the offices and seminar rooms are covered with battleship linoleum, while the library is provided with heavy cork carpet. The halls and stairs have Terrazzo finish.

The roof is of reinforced concrete which is made in large sections and supported by steel rafters. The concrete is covered by wood sheeting in order to give an air space for insulation purposes. The sheeting is covered with building paper and this in turn by slate or sixteen ounce copper plates. The skilful use of dormer windows makes the fourth-floor laboratories light and attractive and adds much to the architectural beauty of the building.

Very little wood is used in the building itself. The furniture is oak with a two-tone dull finish: the table tops and shelves are made of alberene, which material is used generally for window sills, open drains and sinks. The window sills in the halls, library and offices are white Alabama marble; the shelves in some of the rooms are made of milk glass.

Hoods are conveniently placed in all the laboratories. The frame of the hood is wood, the floor of alberene, the lining of white tile and the sides and top of reinforced plate glass. The doors are counterpoised by weights attached by means of a creosoted hemp rope. The pulleys and axles, which are wooden, are exposed, making repairs easy. Each hood has a separate flue running to the top of the building independent of other flues.

Ventilation is accomplished by means of forced draft. Two large ventilation fans with heating coils are housed in the court just outside the walls of the lecture room. This location is central and relieves the laboratories of the vibration of the fans. The fans have a capacity of 74,000 cubic feet of air per minute,

which is driven to all parts of the building, entering the rooms through conduits at the ceiling. Foul air is forced out through the opening in the hood flues. The air is changed six times per hour, the temperature being controlled by automatic regulators. A small exhaust fan in the attic removes the air from the toilet rooms. There are also four chemical exhaust fans, each capable of handling 10,000 cubic feet of air per minute, which are used to remove the impure atmosphere from some of the laboratories and hoods.

Special attention has been given to the electrical equipment of the laboratories, five systems being available in all parts of the building: 10, 110, and 220 volt direct current and 110 and 220 volt alternating current. Besides these many of the laboratories are supplied with current from the storage battery system of 35 cells. Scattered through the building there are 150 wall plugs, 160 experimental plug boxes and 16 motor boxes, making electrical current available in all places. The lighting is the indirect system, there being 730 lighting outlets and 300 wall switches. The total electrical load of the building is 130 kilowatts, there being in use three transformers of 50 K. W. each.

The type of construction and the completeness of the equipment of the new building may be inferred from the following tabulation of materials used:

Structural steel.....	402 tons
Reinforcing steel.....	135 tons
Cement.....	75,000 barrels
Sand and gravel.....	6,000 cubic yards
Lime.....	3,000 barrels
Brick.....	2,000,000
Pyrobar.....	65,000 square feet
Hollow tile for floors.....	50,000 square feet
Sewer tile.....	5,600 feet
Cut stone.....	5,000 cubic feet
Terrazzo steps and risers.....	2,700 feet
Plastering.....	33,000 square yards
Sheet copper.....	30,000 pounds
Skylight glass.....	2,500 square feet
Radiating surface—181 radiators.....	11,000 square feet
Steam pipe.....	10,600 feet
Covering for steam pipe.....	4,330 feet
Pipe for temperature control.....	4,000 feet
Conduits, for electric system.....	8.32 miles
Electric wiring.....	12.78 miles
Iron pipe ^(a) for water, gas, vacuum, etc..	3.6 miles
Block-tin pipe for distilled water.....	2,500 feet
Alberene (21,500 square feet).....	214 tons

(a) Excluding table fittings.

