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A LOOK AHEAD[1]

WE have come to an important milestone in the development of an organized effort to promote the advancement of chemistry in America. Fifty years have passed since the American Chemical Society was founded. Under the inspiration of one of the greatest heroes of science, a few chemists who had come together at Northumberland to honor Priestley's memory and the discovery of oxygen conceived a close association of those who had caught some of the spirit of the great experimenter, and shortly after the society was established in New York. No fitter occasion can be conceived for the birth of an idea that grew into a power for so much good.

The development of chemistry in this country was slow at the start. The new nation had to see to its material advancement. It had unlimited natural resources and its rapidly growing population, made up of those seeing freedom and opportunity, had to be housed, fed and clothed and given facilities for communication and transportation. As a result the best brains were devoted to supplying these necessities. It is only in recent years—in the memory of many of us—that the pursuit of chemistry as a life work has appealed. The young man, fifty years ago, was compelled to go to Europe to prepare himself for a scientific career; and it is only comparatively recently that a wise adviser has been able to emphasize the advantages of study at home.

But the last quarter century has seen in America a steady growth of chemistry, and the record of the last decade can not anywhere be surpassed. The story of these achievements has all been written, and we present it with pride to America and the world.

The American Chemical Society has been an important factor in this development. It has been and will be, in an increasing measure, a stimulus to further advance. Through its publications and its organization that brings together men of kindred interests, it makes possible the kind of cooperation that means success. Its efforts to educate the people to an appreciation of the importance of chemistry in the public welfare are becoming more and more successful. The value of a flourishing chemical industry in times of peace and its necessity as a means of defense in times of war are being brought home

[1] Address of the president of the American Chemical Society, given at the anniversary meeting, Philadelphia, September 6, 1926.

to those of thoughtful minds who make our laws. As we review the past and examine the present we are gratified.

While it is well to stop to look back, it is more inspiring to look ahead. History is the story of past actions; it is knowledge. It can become more only when it is interpreted—when it becomes the background for advance. We should think not of the glory of history but its lessons. This fact is largely overlooked in the study of political history. We are content with the facts and fail to see their significance. The scientist should study history in a different way. In the light of the past he should be able to control events so that the history of the future is more to his liking. The causes that have led to the great advance in the chemical industries of this country in the last few years should be studied, and those who make the laws under which industry thrives or dies should be taught this bit of scientific history so well that they will continue to act for the upbuilding of an industry so vital to the welfare of the people.

The wise look ahead even when taking stock. Several of the divisions of the society are taking this anniversary as an occasion to formulate the problems of the immediate future in their own fields. Such formulation is the first step toward solution; it makes advance more certain.

I have been tempted to bring here some random thoughts concerning what lies just ahead in chemistry. But the rôle of a prophet is seldom a happy one, and real prophets have always been rare. Prophecy based on human behavior is not difficult. Human passions are about the same as in Adam's day. Civilization has taught us to clothe them, even to repress them. But given a situation with defined moral or social aspects and it is not difficult to prophesy what will happen when the controlling forces start into play. It takes no unusual prophetic gift, for example, to foretell another great world war.

But in science it is different. Now and then a great discovery is made that changes completely the trend of affairs. It is true that given this new fact we can bring to bear upon it our knowledge of the past and, with the aid of logic and imagination, look into the future. When Faraday had discovered the relationship between electricity and magnetism—perhaps the most far-reaching scientific discovery ever made, in its effect upon civilization—it was possible to conceive of what would follow as the result of the combination of the new fact with accumulated knowledge. It did not require the gift of a prophet for Faraday to reply to Gladstone, when asked what was the use of it all, that some day the government would be able to tax it.

The scientific imagination must start with some definite germ or stimulus. Pure imagination is rare —the gift of the real poet. Poetry or religion can see the communication of soul with soul through space—science can not. But given the electrical waves of Hertz, discovered in an attempt to test certain mathematical calculations, and a third-rate prophet with a modicum of optimism could foretell wireless communication.

