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THE UNTILLED FIELD OF CHEMISTRY[1]

Two years ago, upon a similar occasion, it was my privilege to address many of you and to point out some of the relationships existing between the chemist and the community. In so doing, there naturally devolved upon me the pleasant duty of recalling to your minds a few of the great and more significant achievements of members of our profession by way of indicating, although briefly and most inadequately, something of the extent to which the chemist has already placed the community in his debt. It is good for any body of men, animated by a common purpose, to take, from time to time, mental stock of what they have accomplished and of the relation in which they really stand to their environment. Where, as in our own case, the record is one of which we all may well be proud, its contemplation brings a new sense of the dignity of the work itself, a pride of fellowship and an incentive to increased endeavor.

We move, however, in a world where it is easy to take much for granted, where symbols and conventions quickly come to take the place of the realities they represent. Our mental processes are apt to run along the line of least resistance and the apparent and the obvious obscure the fundamental truths. This being so, we can well afford to leave our achievements in the security of the past while we consider for the moment the things we have left undone.

The volume of chemical literature has become so great, so many compounds have

[1] Address of chairman of the Division of Industrial Chemists and Chemical Engineers, Baltimore, December 29, 1908.

been described and classified, so many methods have been laid down, so much detail confronts the student, and his field of study has been so subdivided as to suggest and foster the delusion that the total sum of chemical knowledge must be vast indeed. Vast in its detail perhaps it is, but lacking in those fundamental unities which out of the confusion of detail bring wisdom. Chemistry still awaits its Newton. It still justifies the estimate of Kant, who said of it more than one hundred years ago:

> Chemistry is a science, but not a science in the highest sense of that word; that is a knowledge of Nature reduced to mathematical mechanics.

Despite the immense amount of dry detail which we have accumulated, and in some measure correlated, chemistry is still in the imaginative era where generalizations are more the result of happy inspiration than of close mathematical analysis.

Chemistry concerns itself with the changes which matter undergoes in its varying relations to certain forms of energy and yet we do not know what matter is nor have we any conception of the real nature of energy. One has only to state in their ultimate terms the problems confronting us to bring a realization of how very far from their solution we still stand. They are, for instance, thus summarized by Karl Pearson: *What is it that moves? Why does it move? How does it move?* Where, yet, I ask you is their answer to be found in chemistry?

We have built our science upon the assumption that matter, whatever that may be, is composed of indivisible atoms, of a comfortable and ultimate simplicity, only to find that the atom is in fact divisible and that its structure is undoubtedly complex beyond imagination. As to those phases of energy which are concerned with chemical change, even so great a philosophical chemist as Ostwald says:

> Chemical energy is to us the least known of all the various forms, as we can measure neither it nor any of its factors directly. The only means of obtaining information regarding it is to transform it into another species of energy.

So we have gone on for a hundred and fifty years transforming chemical energy into electrical energy or into heat, making minutely refined measurements of the relatively small amounts of energy appearing in our processes, while wholly unconscious all this time of the stupendous stores of potential energy which we now vaguely begin to realize are bound up in matter.

Our study of matter has led us to teach that it manifests itself in some seventy distinct and separate forms which we call elements, and yet our very definition of an element is a confession of our failure. An element is something which we have not been able to decompose into anything simpler. We have discovered some curious and interesting relationships between the elements which point to their common origin. In his heart each one of us believes that they must have had a common origin and that the cycles of development which they exhibit can only have resulted from the action of a periodic variable upon a constant, and yet we very rarely even consider the question of their genesis or why their properties are what they are. We are content to regard them as so many distinct creations. The discovery of a new element is hailed as marking an epoch in the history of our science when our real business should be the elimination of the elements as such.

