SCIENCE

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

*THE RÔLE OF CHEMISTRY IN UNIVERSITY EDUCATION.**

THE installation of a new chemical laboratory as an adjunct to university education, while not unusual in our country, is always attended with interesting features. From a description of the plans of this building, published in SCIENCE, in December, 1900, I learn that an attempt has been made to combine all the modern features of value which recent laboratories have developed. It is true that the material of which this edifice is composed is mostly the product of Kansas. In fact, the stone, in part, was taken from the very site on which the laboratory stands. The plans, however, which were adopted and the details which were carried out are the results of an extensive inquiry and personal inspection on the part of the director of the laboratory and the architect. I could not but notice, in looking over these detailed plans, how many of the best features of modern laboratories with which I have been acquainted have been incorporated into the plans of this building. We have here a complete structure designed for a specific purpose, built under the personal direction of those most skilled and competent, both in architecture and technical knowledge, and now

* Address delivered at the dedication of the new chemical laboratory of the University of Kansas, at Lawrence, October 16, 1902.

it has reached a finished state ready to be dedicated for the great purpose for which it was designed and constructed.

It seems to me that no feature of our modern university education is so strikingly set forth in the last few years as that one which seeks to adapt physical and material means to educational purposes. We are no longer satisfied with a mere enclosure of four walls which keep out the rain and water and which offer no other material advantages for study and research. I am not forgetful of the fact that some of the greatest accomplishments of the human intellect, in the way of search after truth and knowledge, have been secured under the most adverse circumstances. Berzelius, one of the greatest of chemists, pursued his simple researches in a laboratory established in a kitchen and with appliances which a third-grade high school would now reject as totally unfit for any useful purpose. We should not forget, however, that in the impartation of instruction, and in the conduct of research, we have passed the stage of first settlement and the opening of practically unknown ways. The ground which is to be covered is well mapped out. We know its physiography and geography and we are warned by conspicuous placards, which we see everywhere, that this particular field is preempted and already under culture. The courtesy which we owe each other leads us to respect the claims which those who have gone before us have made, and to seek for other fields of usefulness not yet marked out.

Thus the simple appliances and the vast open fields of a hundred years ago are now wanting, and we need the greatest refinement of every possible kind in order to make becoming progress. We hail, therefore, with delight every new foundation embodying new modern improvements devoted to the cause of science, and especially that particular science, which today we are permitted to speak of in detail, chemistry. It is, perhaps, no more fortunate than any of the others with which it is associated in increasing the sum of human knowledge. There are, however, some peculiar circumstances connected with the foundation of an institution for chemical instruction and research which differentiate that science from its sisters and which call for some special comment.

As a factor in the education of our youth, chemistry may be regarded from many distinct points of view. In the first place, the data which chemistry has established are elements of a liberal education. In modern times the whole tendency in chemical work is towards specialization. Unless a man knows some one thing more intimately than anybody else in the world, he has little prospect of becoming professionally useful and renowned. It is no longer a case of knowing one whole science better than any one else, because almost every science has grown beyond the understanding of any single individual, but it is a question of knowing some particular thing, some minute branch of the science, in a way in which no other one comprehends it.

Specialization in science, however, should never be allowed to interfere with the elementary education of the one who is to be devoted to special work. More and more as I study this problem, it seems to me that a man who in his future life is to become eminent as a specialist should, of all others, lay broad and deep the foundation of his training. Whatever function a man may perform in life, he should have a general knowledge of the languages, mathematics, literature and the sciences, and among them chemistry. I would not like to say *especially* of chemistry, because the members of each profession may be justly accused of magnifying their own science so that its relative dimensions are very much distorted. But cutting myself loose as much as possible from the ties of my profession, it does seem to me that the fundamental data of chemistry are especially useful as elements in the foundations of a liberal training. In other words, the liberally educated man ought to know something of the composition of the earth on which he lives, of the minerals and precious stones which it yields, of the water which covers its surface, permeates its atmosphere and gathers in clouds above his head; of the plants which grow upon the soil and the elements which compose them; of the food which comes upon his table and the principles of nutrition; of the number of elementary substances known and some of their general properties; of the principles of physical chemistry which unite chemistry with physics; of some of the technical operations in which the science of chemistry is a controlling factor, such as the manufacture of starch and sugar, of steel and iron, of leather and fertilizers, of dye-stuffs and textile fabrics, and many other similar processes. Why, may I ask, should we expect a liberally educated man to be acquainted with all the heathen mythologies and to be on speaking terms with all the mythical gods and goddesses who inhabit Olympus or Walhalla, and to be absolutely ignorant of the composition of the air he breathes and the water he drinks?