It is very profitable to stop once in a while to review what has been accomplished and to formulate the problems of the immediate future. It may be a source of amusement only to go a step farther and with the use of the imagination picture the possible development of the newer discoveries. The summing up of the nitrogen situation by Sir William Crookes, at a meeting of the British Association for the Advancement of Science, and his look ahead in regard to the world's need of nitrates to fertilize the soil in the production of an adequate food supply, gave an impetus to the experimental study of the production of nitric acid from the air. The work of the chemist solved the problem long before the world was face to face with the starvation predicted by pessimists as the result of the exhaustion of what was considered the most important of natural resources to the welfare of mankind.

This triumph gives us courage to face the future. The economist without imagination and a knowledge of what science has done is now turning a gloomy face toward the day when we shall have used up our supplies of petroleum. And when the world is told that the chemist will find a way out, editorial writers point out that scientists are obsessed with an overconfidence in their powers and that the new synthetic age predicted will result in taking all the poetry out of life.

But lack of imagination is not limited to the uninformed. Even some chemists with a knowledge of what their science has done are unable to see ahead a transformed world and look with a sort of pity on those whose vision pictures such marvels as the future utilization of the energy tied up in the atom.

The recent conferences at Williamstown have brought to the attention of thoughtful people the direct bearing of chemistry on world problems—both economic and social. Experts have told what has been done and what lies just ahead. The problems have been formulated, and when the time comes for a new appraisal of the rôle of chemistry in advancing civilization, it will be found that the problems have been solved.

What I have planned to bring to your attention has not been considered from the point of view which was emphasized at the recent sessions of the Institute of Politics. At these conferences were formulated the future demands of a rapidly growing population for more power to do the world's work, for a more economical use of natural resources, for a largely increased food supply, for a better understanding of nutrition and for a reduction of the economic waste of preventable sickness and death.

I prefer to try to foresee what may reasonably be expected as the result of the future labors of those whose delight it is to question nature, irrespective of the immediate practical value of the knowledge gained.

The last twenty-five years have yielded an astounding knowledge of the nature of the chemist's unit of matter—the atom; and the next quarter century, in my judgment, will see the development of a chemistry of the atom comparable with our present knowledge of the chemistry of molecules. We have learned how to dissect molecules into their constituent atoms, how to bring the latter into new combinations with the result that new substances are formed. A chemist knows how to get hydrogen and oxygen out of water, nitrogen from the air and carbon from coal and with these elementary atoms build up a beautiful dye, an efficient drug, an active poison or a valuable food. He can use his atoms to develop energy to drive his machines. The atoms have been his plaything—his building blocks—and he knows how to play the game.

But he will not be long content with atoms as his smallest blocks. He is now just beginning to learn how to dissect them. Is it unreasonable to prophesy that some of us here may see the day when it will be possible to tear apart the constituents of which the atom is composed and build up from these parts any desired atom at will?

A glimpse into the past may give the doubtful courage to be optimistic. I can recall the day when the scientist's knowledge of the nature of the atom was entirely hypothetical. Even a belief in its very existence required an element of faith. A few observations were made, apparently unrelated, which were seen, however, by thoughtful men to lead to a way to study the atom itself. An attempt to weigh nitrogen with a high degree of accuracy led to anomalous results that had to be explained; the observation that a wire heated to incandescence in an electric light bulb produced a characteristic glow demanded further study, and the striking fact that certain minerals sent off mysterious rays that could penetrate opaque materials and affect a photographic plate set many at work to study the phenomenon. And what has followed from the work inspired by these discoveries? We can now count atoms, one by one; we can even make an atom flash a light or ring a bell to show when it passes. We know that atoms carry electricity and we can determine experimentally the exact amount of the charge. We have been able to prove that the atom is a complex framework built of positive and negative electricity.

Means have been found to tear to pieces complex atoms and get simpler units, which prove to be what we have looked upon as the atoms of other elements. With such a record of achievement accomplished since many of us entered upon a life work, who would dare to oppose the view that before long we shall be able to work with atoms as we do now with molecules. Whether or not mercury has been already changed into gold or gold into mercury lacks importance in the light of coming events. When the imaginings of the past—mere dreams—have come true, we feel a confidence in a future based on such achievements. Some years ago I heard Mr. Elihu Thomson prophesy that before long the technical applications of electricity would resolve themselves into electron engineering. Some smiled then who would not do so to-day.