In their interactions, the elements, as we know them, manifest valences and selective affinities which determine the course of all chemical change, and yet we are without an acceptable working hypothesis of the cause and nature of either valence or chemical affinity. Our ideas regarding the constitution of the molecules of many compounds have been developed in great detail and have led us to so many happy conclusions which the facts have verified as to justify our belief that these ideas must rest upon a substantial basis of truth. This sometimes leads us to forget that the graphic formulas which we build up and write on a plane surface are an attempt to represent in terms of two dimensions actualities which exist in three. Moreover, these formulas depict the molecule as something fixed and rigid, although everything tells us that the atoms within the molecule are in rapid and ceaseless motion. A new chemistry will dawn when we take proper cognizance of these motions and their influence upon the properties and relations of the compound. We state molecular weights with a finality of assurance, forgetting that we know very little of the molecular weights of liquids and nothing of the molecular weights of solids. We write cellulose as $(C_6H_{10}O_5)_n$ but the unknown n is probably the most significant part of the entire formula.

Sulphur passes before our eyes from the crystalline to the amorphous variety, phosphorus assumes the red or yellow form, and an almost complete change of properties attends the transformation. Carbon exists in several markedly different states, and yet as to the meaning and mechanism of these molecular changes we remain in complete ignorance. Fortunately for the comfort or even the very fact of our existence upon the planet, water is denser at 4° than it is at zero. Had it not been so, our lakes and oceans would be simply so many solid ice masses upon which the summer sun could make only a superficial impression, but, in spite of the paramount importance of the fact itself no one of us can say why the water molecule presents this curious anomaly. We write the water molecule as H_2O and commonly regard it as a relatively simple compound. How then shall we account for the fact that the dielectric constant or specific inductive capacity of water is about fifty times that of air, or perhaps ten times that of glass. As the dielectric constant is in a sense a direct measure of the massiveness of the molecule, are we not forced to the conclusion that the water molecule really is built up of many of these H_2O groups? How else, indeed, shall we explain the power of water to knock asunder the molecules of electrolytes which it dissolves, and does not this complexity of the water molecule bear some relation to the essential part which water plays in the ultimate phenomena of living matter?

And this brings me to the main point of my thesis. A great German chemical company tells us in an attractive book just issued that it employs 218 chemists, 142 civil engineers, 918 officials, and nearly 8,000 workmen. It covers an area of 220 hectares, has 386 steam engines, 472 electric motors, and 411 telephone substations. Its plant represents the highest development which industrial chemistry has reached, but, none the less it can not produce an ounce of starch which a potato growing in the ground fabricates from water and carbonic acid gas under the influence of sunshine.

True it is that this great aggregation of engines and dynamos, furnaces, retorts and stills, can, under the direction of its highly trained and specialized chemical staff, produce certain natural products in condition so available and pure as to even improve upon nature, but by what monstrous effort is it accomplished? In the spring the tender grass and the delicate unfolding leaves cover the whole earth with the green of chlorophyll. There is no noise, no smoke, no stench. The grass is cool and grateful to the touch, and clean. In similar manner vegetation everywhere is fabricating cellulose to the extent of several billion tons each year, and not only cellulose, but all the countless other complex products of the vegetable cell. What shall we say of our own chemistry in the face of facts like these, except that we have gone far enough to encourage a faint hope that we may some day be able to approach such methods. Professor Wheeler has defined so clearly a thought which has been in my own mind for years that I can not do better than quote his words. He says:

> The vegetable cell is a laboratory in which are carried out a most remarkable series of chemical reactions. As we contemplate the immense number of organic compounds of all degrees of complexity which are formed within this wall of the plant cell we are convinced that this is the chemical laboratory *par excellence*. Two features impress us particularly; first, the silence in which the operations are carried on; second, the narrow range of medium temperatures required. Notwithstanding this apparent simplicity of conditions, the products are of the most various kind. Some of these man is able to synthesize in his own crude way; others are still the secrets of nature. It is utterly impossible for man to prepare certain naturally occurring compounds except at a temperature which would burn the plant tissue. We are led to wonder whether forces exist with which we are unacquainted or whether we are merely unable to control the forces already familiar to us. It would be difficult to say which supposition is the more probable. It will be granted that investigation into the activities of the cell is of profound importance. In fact it has been said that "it is in the plant cell where synthetical operations are predominant, that we have to look for the foundation of the 'new chemistry' which may be expressed broadly as the relation of matter to life."