No one can accuse me of belittling the claims of classical and historical education in molding character and developing intellect. All of my life I have been a strong advocate of the old system of classical instruction. I have seen with regret the battlements of classical learning broken down under the heavy fire of scientific assailants, and through the embrasures thus made I have seen the heights taken by storm and in many instances destroyed. But while I fully realize the immense value of all such studies in general education, I cannot be brought to the belief that a liberally educated man should be practically ignorant of the physical and biological sciences.

It is not necessary in order to have this general knowledge that he should be a specialist in any sense of the word. Our scientific and popular magazines teem with articles written by specialists which bring within easy access of the intelligent reader all the data of which I have spoken. He can know the principles of astronomy without being a Newcomb; he can know the fundamental data of chemistry without being a Gibbs; he can comprehend the conditions of existence and the evolution of organic life without being a Darwin; he can grasp the practical points of botany without being a Gray. It seems to me, therefore, that one of the great functions of chemistry in university education is to teach to the liberally educated youth the principal data of chemical science, even if it does not attempt to make him a professional chemist.

I think it may, therefore, be taken for granted that what is known as a liberal education should consist in part of a knowledge of the data of chemistry to which allusion has been made.

It perhaps might be pertinent to this subject to discuss the period of higher education which should be devoted to the study of chemistry, and to determine the position in the course of physical studies which chemistry should have. Such a discussion, however, would lead to endless differences of opinion and would probably result only in adding one additional opinion to the many already in vogue. That there is a natural sequence in the study of physical sciences will probably be admitted, but that that sequence is always invariable is a matter of some doubt. The final purpose in view will doubtless have much influence upon the legitimate sequence of studies. If chemistry, therefore, be studied only as a contribution to a liberal education, it seems to me to make little difference in what part of the higher curriculum it comes. If, on the other hand, the student is to become a specialist in any other science, especially physical science, the position of chemistry in the course of study becomes more important. And if, finally, a student is to become a specialist in chemistry the position of this science in his course of study becomes most important.

We find in a study of chemical phenomena that there are certain natural forces which are highly efficient in effecting chemical changes. These are light, heat and electricity, all of which by modern theories are regarded as special forms of vibration in the elementary particles of matter or ether. Since an artisan should be acquainted with the character of the tools he uses, and since light, heat and electricity become important tools in chemical processes, it would seem natural that at least that part of physics relating to these forces should precede purely chemical studies. There are, however, very few purely chemical problems that require the higher mathematics, and thus it happens that the student of chemistry who has a working acquaintance with arithmetic, algebra and a superficial knowledge in geometry and trigonometry, is able to perform most of the mathematical operations which the study of chemistry requires.

Further than this, chemistry may be regarded as a college study only and not in the light of the university proper. Our American universities, almost without exception, are built around the college as the central school, meaning by the college that part of the course of instruction which is destined to give the foundation of a liberal training without specialization. Wherever specialization enters into a college, the college to that extent becomes a university of higher learning; in other words, a kind of a graduate school before graduation.

I have often thought that it might be well to confine the college to the old-fashioned type, especially since it is only an integral part of the university, and to reserve specialization until after the degree of A.B. has been secured.