The atoms are a storehouse of energy that make coal, petroleum and waterfalls sink into insignificance as the means to do the mechanical work of the world. I hold it is not foolhardy to refuse to worry about the consumption of natural resources or to look to the future with confidence that science will always keep ahead of the needs of the world.

Our present knowledge tells us that each individual atom resembles a solar system. Charges of negative electricity—the electrons—revolve at comparatively great distances around a central nucleus composed of positive and negative charges. Until recently the electron has been the smallest unit recognized. But a new era is dawning. Sir Joseph Thompson, who has been a leader in this field of investigation, now proposes a new hypothesis—even the electron is complex; it is itself a solar system of a new order of magnitude. This hypothesis makes it possible to correlate the older with the newer views as to the manner in which radiant energy is transported from place to place. What lies ahead as the result of the experimental study of this new hypothesis no one can foretell. But we can be sure that the developments ahead will be a most important factor in moulding our future civilization.

It is perhaps worth while to picture some of the consequences of the discovery of a method to dissect the atom and to put together the parts into other arrangements. This means practical transmutation of the elements. When this is accomplished it will be possible not only to make gold out of mercury but any metal desired. It is evident that such a result would destroy our present system of values. An economic upheaval would force upon the world a change from the present unsatisfactory system based upon gold to a more rational one based on something more fundamental—perhaps the value of a man's labor or on necessary commodities. Whatever the result, we would see new standards set up which would change society in such a way that a more equable distribution of wealth would follow. Property rights in natural resources would disappear. A family could not live for generations in affluence and produce nothing, as the result of the purchase by a forefather of a copper mine when the demand for the metal had not developed. It is impossible to conceive of the extent of the social revolution that would follow practical transmutation of the elements.

We know that the atoms consist of unthinkable amounts of bound-up energy. They are like a jack--in-the-box. When we learn how to touch the button the energy will spring out and we can use it. There will then be no underground slaves and no coal barons. A limitless supply of energy will make over the world. Every man will have time to taste of the joys of life.

I hold that these views are not phantasy. Contrast life a century ago and to-day. Study the effects of great discoveries and the inventions based upon them. What were the effects of the steam engine, the internal combustion engine and the dynamo? When the world learned how to use heat as a source of energy a new epoch in civilization was marked out. When heat was the only form of usable energy to bring about transformations in matter a great chemistry was built up. With the discovery of electricity and the methods to develop and use it, a second epoch in civilization was created and a new chemistry was born. Substances considered elementary were found to be complex and the science made life easier and happier.

We are now beginning to study the effects of a new kind of energy on matter—the energy tied up in the electron and the atom. We scientists know that energy has two factors—quantity and intensity—and that the latter factor is all important in bringing about changes in matter. We are beginning to learn how to obtain and use energy with a high intensity factor, and the result will be again a new chemistry and a new world to live in.

This new type of energy—an electric charge travelling almost inconceivably fast—can do wonderful things that can not be accomplished by less intense forms. A whole new field in chemistry lies before us for study. When I saw not long ago in the laboratory of Dr. S. C. Lind a tiny drop of a colorless oil that had been formed from methane—the chief constituent of natural gas—as the result of the action of this form of energy upon it, I felt a new era in chemistry had dawned. That droplet meant a supply of combustible liquid to run our automobiles when petroleum is exhausted. We can make methane from carbon and hydrogen when the supply of natural gas fails us. The sun will always be able to convert carbon dioxide into a form from which we can get back carbon. The pessimistic critic will declare this is all impossible. He will say that radium was used to get the kind of energy to bring about the transformation and that there is not enough radium in the world if we could afford to pay the high price for the energy needed. But radium is not necessary. The work of Coolidge shows that we can get this kind of energy from an X-ray tube. But again the rejoinder is that this kind of energy is too expensive to use. Such a critic limits the achievements of the future to the application of known knowledge and can not see that the past has proven that new knowledge furnishes the means for advance. When electricity from a primary battery was first converted into light, who would have conceived of its being ever cheap enough to be used to draw heavy freight trains over mountains?