I expressed two years ago my own belief that the distinctions which we now regard as fundamental between living matter and dead matter would soon break down. This break will, in my opinion, come through the study of the colloids which are the link between matter which we regard as living and that which we regard as dead. At this point, I can not refrain from volunteering a suggestion. We know that the atoms within the molecule are in rotation. It must follow that as the complexity of the molecule increases more and more of its motion of translation must be converted into rotary motion. In the colloidal molecule we know that many simpler molecules are linked together, and in the molecule of living matter, what? May it not be merely that the more or less haphazard and confined movements of the molecules, which together build up the colloid, are in the molecule of living matter coordinated and controlled in a manner which suggests the vortex. Dead matter drawn within this vortex would partake of this movement and exhibit the phenomena of life. Matter thrown off tangentially would resume its rectilinear course and become, for the moment, dead.

When we consider that in theory at least, in which accidents are barred, a tiny bit of living jelly, an amœba for example, can endow with life an ocean of its proper pabulum, it seems obvious that the forces which are to manifest themselves in the phenomena of life are already existent in the pabulum, and that what the living jelly does is to induce a coordination and direction of the atomic movements which then take on the vital aspect. Do we not have something roughly analogous to this in the magnetization of successive pieces of steel drawn across a lodestone? A certain coordination of movement in the molecules of the steel has been induced and magnetism results. So in some manner far more complex life, I believe, may be epitomized as coordinated motion.

The subject-matter of such speculations lies so far outside our present-day chemistry as to almost require apology for their presentation, but they are well within the subject-matter of the chemistry of the future, for, to again quote the words of Pearson:

The goal of science is clear; it is nothing short of the complete interpretation of the universe.

Or as Muir has put it:

The great business of chemistry is to force men into close contact with some aspects of external realities and, with the help of her sister sciences, to remove everything that prevents the full vision of nature.

Arthur D. Little

THE FUNCTION AND FUTURE OF THE TECHNICAL COLLEGE[1]

That the education of the child through the first eight years of school should be at the public expense is a matter generally accepted as fundamental by every intelligent voter in this country. There are, however, those who insist that public funds should not be used in carrying on schools of secondary rank; and that the expense of college or advanced technical training should be met and universities sustained by the state is a proposition many would combat. The teaching of trades at public expense, a matter that a few years since was considered impossible by trades unions and society generally, is slowly but surely making its way in this country. If we are to witness, in the next decade, such advances in the scientific, commercial and industrial world as would appear commensurate with the progress of the past ten years, it will be largely due to the work of the technical schools, and colleges of science and engineering—institutions under state control as well as those on private foundations.

As the opportunity and field for such institutions are becoming vastly greater and broader and the need for technically trained men more and more apparent, the fact is also clear that the training in such schools is too narrow and restricted. This is but the natural revolt against the old scholasticism. From a college training in letters merely, the tendency has been strongly marked in the opposite direction, and pure science and technique in the abstract has characterized the technical courses.

In these institutions men must be prepared, not alone to carry out the will of another; not simply to be exact machines to execute the plans presented to them. The product of these schools must possess initiative, imagination, individuality; they must be experts, leaders, investigators, executives; they must plan and lead, not follow merely; they must create as well as construct. In other words, continued progress means that technical education must produce executive engineers and industrial experts. For these men of the future we must rely upon the endowed institutions, of which there are all too few of high grade, as well as upon public institutions ranking with the former and offering all the advantages of study and research.

The time will soon be upon us when, forced to sustain a much greater population than we now have, and owing to keen competition with foreign countries, the industrial and commercial development of this nation will demand experts in many lines. The depleting of our forests not only robs us of timber needful in developing the arts, but in certain sections of the country will so affect the water supply as to produce regions dry and arid; the storing of water in reservoirs for purposes of power, consumption and irrigation is a matter hardly yet begun; the building of railroads, canals, electric lines; the bridging of rivers and the draining of swamps; the constructing of a system of highways and thoroughfares from city to city and throughout rural districts; the development of scientific farming, the greatest industry before our people to-day; the building of harbors; the perfecting of our great mining industries; these are some of the enter-

[1] Elaboration of an address before the Technical Education Department of the National Education Association, July, 1907.