Thus, for the purpose of this address, it is not necessary to dwell upon the particular year or part of the curriculum when chemical studies should enter. I have, however, very grave doubts of the wisdom of teaching extensive courses of practical chemistry in the high schools. It is not expected that any one should obtain a professional knowledge of chemistry in a high school, and yet working laboratories have been established in most of our high schools entirely similar to those used for training professionals. It may be an erroneous opinion, but I have always held to the view that in childhood and youth we find the proper periods of life for learning languages. Now a knowledge of one's own language, especially if one be an English-speaking person, is quite impossible without a study of the sources whence it has sprung. Therefore, an English scholar must first of all have a working knowledge of the classical languages, so-called, that is Latin and Greek, and also a practical knowledge of German, at least, which is one of the languages evolved from the Anglo-Saxon, or rather the Saxon part of the Anglo-Saxon. While it is convenient to know other ancient languages and all modern languages, it must be confessed that the period of childhood and youth is not long enough to become practically acquainted with more than three or four languages, besides the vernacular. Hence, while not neglecting nature lessons and the teaching of the explanation of the ordinary phenomena with which we are surrounded, it seems to me wiser to devote the period of infancy and childhood and early youth largely to learning English, Greek, Latin and German. The youth who, at sixteen, finds himself ready for college with a practical knowledge of the four languages I have mentioned, has laid one of the cornerstones of a liberal education. There is no other period at which languages can be so easily acquired as that period in which nature teaches languages herself, and a year of Latin at nine or ten is worth two years at twenty or thirty.

I would like, therefore, to see the science training of our high schools confined to the explanation of common phenomena, and not include any expensive, time-consuming and exclusive laboratory practices. This may all seem heresy, coming from a scientific man, but I believe it is good gospel, nevertheless. I have often been mortified at the English composition of college and even university graduates. Men who have attained eminence in particular branches of study often seem incapable of expressing their thoughts in any proper way. Their English is inexact, clumsy and inconsequent. Clear expression seems to me to be the legitimate outcome of clear thinking, and the neglect of those early studies which enable one to express himself clearly and forcibly is a fault which can only be remedied by long years of mortification and hard labor.

Chemistry, in the second place, plays an important rôle as a help in the study of other sciences. Since it enters as an element into so many other sciences, except that part of physics already mentioned, it seems to me that for scientific purposes, or, in other words, for instruction in scientific specialties, chemistry should be practically the first science studied. I would point out only a few instances in which chemistry becomes an important adjunct in other branches of scientific investigation. In geology it teaches the composition of rocks, and this often throws important light upon their origin. The presence of quantities of phosphoric acid in a rock shows that it must have been derived, or probably was derived, from organic life. If iodin and bromin be found in mineral deposits, it is an indication that they were of marine organic origin. The geologist, of course, must know whether his rocks are composed of silicates, carbonates or sand, for these three classes of chemical compounds make up the great bulk of the rock deposits of the earth's crust. To be sure, it does not require a great deal of chemistry to determine this, but it does require chemical knowledge, and thus a knowledge of chemistry must be one of the elements in the education of a geologist.

In the case of mineralogy, the importance of chemistry as a preliminary study is more pronounced. Morphology is, of course, an important aid to the mineralogist in determining species, but the final test is always composition. The mineralogist, therefore, must be not only a chemist, but a chemist of skill and experience, or else he is ignorant of an important part of his profession.

In metallurgy we find chemistry again playing a most important rôle. While the working of metals, from an artistic point of view, is entirely independent of a knowledge of their composition, the production of metals from their ores is a chemical process pure and simple. The metallurgist is first of all a producer of metals, but when he works them into given forms he becomes an artist. Chemistry, in the guise of metallurgy, was the foundation of the first of the arts, for it is evident that if man had never emerged from the Stone Age he never could have progressed in knowledge and civilization to the present point. It was the discovery of the science of metallurgy which enabled the human race to span that great chasm between the age of stone and the age of steel.

In a science apparently utterly removed from chemistry, viz., astronomy, chemistry plays no unimportant part, for it is through the aid of physical chemistry only that the composition of the sun and the stars has been revealed to man.

In the biological sciences chemistry plays no less an important rôle. It is the fundamental basis of animal and vegetable physiology. The processes of growth in the animal and vegetable are purely chemical. It is true that modern chemistry has not reached the skill of nature, and we are unable to reproduce in the laboratory all the changes which matter undergoes in the animal and vegetable organism, but those we are not able to reproduce are none the less purely chemical and show the high order of talent which nature has provided in her chemical processes, talent which it is well we should emulate, although we may never be able to imitate.