THE LABORATORY EQUIPMENT

THE DIVISION OF INORGANIC CHEMISTRY AND QUALITATIVE ANALYSIS occupies one laboratory on the fourth

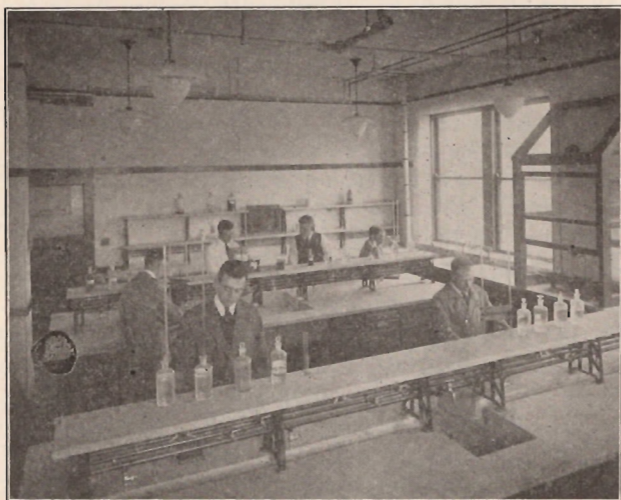
floor and the entire third floor with the exception of the rooms used temporarily by the guests of the department. Provision is made for the accommodation of about 1300 students, 400 of whom may work at any one time. In the new laboratories there are two special features worthy of mention, (1) the ventilation and (2) the commanding view of the entire room which is afforded an instructor in charge. In addition to the usual system of ventilation an independent suction system is used in these laboratories. Upon each student desk there is a 6-in. conduit which rises 8 in. above the table; a cap closes the opening when not in use. The conduits are made of canvass-coated fiber which has been thoroughly treated to make it a non-conductor, as well as water-proof and acid-proof. The exhaust fans draw the offensive gases downwards from the student tables and discharge them into a separate flue in the main ventilating stack. By this means the air in the laboratory may be changed eleven times per hour. Hoods of the regular type are also conveniently located for special experiments, and for the use of hydrogen sulfide.

An uninterrupted view of the laboratory is obtained by placing the ventilation flues and plumbing beneath the table top and omitting the usual reagent rack. Each student has at his own desk a set of reagent bottles, gas, suction, tap water, a sink and an open down-draft hood, while within easy reach there are also supplied compressed air, distilled water, steam, hydrogen sulfide, the electrical circuits and the regular hood system. An ingenious device is in use to permit the student to use his sink as a pneumatic trough. A piece of lead pipe 6 in. long is tapered to fit tightly into the outlet for the sink, the upper end of the pipe being closed with a perforated cone. In this way a depth of four inches of water is obtainable with no danger of overflow. The sink is quickly drained by removing the lead pipe. These lead risers in the sinks as well as the ventilating conduits are plainly visible on the table in the foreground of the accompanying illustration of the inorganic laboratory.

Besides the large student laboratories, there are twelve small laboratories available for research problems and for private laboratories of the teaching staff. There are three balance rooms for student use and one for research workers, the latter room being insulated

with cork. There is also a dark room for spectroscopic work.

THE DIVISION OF QUANTITATIVE ANALYSIS occupies the entire north end of the second floor. There are laboratories for beginning quantitative courses, advanced courses and food analysis accommodating in all 400 students. A large working space is assured to every student and double-length drawers are provided for condensers, burettes and other lengthy apparatus. The student desks are equipped with gas, water,



LABORATORY FOR STUDY OF PAINTS, OILS AND TARS

waste and suction, while in the hoods compressed air, hydrogen sulfide, high pressure steam and electrical connections are supplied. In the hoods are also placed specially constructed steam baths, the tops of which are terraced with three levels in order to make the rear openings more accessible and to decrease as far as possible danger of accident to dishes on the front row of openings. There are three conveniently located balance rooms, containing 53 balances for student use. A Kjeldahl room is provided with equipment such that 150 digestions may be carried on at one time and the distillation apparatus has room for 50 flasks. A separate ventilation system is provided for this room. A dark room contains a polariscope, a refractometer, a thermostat and other equipment needed for work of this type. An electrolytic laboratory is fully equipped for various types of electro-analysis. There

are eight well-equipped smaller laboratories, which are used for research and private laboratories.