The study of the behavior of matter under the action of energy with a high intensity factor will lead to a new chemistry. The ground has only been broken in the investigation of action of sunlight, ultraviolet light and X-rays. And now the highly penetrating rays studied by Millikan furnish an opportunity for the discovery of startling facts. The utilization of the radiant energy supplied free and in unlimited amounts will follow further study in this field. At present we rely upon the slow-going processes of nature to convert the waste carbon dioxide of the air into the cereal foods so necessary for living things. Bailey has shown that ultraviolet light will convert formaldehyde into a sugar. And since formaldehyde can be made from the products formed when coal is heated with steam, it is possible to see ahead the synthesis of foods without the slow process of passing through the vegetable kingdom.

Turning now to a consideration of the molecule, the next step up in the complexity of matter, it is possible to speak with more confidence. We have had a chemistry of molecules for over two centuries, whereas the chemistry of the atom is still an infant. The last half century has yielded an astounding amount of knowledge in regard to the architecture of the units of which individual substances are built up. Structural organic chemistry holds the first place among the intellectual triumphs in this field of science. It is possible to pick to pieces a complex natural substance in such a way that each operation gives us information as to how the atoms are united. And when the work is finished we can construct a model which shows how the many atoms present are linked one with the other. But we can go farther. Guided by the model we can, like the architect, gather together the pieces required from many sources and fit them together in such a way that our finished product is identical with the substance from which the model was constructed. Nature furnishes us with a blue coloring matter which is the highly prized and useful dye indigo. The detailed study of the substance led to the drawing of the plan of the complex molecule; and later, with this as a guide, it was found possible to construct from simpler and readily obtainable building material the same kind of molecules elaborated in the plant.

Not content with copying natural products, the chemist has made hundreds of thousands of compounds, many of which have been found to be useful. Future developments in synthetic organic chemistry will add much to the health and happiness of the world. We have many trained architects and builders for the work, and the technique is well understood. In the past many chemists have contented themselves with applying the methods to build up thousands of compounds without any thought as to value of the finished product. The game has been such a fascinating one, and in most cases so easy to play, that sufficient satisfaction came from merely building the new house. But this point of view has largely disappeared. The incentive now is the need for a substance to be used for a particular purpose. We follow the architect again. He designs a building to be used for a definite purpose—a schoolhouse, a church, a factory. There may be need for a substance with a particular color, odor or other desirable property; a liquid having a definite boiling point and volatility may be required for the preparation of lacquers or varnishes; or a substance may be sought to combat a particular disease. The solution of such problems as these is becoming an incentive for work in synthetic organic chemistry. Another important driving force is the desire to prepare from cheap raw materials important industrial products whose future applications will be so extensive that the present source of supply will be inadequate.

The processes to be used in this work are drawn from the work already accomplished. And while some chemists are solving these problems, others will be busy in finding new and better ways of laying the bricks.

Recalling the achievements of the past one can boldly prophesy future triumphs. As an example, let us consider but one field in which synthetic organic chemistry will prove itself to be perhaps the most potent factor of all those that are working toward the advancement of civilization and the peace of the world. I refer to the use of chemical compounds in combating disease and, as a result, prolonging life—the modern science of chemotherapy.

Some of us have heard discussed recently at Williamstown the astounding loss of efficiency of the human race that results from preventable sickness and death. An eminent statistician whose business it is to study such problems for a life insurance company with world-wide activities evaluated the loss from data based on a definite mathematical knowledge of the facts. The figures were appalling, and considered along with the fact that the causes of the great wars in modern times can be traced back to economic pressure in one form or another, but one conclusion can be drawn: the world must focus its attention upon this, the greatest of world problems.

We heard, too, at Williamstown, what chemistry has done to combat disease. Dr. Loewenhart told an inspiring story. Sleeping sickness, hookworm disease, syphilis and allied scourges have been taking a toll of millions, but synthetic organic chemistry has produced substances that are conquering these terrors. A start only has been made. Malaria, spread in the most fruitful parts of the globe, is incapacitating and destroying millions and we have used but one drug—quinine—with which to fight it.

It is the aim of chemotherapy to build up substances, not supplied by nature, which have such physical and chemical properties that they destroy the organisms which cause disease. This great new science has been woefully neglected in this country. The Rockefeller Foundation that has spent millions of dollars in promoting world health is content to make use of known facts and has done nothing toward increasing knowledge in this field.