"The weapons in the armory of the modern physiologist are multitudinous in number and complex in construction, and enable him in the experimental investigation of his subject to accurately measure and record the workings of the different parts of the machinery he has to study. But preeminent among these instruments stand the test-tube and the chemical operation typified by that simple piece of glass.

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"If even a superficial survey of modern physiological literature is taken, one is at once struck with the great preponderance of papers and books which have a chemical bearing. In this the physiological journals of to-day contrast very markedly with those of thirty, twenty or even ten years ago. The sister science of chemical pathology is making similar rapid strides."*

I shall not speak in this address of the purely chemical industries, because they have so often been described. There the rôle of chemistry is paramount. It is no longer an aid, but a master.

Thus in this rapid review is seen the importance of chemistry in other sciences, and, therefore, its place in the university curriculum must always be a capital one. This necessity has been recognized from the very first in the higher education in this country. In the old-fashioned colleges in which our fathers received a training which made them, perhaps, more eminent than their sons have become, before the days of the renaissance of science, if we may regard it as ever having been vigorous in the past, chemistry was always the first of the sciences provided for. When the laboratory gradually became evolved as a means of instruction, it was always the chemical laboratory which was first established in all our higher institutions, and when the day of specialization permitted more than one professor to teach the sciences, it was usually the professor of chemistry who was first segregated from the scientific chaos. And for this reason to-day in every institution of higher learning, whatever the specialty may be which the student of science studies, chemistry becomes an integral and fundamental part of his course of instruction. While in schools of chemistry it may not be necessary for the student to study mining, civil and electrical engineering, in schools of mining, civil and electrical engineering the student is always required to study chemistry.

Chemistry is also the fundamental sci-

* Extract from presidential address delivered by W. D. Halliburton to the Physiological Section at the Belfast meeting of the British Association for the Advancement of Science.

ence in the training of the pharmacist and the physician. Take out of the pharmacopœia and the materia medica the contributions which chemistry has made, and you have little left but empiricism.

The remedial principles of plants are separated, purified and studied by chemical means. Synthetic chemistry has added to materia medica hundreds of valuable remedies. Standards of purity for drugs are fixed by chemical processes.

Thus we see the importance of chemistry in the rôle of training, not only as a means of a liberal education, but also as an adjunct to other scientific professions.

Let us now consider for a short time chemistry in the rôle of the higher university instruction or in the graduate schools. We now emerge from the region where chemistry is studied for education and for help, to a region where it is studied as a profession. There is no other science to my mind, and I think I will be able to prove it to you statistically and otherwise, which holds the place in the higher universities and graduate schools which chemistry occupies. Fortunately, I have been spared the labor of collation in this matter, by an interesting article which appeared in SCIENCE for September 5, 1902, entitled 'Doctorates Conferred by American Universities.' The doctorate referred to is doctor of philosophy, and in most instances it was conferred in the graduate school of the university mentioned; if not it was conferred only as the result of a special training in the university itself. Twenty-seven universities, representing the principal institutions in the United States of the university class, enter into the statistical data referred to. The period of observation extended over five years, from 1898 to 1902 inclusive. During this period, 1,158 degrees of doctor of philosophy were conferred by the universities mentioned. Of this number 568 were conferred for purely scientific studies, as distinguished from those other studies in universities which, I think, are known as the humanities. It was always a mystery to me why such studies as chemistry, physics, geology and botany, which lie so near all the necessities of life, should be excluded from that class which has received such a high-sounding name. I think there is more humanity in a science which produces edible roots than in one which studies those of Greek and Latin origin, and more philanthropy in the arts which produce fuel and clothing than in those which bring forth syntax and prosody. But we will not stop to quarrel with appellations, and if the sciences are not humanities in name they are certainly so in fact.

Thus, of the total number of degrees of doctor of philosophy conferred in five years, 49.5 per cent. were given in the sciences; in round numbers, half of the whole number.

An interesting table is also given of the percentage of the degrees conferred in the various sciences. We find that of the 568 degrees of doctor of philosophy conferred in the sciences, 137 were granted for the study of pure chemistry, 18 for physiological chemistry and physiology, and 3 for mineralogical chemistry and mineralogy. The total number of chemical degrees, therefore, was 158, which is 27.8 per cent. of the total number of degrees given in the sciences. Compare this number of 158 with the degrees given in the other leading sciences, viz., 68 in physics, 65 in zoology, 63 in psychology, 61 in mathematics, 53 in botany and 32 in geology. No other science had as many as 20 degrees, and three had only one each.