THE DIVISION OF ORGANIC CHEMISTRY occupies the second floor at the south end of the building. Two large laboratories accommodating 280 students are used for the undergraduate course. In the new laboratory each student's desk is supplied with gas, water, waste, suction and live steam. The latter is available either as a jet for steam distillation or in a cone for distilling inflammable materials. In this way the amount of gas consumed is greatly decreased and greater safety is assured. Special attention is given in this laboratory to the electrical equipment for synthetic work and an unusually large amount of hood space is provided. On the side shelves connection may be made with the high vacuum pump; blast lamps are conveniently placed at the sides; and near the entrance to the laboratory is located a fire shower for use in emergencies.

In addition to the large laboratories there are several smaller rooms equipped for special lines of work. One room, the atmosphere of which is kept pure, is reserved for accurate physical measurements, such as determinations of conductivity and molecular weight. Accurate instruments, hung from a special solid wall, are in use. A dark room is provided for the study of reactions in the absence of light and two dark rooms are equipped for work with the refractometer, polariscope and spectroscope. A special feature is a collection of organic preparations from various lines of investigation in the laboratory. This collection is kept in a separate room, and is indexed for ready reference. The research and private laboratories have adequate equipment for the problems under investigation. The division is rapidly accumulating permanent equipment for the manufacture of the chemicals needed in the usual organic courses.

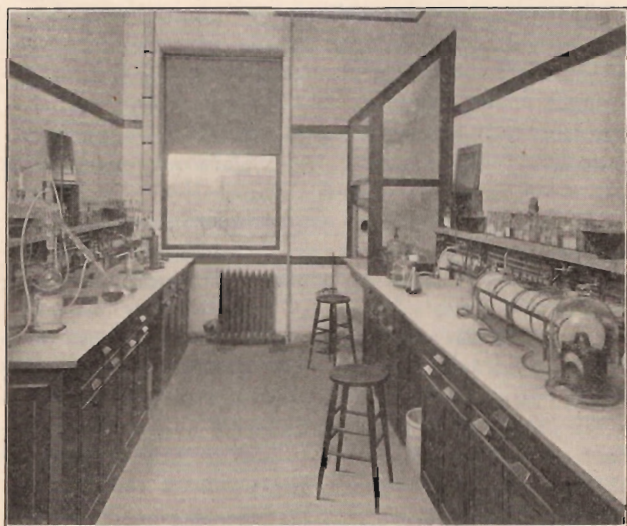
THE DIVISION OF PHYSIOLOGICAL CHEMISTRY occupies the greater part of the fourth floor. The main laboratory has desks for 108 students, the equipment being similar to that in the organic laboratory. There is an advanced laboratory for 16 students and two smaller private research laboratories. An instrument room is equipped with high-speed electric centrifuges, thermostats, apparatus for accurate titration, etc. The following special rooms are also equipped for their particular needs: a metabolism room,

an operating room, refrigerator room, and a dark room.

THE DIVISION OF PHYSICAL CHEMISTRY occupies the north end of the first floor and in addition has a calorimetric laboratory and an electric furnace laboratory in the basement. The space devoted to undergraduate work is in the old building except one optical laboratory and a balance room. The large undergraduate laboratory has working space for 50 students.

A feature of the arrangement of space in the new building is the segregation of certain kinds of work in rooms designed for special purposes. The preparation and purification of all chemicals will be carried out in the two preparation laboratories. One contains various types of distilling and subliming apparatus, vacuum pumps, electrical furnaces, and generators furnishing a variety of pure gases. The adjoining room is furnished with apparatus for precipitation, crystallization, filtration, centrifuging, drying, cooling, etc.

The cleaning room is equipped with a steam drying closet; an iron vat which is surrounded by steam coils and is filled with chromic acid cleaning solution; and a deep roomy sink with glass drain boards. The titration laboratory has a white tile floor and the walls, ceiling and furniture are finished with white enamel laboratory paint. The room has a north and east



TYPICAL PRIVATE LABORATORY FOR RESEARCH

exposure and its four windows are fitted with ground glass panes. The equipment includes qualitative reagents and indicator solutions, weight and volume burettes, pipettes, volumetric flasks, cells for electrolytic titration, colorimeters with sets of color standards and suitable balances.

