SCIENCE

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MSS. intended for publication and books, etc., intended for review should be sent to Professor J. McKeen Cattell, Garrison-on-Hudson, N. Y.

THE TRAINING OF CHEMISTS[1]

THE address of Dr. Whitney on research, which follows mine, deals with that aim of the chemist which always receives the most enthusiastic recognition, namely, the elaboration of the content of the science, the farther coordination of that content, and the expansion of the boundaries of chemistry. 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 prin-

[1] Address delivered in Urbana at the opening of the Chemical Laboratory of the University of Illinois, April 19, 1916.

ciples 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 boresome. 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 can not 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 himself 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 only overlaps about half of the preceding course, the inevitable result is that the pupil gains in four years only what, with better coordinated 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 the instructors often 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 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 continuous 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 class-room 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 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. Of course, 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 thoroughgoing applications and connections that are required to weld the whole into a science. Modern chemistry simply teems with applications 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 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 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, is in place. 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 practise 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 practise 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 practise, 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 class-room 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 practises 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 remained 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 practise, 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 real 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 class-room work is simply a discussion and adjustment of what he has 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 can not 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 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 sixty to eighty thousand dollars.

In all laboratories, much glass apparatus is returned in dirty condition. Since it will not be accepted in this condition by another student, it can not 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 $1,200. 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 the influence, into clean-cut and satisfactory manipulation.

The sand-blast reminds us that a mechanic and a workshop 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 can not 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. Can not 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?

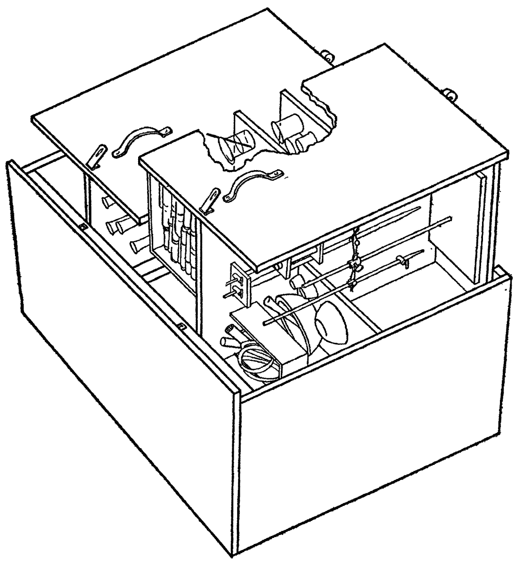

Fig. 1.

A desk designed by Dr. Fales seems to solve this problem (Fig. 1). 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 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 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 required with the common arrangement, and instead of taking 3–4 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 four to twelve pounds. That necessary to draw forth the rack with its complete load of apparatus and chemicals (weighing 40 lbs.) is only two 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 practise 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 manipulation to be introduced, and so gives more mental training and greater technical skill.

The magnificent addition to this 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 can not 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.

ALEXANDER SMITH
COLUMBIA UNIVERSITY

RESEARCH AS A NATIONAL DUTY

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, from the youngest to the oldest chemist, it is not always recognized. It is very natural for us to think we can think new things into being. Chemistry has advanced only in proportion to the handling of chemical substances by some one. When the study of our science was largely mental speculation, and the products and reagents largely immaterial,