Thus we see the enormous preponderance of chemistry in the higher scientific education. It has more than double the number of degrees of any other science. It must be remembered also that chemistry is a most expensive and most difficult science to teach. While other sciences require extensive collections of material, these collections remain available for all subsequent classes. On the other hand, chemistry requires the most extensive and expensive of all scientific laboratories, and the materials and fixtures of these laboratories are subject to the severest strain and the greatest wear and tear. For this reason, in many universities, not only are the students required to pay the ordinary fees, but also special laboratory fees to cover the wear and tear of the materials which they use. But in spite of this increased expense, we see in this country, and doubtless it is true in other countries, that chemistry leads all the sciences in the number of students of higher learning and secures the lion's share of the degrees of doctor of philosophy. In this respect chemistry must be regarded, in the light of statistics which are indubitable, as the most important of all the sciences in the rôle of the university instruction.

It may be thought by some that the hard and cold facts of a science like chemistry have a tendency to repress the imagination and arrest the development of those faculties of the mind which create poetry, romance and oratory. There may be some foundation in fact to such a suggestion. The legitimate functions of the imagination are doubtless to supply the data which knowledge and experience do not give. From this point of view it is evident that, as knowledge advances, the field reserved to imagination grows smaller. There is little room in the domain of science for the rhythm of poetry or the creatures of fancy. Yet it must be admitted that many of the exact sciences do afford opulent opportunities for the exercise of a trained imagination. Indeed, so apparent is this fact that John Tyndall, one of our great scientists, has written a treatise on the scientific use of the imagination.

It is as difficult to grow eloquent over atomic weights and percentage composition as over statistics and finance. Oratory deals with the possible and perhaps probable, the ornament rather than the reality. Thus it comes that the great poets, the great orators, the great painters, and, to some extent, the great writers, are found in the early history of a people or a language. Advancing knowledge clips the wings of poesy and pricks the rotund phrases of the orator.

Nevertheless, even in so prosaic a science as chemistry the imagination has played no unimportant part. It was the genius of a Dalton that first imagined the atomic theory. Newlands and Mendeleeff pointed out the existence of undiscovered elements, and with an imagination as scientific as it was brilliant assigned those missing elements their proper places, and, in a measure, described their properties. A Rayleigh and a Ramsey saw in the realm of nature the probability of a series of elements of negative properties, and argon, krypton, neon and xenon have been isolated. The creation of the infinitely attenuated ether with its vibrant properties is purely a result of imagination. Though it may be erroneous in conception, it certainly has been helpful in classifying the phenomena of light, heat and electricity. So, too, the structural formula of molecules, assigning to atoms and groups of atoms a definite position in the molecular edifice, has been highly helpful in explaining chemical relations and physical properties.

These are only some of the instances which show that, even as a training for the fancy and imagination, chemistry holds no insignificant position.

From the point of utility the rôle of chemistry in education has no mean place.

Unless an educated man can perform some service for humanity better than he could have done without training, then to this extent education is useless. It has been said education often spoils a boy. Quite true. Food often kills. Water carries germs of disease and death and destroys thousands. Yet food and water are necessities. Because education often proves powerful for evil is no reason for opposing it. What crimes have been committed in the name of liberty! What sins in the name of religion! It is too late in the progress of the world to declare against the higher education for this reason, either in its purpose or in its results.

George Sand fifty years ago discussed this supposed tendency of science to harden the heart and blunt the sensibilities. Following is a colloquy between Jean Valreg and the author:

Jean Valreg.—"It [society] seeks in science applied to industry the 'kingdom of the earth' and it is *en train* to acquire it. Do you believe then that all these great efforts to know, of invention and activity by which the present age shows its riches and manifests its power will render it happier and stronger? As for myself I doubt it. I do not find the true civilization in the improvement of machines and in the discovery of processes. The day when I learn that every cottage has become a palace, I shall pity the human race if that palace covers only hearts of stone."