The constant temperature room has walls, floor and ceilings insulated with a layer of cork board. The room contains a pier, which is insulated from the earth by a layer of the same material. The temperature of the air in the room is controlled by an electric thermostat and heater, and the air is kept in motion by an electric fan. Provision is made for a future installation of brine coils for low temperature work.

Along the east side of the building is a series of research laboratories and dark rooms. Two rooms are designed for electrical conductivity and transference investigations. A large constant temperature bath in the doorway between the two rooms serves both of them. The electrical conductance room contains a large sound-proof booth, resting on a thick layer of felt. An adjoining room contains the apparatus for producing and controlling the high frequency alternating current and a still for the production of conductivity water. In this series is to be found also the following special rooms: for the calibration of electrical measuring instruments; for the polarimeter; for the purification, storage and handling of mercury; for investigations in colloid or photochemistry; a dark room for ultramicroscopic investigations and another dark room for photographic work and refractometric measurements.

A large laboratory is equipped for the use of students in advanced physical and electrochemistry. In this room is also situated the electrical distribution board for the division. In addition to the regular currents found in other parts of the building this distributing board is provided with 250 volt a. c. and d. c. connections.

There are several offices and private laboratories for the instructional staff; the general office of the division is provided with a collection of books and reprints and a large plotting table with drafting equipment. Opening off this room is the office and private laboratory of the professor in charge of the division. Two other offices with private laboratories are advantageously placed. An ingenious device permits some

of these rooms to be used either as offices or as laboratories. A narrow ledge is placed against the wall at the height of an ordinary table. Upon this ledge is arranged a system of service supplies usually required in a laboratory. By placing a table against the ledge a convenient laboratory desk is obtained and by removing the table the room is quickly transformed into an office.

The work tables and laboratory desks are in most instances constructed with built-up birch wood tops, treated with aniline black. In some of the rooms, however, alberene stone has been used. Many of the lockers in the desks are fitted with wire-glass doors.

THE DIVISION OF APPLIED CHEMISTRY occupies the south end of the building upon the basement and first floor. The equipment of this division provides for work in all lines of industrial chemistry and metallurgy excepting water chemistry and electrochemistry.

The large general industrial laboratory in the basement has desks for about fifty students in advanced industrial and metallurgical courses. The desks are of a special design with high sanitary base. The west half of the room is used for the installation of larger scale apparatus and machinery for both instruction and research. Supply pipes for gas, compressed air, high pressure steam, vacuum, etc., are conveniently placed, as well as switchboards with outlets for the power circuits. A room for fine balances and an instructor's office and record room are adjacent to this room.

METALLURGICAL WORK is provided for in a suite of rooms. For assaying and furnace work of all kinds a large room contains permanent installations of coal-, oil- and gas-fired muffle and crucible furnaces, a large roasting furnace, besides various experimental furnaces of special design. A fuel storage room is on the east side while oil supply is kept in a large underground reservoir located outside the building and designed for convenient filling from the street. From this tank the oil is forced to a constant-level distributing tank in the fuel room. The pyrometer laboratory located opposite the furnace room is designed for calibration and use of pyrometers, cooling curve work and preparation of metal specimens. Adjacent to this is the metallography laboratory with a pier for supporting two large metallurgical microscopes with cameras. A third microscope will be supported on the firm wall of the vault stack on one side of the room. A large

dark room opens from this laboratory with ample facilities for the photographic work of metallography. All of the rooms of this suite have suitable electrical



LABORATORY FOR ELECTROCHEMICAL RESEARCH

circuits for small experimental furnaces and electrolytic work. A large storeroom and an ore sampling room are placed near the furnace room.

In the basement of the older portion of the building several smaller research rooms are equipped for the study of various problems. Here also are shop facilities for work in connection with industrial courses and investigations; a coal grinding and sampling room, and other rooms for special purposes.

On the first floor are laboratories for gas and fuel analysis, calorimetry, technology of gases, paints, oils, asphalts, paper, textiles, etc., as well as the laboratories for the chemical work of the Engineering Experiment Station and the State Board of Administration.

