SCIENCE

VOL. 82 | FRIDAY, OCTOBER 18, 1935 | No. 2129

SCIENCE: A Weekly Journal devoted to the Advancement of Science, edited by J. MCKEEN CATTELL and published every Friday by

THE SCIENCE PRESS
New York City: Grand Central Terminal
Lancaster, Pa. Garrison, N. Y.
Annual Subscription, $6.00 Single Copies, 15 Cts.

SCIENCE is the official organ of the American Association for the Advancement of Science. Information regarding membership in the Association may be secured from the office of the permanent secretary, in the Smithsonian Institution Building, Washington, D. C.

THE WAY FORWARD IN CHEMISTRY[1]

By WILLIAM ALBERT NOYES
UNIVERSITY OF ILLINOIS

SOME years ago Professor Lewis published an article on "Two-way Time," based on the principle of relativity. Instead of the older idea that time progresses only in one direction—forward—he expressed the thought that time is an inseparable whole. In terms of relativity time is a fourth dimension correlated to the three dimensions of space.

I shall not attempt to discuss the mathematical aspects of this question. I am quite incompetent to do that. I wish to emphasize the fact that the future is of far greater interest to us than the past and should have a greater influence on our conduct. I shall speak of the past this afternoon only as it has a relation to the future.

I think I may be pardoned for a reminiscence. When I graduated from Grinnell College, somewhat more than fifty years ago, it was customary for graduates to give short "orations" on commencement day. I chose for my topic "The Unity of Force." It should have been "The Unity of Energy," but the mistake in nomenclature may perhaps be excused in a young bachelor of that period. My thought was that all forms of energy consist in the motion of material substances, sometimes taking the form of the motion of large bodies, at other times the motion of atoms or molecules, but, whatever its form, capable of being transformed in some definite manner into the sort of motion expressed in some other form of energy. My thought at the time was that there are two fundamental entities in the universe, matter and energy.

The twentieth century has broadened and simplified our concept. We now think of a single entity which we may call matter or energy, since each may be transformed into the other.

[1] An address delivered at San Francisco on August 19, 1935, on receiving the Priestley Medal of the American Chemical Society.

A similar change has occurred in our chemical concept of matter. We then thought of all material substances as composed of about eighty different kinds of particles, each of its own special sort, and that the transmutation of one of these into another was impossible. A noted astronomer spoke of these atoms as "manufactured articles." Now we place no limit to the possibilities of transmutations, and as the ultimate constituents of matter we recognize electrons, positrons, protons (or neutrons) and photons. The last are of an infinite variety and may be spoken of as in some sense the connecting link between matter and energy.

I do not present these ideas as a final and complete concept of the structure of the universe but as a rough outline of the direction in which our thoughts have changed during fifty years. The surprising thing is not that the changes have been so great, but that our present thoughts contain so much that is old. The changes have been by evolution and addition rather than by revolution. Revolution discards what is old and wishes to build entirely new.

During the middle ages a philosophy called "Holism" was prevalent. This philosophy thought of God as the center of the universe and of the Bible and the church as His infallible interpreters.

There is growing before our eyes a new "Holism," for which the plain common sense which we call science furnishes the background. We have abandoned the idea that we can find an infallible guide, but we have a conviction that science may give us a reliable basis for the interpretation of the best knowledge that we can get. It will lead our way to the truth which should guide our conduct. It will do this for all questions which concern our intellectual lives, not only in regard to the so-called material universe, where scientific methods are already supreme, but also, more and more, in social, national and international relations. One of the most important characteristics of this method is that the individual endeavors to free himself from all personal and national prejudices. We recognize the value of such a spirit in dealing with international relations. It is the indispensable foundation for justice in all our affairs.

If what has been said is true, we shall see that the way forward in chemistry is not that we shall think of it as an isolated branch of science and as independent of the rest of our lives. The days when isolation and "rugged individualism" were appropriate are passed. We must always retain the units of which the whole is made and must provide for the development of personality and initiative. We should permit freedom of opinion and avoid regimentation. But we must also restrain the individual who will not contribute his share in cooperative service and we must stop the person or nation that wishes to exploit others.

During the nineteenth century England was well satisfied that she was separated from the continent by the ocean and that her powerful navy was a protection against attack. She received a rude shock when she found that a cargo of wheat from Argentina could be "spurlos versunken" in mid-ocean, that London could be bombarded from the air, and that a "Big Bertha" in Germany could bombard Paris. A British statesman has recently said that England's boundary is now the Rhine, and England realizes that her safety no longer lies in her navy but must depend on cooperative action of the nations of the world against an aggressor. The United States is no more isolated by the Atlantic Ocean to-day than England was by the English Channel a century ago.