Some broad-minded philanthropist with vision will see the opportunity for world service and endow an institution in which synthetic organic chemists, pharmacologists and doctors skilled in chemical medicine will cooperate in solving the greatest problem before the world to-day. As knowledge grows, the curative effects of antitoxins and other complex organic substances developed in the body will be traced to specific organic molecules capable of synthesis in the laboratory. Disease after disease will be conquered and a new era will dawn.

I have just sketched a few important applications of our accumulated knowledge of the molecule. But it is also important to stress the fact that while we have gone far in interpreting molecular architecture, much remains to be done. We know a great deal about the relative positions of the different kinds of building stones that make up the whole, but are densely ignorant as to the forces that bind them together. When we come to consider their energy relationship our analogy between a molecule and a building made up of many parts fails. The parts of which the molecule is made up—the atoms—attract one another with different degrees of affinity and forces are thereby set up that come into play when an attempt is made to alter the molecule in any way. It is comparatively recently that inquiry has been turned toward this problem in organic chemistry. Attention has been centered largely on the changes in matter that take place when one kind of molecule is changed into another kind. The future will see a great development in our knowledge of the energy transformations in chemical change. We shall be able to evaluate mathematically, in definite units, the forces that come into play when transformations between organic molecules take part.

In fifty years the graphic formula of an organic compound will be far different from the crude pictures of to-day. It will apparently be very complicated, but to one who understands the significance of the symbols used it will be simplicity itself and will indicate a wealth of knowledge that will make it possible for the adept to handle the molecule with certainty as to the results.

We have much to learn as to how molecules interact one with another. In very many cases we know what is the result, but we do not know how the forces come into play—what we call the mechanism of the reaction. A start in this difficult field has been made and much lies just ahead. It is my opinion that the time has come for an intensive study of the molecule from this point of view.

Many of the processes now used more or less empirically will be understood, and we shall be able to apply them with mathematical precision. Catalysis will be used with an understanding of its laws as we use chemical equilibrium to-day.

I have limited what I have said up to this point to a consideration of what future work may reveal as the result of the intensive study of atoms and molecules, and I have noted briefly a few possible applications of the new facts that will undoubtedly be discovered. It would be possible to look ahead from another point of view and see other things that are in the immediate foreground. One could first look back on the highly specialized branches of chemistry, see what has been done and the present trend of inquiry and then project his vision into the future. But there is not time for such a fascinating survey and exercise of the imagination.

The industrial division of the society will devote a part of its time at this meeting to such considerations, which I believe will be helpful in pointing the way to future advances. I found it an interesting task to examine the possibilities that lie ahead in the field of petroleum chemistry, and, as a result, came face to face with many problems the solution of which will be sought through personal work and influence.

We have many young investigators who are looking for worlds to conquer. Their point of view is not yet broad enough for them to be able to settle upon some research problem, capable of solution in a reasonable time, the results of which will be a definite, worthwhile advance in knowledge. Any agency that can be helpful in directing research in this way should be encouraged. The division of chemistry and chemical technology of the National Research Council has made it a part of its business to advise in regard to problems for research, and I am sure that many suggestions will be found in the addresses by the experts who are to review the various activities in industrial chemistry. It is to be hoped that the workers in pure science will soon stop to look ahead in their several fields and outline as specifically as possible problems worthy of immediate study.

At this time in the history of the society we are looking back on the growth of chemical knowledge in the last fifty years and on what chemistry has done for the world. We must not forget that all the results of which we are proud are based on painstaking research. If we are to go ahead it will be only through research that the desired aim will be reached. The appreciation of the value of research is rapidly growing in this country, and the American Chemical Society has taken no small part in bringing about this satisfactory state of affairs. It has been a hard fight. With the financial control of our industries largely in the hands of those who know nothing of science or its uses, it has been difficult to obtain the support for research that it needs. When the attitude of certain executives is to oppose research on the ground that anything new might disturb the present state of affairs—might even make their expensive plants obsolete—it is easy to see why we do not hold first place in developing new and important industries. We have been building largely on the fundamental work of others. But this condition is slowly changing. It is a fortunate thing for the chemical industry of this country that trained chemists are working their way up to positions of responsibility that control financial policy. Such men know that research pays even when the company itself must meet the bills.