The laboratory for gas and fuel analysis accommodates 120 students working in sections. The student calorimeter room permits the use of 15 calorimeters at once. A balance room is adjacent to this laboratory.

Three laboratories for advanced work in fuels, oils, road materials, tars, paints, etc., are fitted with the standard equipment of the new laboratory as well as for steam and electrical distillation. A large dark

room is provided for photometric and optical testing.

The suite of rooms in the older portion of the building devoted to state chemical work is of especial interest. Here the chemical work for the Engineering Experiment Station, the State Geological Survey and for various university departments is done, and here is carried out the chemical work connected with fuel inspection for the university and for the State Board of Administration. All coal used in the various state institutions is purchased upon the basis of analyses and calorimetric determinations made by this laboratory.

Several rooms devoted to offices and research laboratories complete the space allotted to this division.

THE DIVISION OF SANITARY CHEMISTRY AND THE STATE WATER SURVEY occupy the ground floor at the north end of the building. Offices are provided for the director, the chief engineer, the assistant engineers and draftsmen. In the drafting room is a special library of sanitary chemistry. Separate laboratories are provided for sanitary chemical analysis, bacteriological examination, and mineral analysis. These laboratories are separated from each other by glass partitions, making a particularly light and attractive environment. There are two incubator rooms, one kept at 20° and the other at 37.5° , heating and regulation being accomplished by accurate electrical devices. In the wash room there are large sinks and drain boards; the permutit water-softening apparatus; a hot air sterilizer with an insulated oven; and a roomy new-model autoclave which is operated by high pressure steam. There is also provided a laboratory for research on special problems; a private laboratory for the director; a conference room; a special fireproof vault and a well-located shipping room.

The student laboratories for instruction in water analysis contain 48 desks as well as rooms for ammonia distillations, technical experiments, incubators and balance cases.

THE GENERAL SERVICE EQUIPMENT

STOREROOMS are placed conveniently about the building, one on the second floor, two on the third floor, and one on the fourth floor. The main stock room is in the basement, under the lecture room.

An electric elevator facilitates the distribution of supplies to all floors.

THE WORK SHOPS are three in number. The *mechanician's* shop is equipped with lathe, power-saw, emery wheels, drill press, oxyacetylene outfit and tools needed for the manufacture and repair of apparatus. The *glass blower's* equipment includes 13 blow-pipes, a small lathe, and a motor for grinding glass apparatus; a small laboratory is also equipped for instruction in glass blowing. The *plumber's* shop contains tools and materials needed for making repairs to the plumbing of the building.

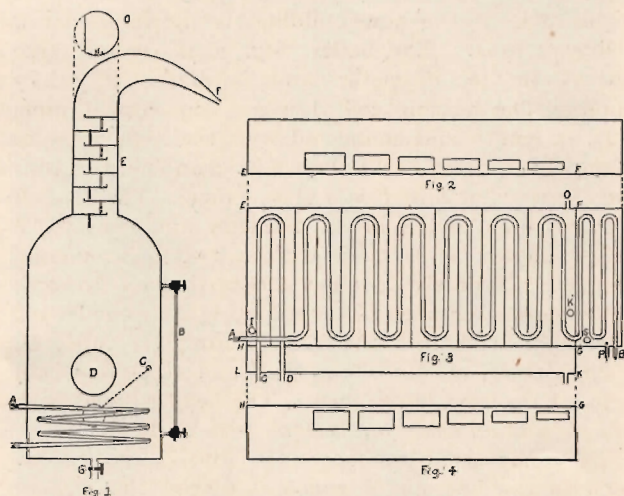
FIREPROOF VAULTS AND THE ELEVATOR are available from all floors.