The two outstanding problems to be solved by our generation are the abolition of war and a better distribution of work and the products of our industries. We have no right to bury ourselves in chemistry and think we are under no obligation to contribute our share to the solution of these problems. The scientific men of the world have done their full share toward solving the problems of production and of health. We have immensely increased the fertility of our soils, we have furnished beautiful dyes for our clothing, we have made artificial silk from cotton and have provided thousands of new materials not available twenty-five years ago.

There can be no doubt that America and the nations of Western Europe are abundantly able to furnish work and a reasonable standard of life for all their people. It is absurd that during the last fifteen years millions of men and women have been unemployed and dependent on "relief." We as chemists should do our part in the solution of this problem.

We have done better, though by no means too well, about health. The expectation of life for a baby born to-day is more than double that of seventy-five years ago.

In 1906 steps were taken to organize *Chemical Abstracts*. Learning from the experience of the German Chemical Society, we increased our dues and required all members of the society to contribute to the support of the new journal. Avoiding the mistake of the English chemists, *Chemical Abstracts* included both industrial abstracts and those giving an account of researches in non-industrial fields. As a result of these two policies, we have succeeded in holding all classes of chemists together in a single society.

Before *Chemical Abstracts* was well established, financially, we discovered that the industrial chemists felt that their interests were not well cared for and that some of them were considering the organization of a separate society. At one time the English Society of Chemical Industry had 1,500 members in its New York Section. From a financial point of view the time was not opportune, but it was decided to increase the dues again and establish our *Industrial Journal.* Partly because of the policy of our society to care for all classes of chemists, but also, in no small measure, because of the splendid organizing ability of our secretary, Professor Parsons, it has been possible to carry on almost entirely on the basis of our membership dues and the income from advertising in our journals.

During the earlier years following the expansion of our functions as a society our success depended largely on the membership dues paid by all our members. When costs of paper, printing and postage became a larger proportion of the cost of issuing our journals, it was possible to introduce a new policy. An initial payment of $9.00 is required from all members to pay for the general expenses of the society and a part of the cost of editorial services and of putting the journals on the press. Each member receives a copy of the News Edition of the *Industrial Journal* and may receive *Industrial and Engineering Chemistry* or the *Journal of the American Chemical Society* for $3.00 or *Chemical Abstracts* for $6.00. From $10.00 to $25.00 would have to be paid for similar journals published anywhere else in the world. This arrangement has been in effect long enough to demonstrate that it is financially possible.

At the present time there is a rather strong feeling on the part of some of our members, especially on the part of those interested in organic chemistry, that we do not provide adequately for the publication of researches of a non-industrial character. This has gone so far as to lead to a proposal to start a *Journal of Organic Chemistry.* The policy followed in connection with our other journals indicates another solution of this problem as possible. The *Journal of the American Chemical Society* might be divided into two parts. One part would be devoted to inorganic and physical chemistry and the other to organic and biological chemistry. If members who subscribed for either part were to pay $3.00 and those subscribing for both, $5.00, a sufficient sum might probably be secured to pay for the additional space needed. A canvass of all who now receive the *Journal of the American Chemical Society* would probably give reliable information about the possibility of such a proposition.

I am submitting this proposition, personally, as one who edited the *Journal of the American Chemical Society* for seventeen years, took an active part in organizing both *Chemical Abstracts* and the *Industrial Journal,* and arranged for the incorporation of the *American Chemical Journal* in our journal. I think the question should be carefully considered and adopted or modified in accordance with the wishes of the 10,000 individuals and organizations who now subscribe for the journal.

We organized *Chemical Abstracts* on the basis of an increase of $3.00 in the dues and a subscription list of about 3,000. The *Industrial Journal* was organized with an increase of $2.00 and a slightly greater subscription list. If the present subscription list were divided equally between the two journals there would be 5,000 for each and certainly some additions, because some would take both journals. I firmly believe that we have the opportunity to establish a very important *Journal of Inorganic and Physical Chemistry* and also a very important *Journal of Organic and Biological Chemistry.* The success of the journals, if established, will depend, however, not on their subscription lists but on the research work of American chemists, which is giving them high rank among the chemists of the world.