There are at present several agencies at work that will lead to an increase in the scientific productivity of this country in the immediate future.

Research from the standpoint of pure science—the basis of all advance—will receive a stimulus from the great fund now being collected by the National Academy of Sciences through the activities of a committee of which Mr. Herbert Hoover is chairman. With two million dollars a year for ten years to cover the cost of research in all fields of pure science, such a start will be made that assistance in the future will be assured.

The growing demand of industry for men to improve old processes and devise new ones through research is attracting many young men of brains to that field. Our universities are overtaxed with graduate students in science; and each one, under careful supervision, is extending the boundaries of knowledge in learning how to solve scientific problems.

The development of research of this type is assured, but there is another kind, equally important, if the industries based upon chemistry are to progress. There is an immediate need for the intensive study from a fundamental point of view of the chemistry underlying these industries. It can not be expected that a single organization will finance such work, the results of which should be available to the entire industry. In my judgment, cooperative effort will be the solution of the problem. We have seen that England, after the war, came to this conclusion; and the laboratories set up by the more important industries are doing the kind of work that will help England hold its position in the industrial world.

We are only now learning in this country the value of cooperation in industry. Where it has been tried it has succeeded. It is a different type of cooperation that has made fruit-growing so profitable in the west. The farmers of the middle west will stop their complaints when they have learned their lesson. The day of the individual and the small business organization is passing. We are learning that trusts are not entirely a menace. The individual units in great industries will find some day that they have a common ground on which they can meet and problems which they can attack in common.

Suppose a large industry—like that devoted to the utilization of rubber—should establish a research laboratory to investigate problems fundamental to the industry and for the study of which no provision can now be made in a single organization. It is easy to see that great good would come from such cooperation. Would not a cheap and reliable source of synthetic rubber be a boon to the industry as a whole? Is any single company willing to finance such an expensive research, even though the prize if won is so valuable? But if the work were to be undertaken by cooperative effort each stake in the gamble would be so small it would be a very minor item in the budget.

There is still a third type of industrial research that is growing rapidly, as it has already shown that it pays. This has to do with the detailed study of the processes used by individual companies. There is, however, a chance for improvement here. If we are to utilize the results of research in pure chemistry and in so doing make them of service to the world, we must develop new processes based on these results. The United States lags far behind in this field. Some progressive industries have seen the significance of certain phases of research in pure science and have built up industrial processes of great economic value. The application of catalytic action has added to the world's wealth.

Pure science has told us that carbon monoxide and hydrogen can be converted into formaldehyde and methyl alcohol, but others had the initiative to do the work upon which a great industry will be founded.

I am optimistic about the future of industry from this point of view. We have seen many examples and have learned the lesson. Our chemical industries are growing and producing wealth. We are getting to be a rich nation and those who have the money want to see it work and will in time learn that chemistry can produce gold in more ways than one. The financial backing will be at hand; we have but to teach the people to wait for profits.

As a result of a look ahead I am filled with confidence in the future. I see in the next half century a great development in chemistry in the world, and especially in this country, where the conditions are most favorable. I see our knowledge of matter extended so broadly that what we know to-day is but the foreground of an impressive picture. And I see an unparalleled utilization of chemical knowledge for the physical, esthetic and economic welfare of man. And when through the efforts of chemists the world has more of good health, and every one more leisure to get to know his fellows, to travel, to enjoy the best in life, the day will come when the world will be a better place in which to live and international good feeling will prevail.

James F. Norris
Massachusetts Institute of Technology

JOSEPH PRIESTLEY[1]

The intelligent world marvels and admires the ubiquitous manifestations and astounding properties of at least one elemental body, *viz.*, oxygen. Its discoverer—from the humble walks of life—a simple-minded pedagogue—an earnest, disenthralled Calvinist in religious adherence—but happier and most active as a dissenting clergyman, as well as a dissenting subject as to forms of government prevalent in the land of his nativity—was not, on the other hand, so universally admired and appreciated, indeed, was despised, hated and persecuted by untold multi-

[1] Priestley Lecture given at the anniversary meeting of the American Chemical Society after the Priestley Medal had been conferred on Dr. Edgar F. Smith.