DISTILLED WATER is produced by two special stills designed by Professor Noyes. The new still, located in the attic of the new building, is shown in detail in Figs. 1 to 4. The boiler, Fig. 1, is 36 in. high and 24 in. in diameter and is made of heavy copper. The heating coil *A* is a $\frac{3}{4}$ -in. copper pipe, 15 ft. in length and connected with the high pressure steam, *G* is a drain cock, *D* an 8-in. manhole, *C* a constant level valve and *B* is a glass gauge. The head *E* is 20 in. high and 8 in. in diameter and contains 8 shelves shown at *O* each with a two-inch opening arranged alternately to allow steam to pass upward. The edge of each shelf is turned up $\frac{1}{2}$ in.; condensed water runs back into the boiler through a tube, *H*, which rises $\frac{1}{4}$ in. above the shelf and extends within $\frac{1}{8}$ in. of the next lower shelf. The head is lined with pure tin and all soldering is done with pure tin.

The condenser box, shown in Fig. 3, is 12 in. deep, on the bottom of which is placed the $1\frac{1}{4}$ -in. tin condensing tube *A B*. The end *LE* is 4 in. higher than the end *GF* to give proper drainage. The successive partitions from *HE* to *FG* have a space of two inches at alternate ends, while *FG* is solid. The compartment *L H G K* is designed as a flue to carry off gases and steam to a ventilator with a strong draft. The sides *H G* and *E F*, shown in Figs. 2 and 4, have windows to facilitate the ventilation. *O* and the opening near *K* are drains. The box *LEFK* is covered, but the small compartment below *FG* is open. Feed water enters at *K'* through a constant level valve set to give a depth of 8 in. at *FG* and 4 in. at *HE*. As it passes back and forth across the box it is warmed by the condensation within the tube

A B. The single coil *C D* is a 3-in. copper tube connected with the high-pressure steam permitting more thorough preheating of the feed water. The exit *I* is raised two inches above the bottom of the condenser box in order to leave behind any sediment. From *I* the feed water passes to *C* (Fig. 1). The final condensation of the steam is effected in the compartment below *F G*, into which cold water passes through *P*. The overflow *S* rises 8 inches from the bottom. The distilled water leaves the apparatus at *B* and is stored in a heavily tinned copper tank which has a capacity of 2800 liters.

The feed water used is rain water from cisterns when this is available; at other times use is made of the water from the university wells which has been softened by the permutit process. An amount of



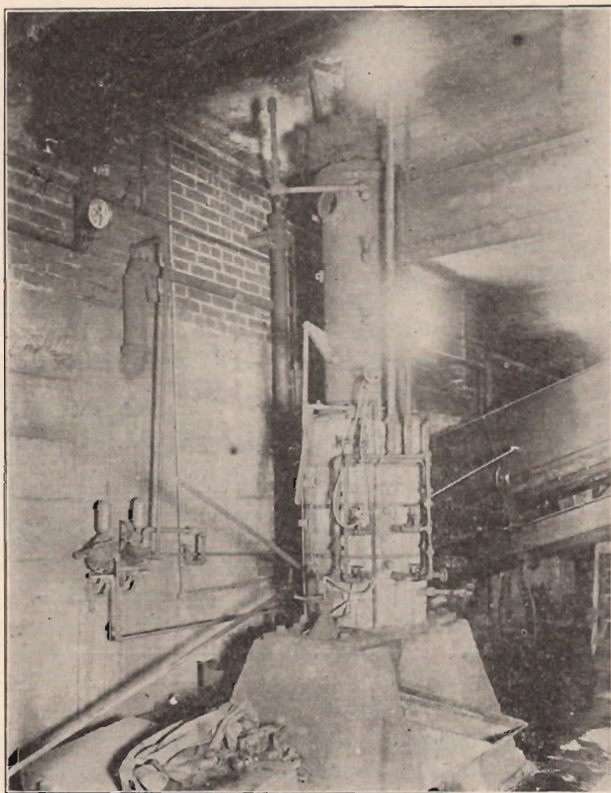
DISTILLED WATER APPARATUS

alkaline permanganate is added which is slightly in excess of the amount required by the oxygen consuming power of the feed water. The capacity of the still is 80-100 liters per hour but when running at full capacity the product contains somewhat more ammonia than is desirable. When running at the rate of 60 liters per hour the nitrogen in the form of ammonia may be reduced to 0.06 part per million or less. The original water contains 2.0 parts per million of nitrogen in the form of ammonia and 0.15 part as albuminoid ammonia.