In correspondence with Professor Lamb, chairman of a Committee of the Directors of the Chemical Society which is considering the possibility of dividing the *Journal of the American Chemical Society,* he objects that it is not desirable to carry specialization too far. With this objection I am in hearty sympathy and I have made the following alternative suggestion:

The papers in the journal are already divided into two classes. The first class of papers might be published on the 5th of each month, with the heading, *Journal of the American Chemical Society* and subheading, *General, Physical and Inorganic,* with which is incorporated the *Journal of Physical Chemistry,* founded by Wilder D. Bancroft. The second class of papers would be published on the 25th of each month with the heading, *Journal of the American Chemical Society,* with the sub-heading, *Organic and Biological.* The pagination of the two parts should be continuous, and a single index would be issued for the two parts.

An editor for the first part should be nominated by the Division of Physical and Inorganic Chemistry and the Division of Colloid Chemistry and an editor for the second part nominated by the Division of Organic Chemistry and the Division of Biological Chemistry. The elections should be by the council of the society, of course.

The additional expense might be covered by making the subscription, to members, $4.00. It may be remembered, however, that when the Analytical Edition was separated from *Industrial and Engineering Chemistry* the expense was borne by the general budget of the society.

We all know that non-industrial research lies at the basis of our industries. It was Faraday and not Edison who laid the foundation for the development of our electrical industries. It is certainly an important function of our society to provide adequately for the publication of such research.

I have emphasized the fact that chemistry is not an isolated science with sharp lines separating it from physics and biology or even from economics, sociology and political science. We should see clearly that we live in surroundings that are, in reality, a *universe,* in which each part has relations with every other and that we ignore these relationships at our peril. This knowledge should have a profound effect both on general education and on the way in which we train men to be chemists.

In spite of the simplification and unification of the foundations of our knowledge, the detailed information in each branch of science has increased tremendously and tens of thousands of men and women are eagerly engaged in extending the boundaries of science. One needs only to look at the annual index of *Chemical Abstracts* to realize that the detailed knowledge available to chemists to-day far exceeds that available in all science fifty years ago. No individual can possibly gain a comprehensive acquaintance with any branch of science. Every chemist knows that he often needs to use some fact far afield from his special domain. It becomes daily more evident that any attempt to gain a comprehensive knowledge of a particular science, such as chemistry, or of science as a whole, is futile. Instead of that we must endeavor to give all students a broad knowledge of the heritage available to those who know how to use it.

Fifty years ago we had a book called "Fourteen Weeks in Chemistry." Many scientific men thought such a book quite useless, but some who studied in academies and colleges in those days got a better acquaintance with the universality of science than is gained to-day by a more specialized training in one or two branches of science.

I wish to say a few words about the early training of a child and the relation of this to the training of a chemist.

The first lessons of the child are in practical sociology. These must necessarily be in the home or sometimes through a poor substitute furnished by an institution. Professor Ralph S. Lillie, in a paper read before the Chaos Club in Chicago and published in the *American Naturalist* in 1934, has stated two of the most fundamental laws of the universe which every child learns, in part, before he is four years old.

(1) We live in a stable and reliable environment in which consequence follows antecedent with an almost inexorable certainty.

(2) We may, in very large measure, so adjust ourselves to our environment as to make it serve us.

Professor Lillie characterized these laws as the principle of stability and the principle of change.

Not every one accepts the second principle, philosophically, but I know of no one who does not act on it practically. Without it, education would be useless. Without it, the human race would be in nearly the same condition in which it lived for hundreds of thousands of years before a written language was invented.

The early years in school are necessarily given to instruction in the "three R's" to furnish the child with the tools which unlock for him the storehouse of knowledge. Parallel with this he learns further lessons in sociology and in other things, on the playground and in the mingling with other children. In Heidelberg, four years ago, we learned that all German children attended the same schools for the first four years and that private schools for these grades were not permitted. This secured a mingling of the children which seems desirable in a democracy, if the classes are not too heterogeneous.

During the first six years of school the studies for all children should be essentially the same, but the classes should not be so crowded as to prevent the teacher from studying the personal characteristics of individuals and adapting the instruction to suit each.

The segregation of the seventh, eighth and ninth grades as a "junior high school" is giving an opportunity which has not yet been fully utilized. It has been found that capable pupils can accomplish the scholastic work of the seventh and eighth grades in a single year and it is evident that such pupils will waste their time and acquire bad habits of study, or lack of study, if there is no opportunity for individual treatment.