George Sand.—"You are both right and wrong. If you take the palace filled with vices and excesses as the aim of human labor, I am of your opinion, but if you regard the common welfare as the necessary way to reach intellectual health, and the development of the great moral virtues, you would not curse this fever of material progress which tends to deliver man from the ancient servitude of ignorance and misery."*

Among the useful sciences none compares with chemistry in nearness to human needs and in ability to supply them. We have already seen what an important adjunct it is in the study of other sciences. Equally potent is it in its relations to the useful arts. Many standards may be used in measuring the progress of a nation and its relative position in respect of other countries. Some would gauge its progress by its churches; some by its schools; some by the liberties of the people; and some by the reverence paid its women. I have often said, to descend to more material things, that the most reliable rule with which to measure the progress of a people is the quantity of sugar and soap it consumes. Sugar and soap are only illustrations of what the chemical arts have done for man.

There is scarcely an art into which chemistry does not enter. Iron and steel are chemical products; so are paper, pens and inks. Textile fabrics and their dyes owe almost everything to chemical science. In nearly all the manufacturing arts chemistry is the chief factor. In the agricultural arts it is the dominant science. In Kansas chemistry has developed the deposits of coal, of oil and gas, of gypsum and building stones, of materials for the manufacture of cement. Here in this university has been made a careful study of your mineral waters which cannot fail to bring material profit to your people. The wonderful fertility of your fields has heretofore shown little need of chemical study, but you should not lose sight of the fact that the continued prosperity and advancement of agriculture must depend largely on chemical investigations. The conservation and increase of plant food, looking to an increasing yield of crops, must condition

* 'La Daniella,' Vol. I., pp. 13–14.

any lasting agricultural prosperity. The demands on agriculture increase with each passing year, and science will show the way to make surely productive those areas which are now of little value because of deficient rainfall. Water is the chemical reagent which is most potent in crop production. The chemist and the physicist, with the help of the engineer, will show the way to its most economical utilization. Chemistry will supply the mineral foods which the plant needs. In the early history of a new country we uniformly notice the rapid decrease in the fertility of the virgin soil. This is due to a system of farming little better than robbery. Its basic principle is to take from the soil everything possible and give nothing in return. Necessity finally puts an end to such practices and education provides the means for the inauguration of scientific agriculture. Then the exhausted fertility of the soil begins to return. The fields become more productive and each step in advance is retained and becomes the base for further progress. We may confidently predict that the future years will see abundant food for the increasing millions of population. Life will have less of labor and more of leisure for study and recreation. In all the arts which will help in the amelioration of the conditions of existence, chemistry will enter as an important part.

The state builds well, therefore, in an endowment of the kind we celebrate today. As in astronomy we study the infinitely great, so in chemistry we investigate the infinitely small. We seek the very nature and origin of matter and thus come near to those first combinations of simple cells which condition the vital spark.

In the early history of the race we find men dedicating fountains, groves and temples to the worship of mythical deities. To-day we set apart churches, schools, libraries and laboratories for the public good.

More than a liberal training, more than professional ability and technical skill, are those attributes of the man, which make him a source of help to the family, the community, the municipality and the state. Providence in the family, morality in the community, public spirit in the municipality and patriotism in the state are the real purposes of all training. To these ends the educated man must be a bread-winner, of upright conduct, ready to give his services to the city and his life to the republic. He must know how to produce wealth. He must be acquainted with the needs of the community. He must understand the service he is to render to the municipality and have that enlightened patriotism which, while not separating him from a political party, acts first of all for the good of the whole people. The future years will find the leaders of the people among the graduates of the universities, because if the universities are not remiss in their duties, their graduates will be better fitted for leadership. There is no talisman in a diploma. Only ability will count. We recognize the important contributions which all branches of learning will make to this equipment of the successful man of the coming years. In dedicating this building to chemical science it has seemed only meet to point out some of the ways in which our science may aid in the work.

H. W. Wiley.

U. S. Department of Agriculture.

THE HUXLEY LECTURE ON RECENT STUDIES OF IMMUNITY WITH SPECIAL REFERENCE TO THEIR BEARING ON PATHOLOGY.

II.

The methods hitherto employed for the study of bacterial poisons have not gener-