HYDROGEN SULFIDE is to be generated in an attic room which is thoroughly ventilated and completely

shut off from the rest of the building. It is planned to install a generator patterned after the one in use at the University of Wisconsin. Distribution is to be made through a 500-gallon gas tank in order that the pressure of the gas may be as constant as possible.

STEAM is supplied from the university power house, through the service tunnel. The heating system is run under four pounds pressure; the supply for the



LOW TEMPERATURE COKING APPARATUS

steam baths and laboratories is under a pressure of 15 lbs.; the high-pressure system is run at 30 lbs.

VACUUM is furnished by a 14 X 8 in. vacuum pump in the machine room, which gives a vacuum equal to from 16 to 20 in. of mercury. In many of the research rooms and some of the student laboratories a special vacuum system is available which produces an exhaustion equivalent to 1 millimeter of mercury.

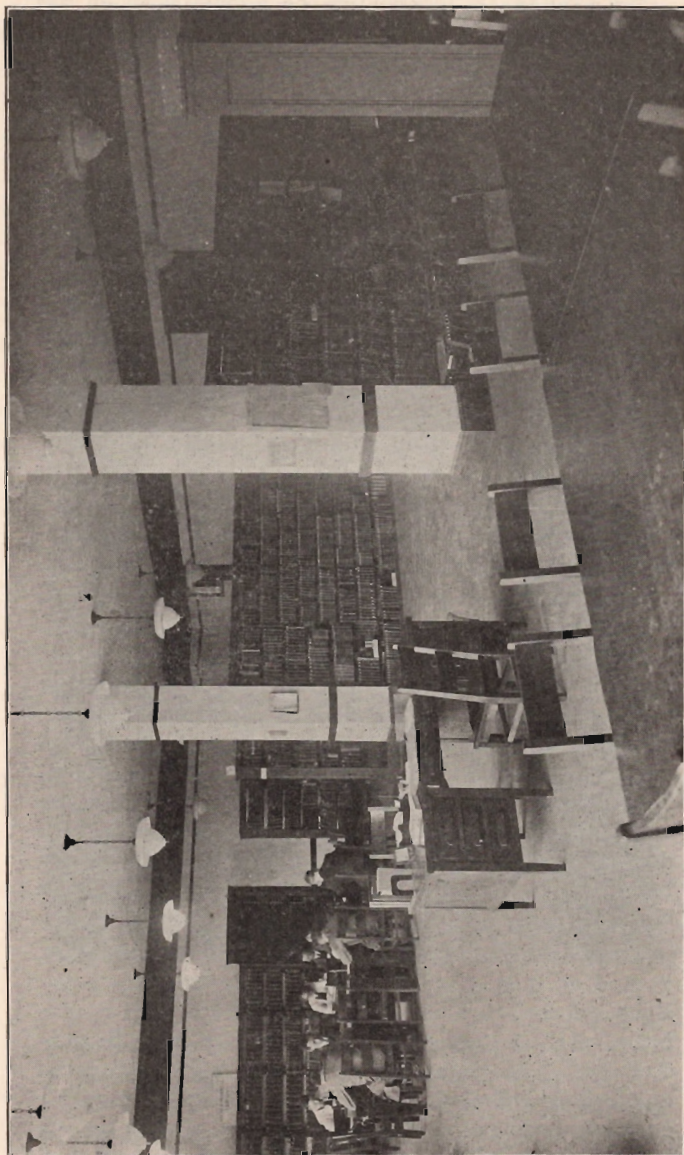
COMPRESSED AIR is also supplied from the machine room in which is placed an air compressor capable of supplying a pressure up to 80 lbs. per square inch.