In schools abroad the study of languages is begun at a much earlier age than with us, and the introduction of a language in the junior high school, for those who wish it, should be carefully considered. A good teacher of Latin or French or German may give a better training in the correct use of the English language than that given by much of the current instruction in English.

In the junior and senior high schools we have given too much emphasis to the preparation of the student for economic production and not enough to his preparation for a sane and happy intellectual life. It seems clear that if we are to distribute work equitably under modern conditions men and women in the future should devote fewer hours to toil and will have more hours for recreation. To use this happily they must have intellectual resources. There should be training in art, pictorial, musical, dramatic and literary.

It is estimated that 60 per cent. of our young people of high-school age are in the high schools. I can think of no other respect in which our civilization differs so radically from that of Europe. A part of these high-school years should be used to give our young people a comprehensive—not a detailed—knowledge of their environment; of its historical background in astronomy, geology, archeology and ethnology; also of the cultural development of the race in art, literature, government and science. Especial emphasis should be placed on the scientific method and on the way in which the use of that method has transformed our environment within a few generations. The development of the automobile and of the airplane are significant as recent applications of such methods.

The scientific method should also be illustrated by laboratory instruction. This should be used to show the connection between experiment and the theories which furnish the golden threads by means of which, alone, a comprehensive knowledge of our environment is possible. We must understand that the acquisition of detailed facts is an incidental rather than a primary purpose. In high school, pupils should begin to think seriously about their future careers, but unless they develop some very definite aptitude they should not prepare for any particular science. There is great danger in too early specialization. They may well decide, however, whether they wish to enter some academic or professional career or whether they prefer to follow some other course in life. If they decide on a career of the former type they should almost certainly make a beginning with French and German, the two languages which will open to them rich storehouses of material.

The most indispensable element in the training of any high-school pupil, no matter what his career is to be, is that he should form the habit of testing his knowledge by observation, experiment and experience and that he should be careful about accepting dogmatic statements before subjecting them to these tests. He should learn, however, that hasty conclusions from experience are often wrong and that conclusions should be examined from many different angles before allowing them to become fixed convictions. A clear understanding and constant use of the scientific method is even more necessary for historians, economists and students of political science than for the chemist or biologist.

In college the man who wishes a thorough training in chemistry and who aspires to become something more than ordinary should continue to broaden and deepen the foundation for his studies, especially in mathematics, physics and biology.

The complaint has often been made of teachers of chemistry that they expect of their students too much detailed knowledge of the subject. Chemistry has been contrasted unfavorably with physics in this respect. It is especially important that the student should cultivate a selective rather than an encyclopedic memory. Such an ability comes from storing the mind with a very considerable amount of detail and by gaining the experience necessary to distinguish between things which are trivial and those which are important. The ordinary examination is poorly adapted to discover this sort of ability. For advanced students it is probably best developed by "seminars" in which students report on articles in current literature.

The ability to find needed information in handbooks and journals is increasingly important. The student should not be expected to find his way alone in the labyrinth of material available, without some special instruction in its use.

The practical application of knowledge is one of the best methods of fixing it in the mind and making it permanently useful. For this reason some experience in solving a new problem is a valuable element, even in a four-year undergraduate course in chemistry or in chemical engineering. A piece of experimental work carried out by a senior at the Rose Polytechnic Institute proved to be the starting point for some of the most important work that I have done. However, no professor should ever consider a student, whether an undergraduate or a candidate for the doctor's degree, as merely a tool to perform experiments of interest to himself. The advantage to the student should always be considered as the primary purpose. Not only should the topic be selected with the student's interest in view, but the student should be compelled to develop the greatest possible initiative in the preliminary study of the literature and in his work in the laboratory.

There is a fundamental difference between the work of a student and that of an employee in a factory, but the distinction is not so sharp as is generally supposed. Some of our most efficient industrial laboratories allow a certain amount of work that has no immediate economic significance. The laboratory of the General Electric Company is a notable exponent of this policy.

Whatever the policy of the management, the industrial chemist should never permit himself to think that he is merely a cog in a machine that is accumulating profits for a corporation whose directors often know very little about chemistry. Whether his work may seem small or great, he should think of it as a unit in a cooperative, democratic organization which serves the community and gives a reasonable return to workers, directors and capital. It is as this spirit permeates the whole community that we shall find the way out of the depression which has hung over us for six years past.