THE LIBRARY is located on the second floor at the east front in a room which is commodious, attractive, fireproof and easily accessible from all parts of the building. The library contains 3500 books selected to cover all branches of pure and applied chemistry and 6500 bound volumes of chemical periodicals. An important part of the library equipment is the *Palmer Memorial Library*, which consists of the private collection of chemical works of the late Professor Arthur W. Palmer. In addition to the bound volumes the library receives 105 current periodicals. At present the book stacks contain 1500 linear feet of shelving; the plans provide for doubling this amount. Further expansion of both the library and reading room is possible by the use of an adjoining seminar room. The card catalogue lists under both author and subject all literature of interest to chemists which is to be found upon the university campus. The library is open daily (except Sunday) from 7.45 A.M. to 10.00 P.M.

THE LECTURE ROOM is an amphitheatre of hexagonal shape situated in the court at the center of the building. It was erected in 1902, but was remodelled in 1914, making it fireproof. The seats, of which there are 390, are elevated upon tiers of concrete benches, affording a good view of the lecture table from all parts of the room. It may be entered from the first floor directly opposite the main entrance or from the connecting corridor and from the second-floor corridor. The lighting is mainly by skylight, provision being made for darkening the room for the use of the lantern.

Three other smaller lecture rooms seating 100, 75 and 60, respectively, are in use for smaller classes. Each lecture room has a preparation room and is supplied with the equipment needed for lecture demonstration. The lecture room used jointly by physical and applied chemistry has a lecture table with movable end sections, permitting experiments to be set up in the preparation room or displays to be arranged in the museum. In addition to these four rooms there are eight recitation rooms and three seminar rooms.

THE MUSEUM contains an extensive collection of



THE CHEMICAL LIBRARY, UNIVERSITY OF ILLINOIS

mineral specimens, samples of manufactured products and other displays of interest to students of chemistry. Some cases containing specimens of general interest are placed in the connecting corridors in which are hung pictures of noted chemists.

THE CLUB ROOM is an attractive room on the first floor provided as a home for the Chemical Club and *The Illinois Chemist*. The adjoining seminar room may be thrown open by double doors, the two rooms furnishing delightful social quarters. An open grate, appropriate decorations and comfortable furniture make these rooms homelike and popular.

GUESTS OF THE DEPARTMENT

THE DIVISION OF BACTERIOLOGY OF THE DEPARTMENT OF BOTANY occupies temporary quarters on the third floor. The large laboratory, which accommodates the students in elementary bacteriology, has 108 lockers. There are two smaller laboratories, one for applied bacteriology with locker provision for 34 students and the other for research with accommodations for 44 graduate students. Included in this suite are smaller rooms arranged and equipped as follows: a preparation room, a sterilization room, two constant temperature rooms which are kept at 37.5° and 20°, respectively, a seminar room, a supply room, two offices and two private laboratories for use of the teaching force.

The furniture and arrangement of these rooms are in harmony with that in the other portions of the building. As future growth makes expansion necessary, these rooms are to be occupied by the department of chemistry.

THE BOARD OF TRUSTEES OF THE UNITED STATES PHARMACOPOEIAL CONVENTION is granted the use of an office and private laboratory upon the third floor which are occupied by its chairman, Dr. J. H. Beal. While the work done here is not strictly a part of the university curriculum, the presence of this laboratory is a great help to those students who are interested in pharmaceutical chemistry. Dr. Beal has consented to act as director of pharmaceutical research and accepts a limited number of graduate students for work upon special problems.

THE VALUE OF THE BUILDING AND EQUIPMENT

The original cost of the building erected in 1902 was little short of the total appropriation which was

\$100,000. For equipment a special appropriation of \$20,000 was made in 1903, and frequent additions to these amounts were made from time to time. In the following estimate of the present valuation of the entire plant of the department the items relating to the old building and the stock are taken from the report of the university comptroller June 30, 1915, and the data concerning the new building were supplied by the office of the supervising architect April 25, 1916:

Chemistry building (old portion).....	\$ 80,200.00
Laboratory apparatus.....	32,095.08
Office equipment.....	1,241.95
Furniture.....	5,433.62
Small apparatus and chemicals.....	23,000.00
New building, including permanent equipment.....	\$400,000.00
<hr/>	
TOTAL VALUATION.....	\$541,970.65

