nism of the process is seen in the contraction of a lot of black spots in the skin (melanophores). When these are expanded the color is black, but when advised by messages from the optic nerve they contract and the animal becomes light-colored. In the case of the embarrassed shrimp, its eye stalks have been removed and extracted with water. This solution, when injected into an unembarrassed shrimp, produces the anticipated change in its color. Finally, and very significantly, Parker has shown that in certain cases the chemical nerve-product is not soluble in water, but may be extracted by oil, so by injecting the oil-solution into other fish the color becomes changed near the treated spots.

This is one of the many cases where the immiscibility of oil and water is emphasized and utilized in nature. It is not new that fats are oils, and that contact between the two is common in animals and plants. Probably many processes of growth depend on the presence of the pair in contact. Surely nature has adapted itself to this mixture and adopted its dependable properties. So while we may never completely understand their functions, we like to consider them just the same. The oils may carry in solution compounds insoluble in water. The aqueous plasma carries salts insoluble in oil. When the two solutions come into contact, new compounds of the two components may be found. Such reactions may well be closely connected with nerve action, as they probably are with tissue growth, calcification, etc. This makes some of Langmuir's researches on molecular films doubly interesting to me. For example, an inert oil floats as a lense on water. If a little stearic acid be dissolved in the oil, and if the water contains a little calcium, there is formed at once a film of calcium stearate which is quickly forced out from the oil-water surfaces and grows to a compact molecular film on the water. This film neither the water nor the oil seems to care any further about. Perhaps this is a part of the picture of growth. At any rate, it lies at the extremity of current biological science.

Cannon looks "forward to new triumphs of physiologic investigation, and that fair prospect lies in the direction of the nervous system." This is scientific modesty. Knowing much less of the subject, I am not so careful. All our troubles and pleasures are in the final analysis neural. From the pain of a cold toe to the happiness of some constructive process, our nerves are the necessary generator and network. From dreams of avarice to indigestive nightmares, all the information comes to nerves through nerves. Moreover, all the storage of past records lies probably intact in nerve structures and might be available if we better knew the system.

The nerve groups which control our insides willy nilly, without consulting our cerebral system, seem to differ in themselves as though competition were necessary even for the smallest organ. Chemists understand balanced reactions and know that the equilibrium condition is not idleness but represents stability, just because two necessary reactions are doing all they can in opposite directions. This proves that good living itself is process rather than product. Researchers discover that one group of nerves cooperate with ductless glands and the heart to keep the blood supplied with various catalyzers, which react on all the organs both to buck them up and tone them down. And as though this were insufficient, the parasympathetic part of our automatic outfit gets in its work by quickly supplying particular organs, modifying and controlling chemical products which refine, correct or overrule, where needed, the general actions of the less exacting and more diffuse sympathetic system. Probably all processes that proved desirable, among those of the simpler nerve-system, were adopted into the cerebral system as it developed from the lower states of man. So some day we may begin to see how beer and pretzels change into music, arts and science—or Brahms, Cellinis and Pasteurs.

Just imagine how far such studies might extend! I have thus speculated at this point, because I am speaking of the future of physical science.

THE CONTRIBUTIONS OF ARTHUR A. NOYES TO SCIENCE

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AN old letter came to light, by the merest chance, just one week to a day before Arthur Noyes died. It was dated November, 1901, bore his familiar signature, had been dispatched from Boston to a student in Leipzig and contained the following paragraph:

> . . . I have made a proposition to the President [Pritchard, M. I. T.] in regard to the establishment of a Research Department. It is rather an audacious proposition to make for a person who hasn't much more property than the obligations involved in the proposition require, but I feel the highest ambition of my life would be realized if I were in charge of such a department, and it is a favorite sentiment of mine that:
>
> "Those love truth best who to themselves are true,
> *And what they dare to dream of dare to do!* . . ."[1]

[1] The italics are those of A. A. N.

This paragraph reveals much of the man—of his vision, his courage, his passion for research, his humor, his unquenchable idealism. Subtly, too, it evidences the means by which he was so adept in passing—from mind to mind, from teacher to student—the inspiration to dare and to do. Most striking of all, perhaps, is that the whole paragraph reflects, quite without conscious intent, that inescapable forward surge of spirit which was to make him preeminent in three fields, education, research, leadership.

The "audacious" proposition was accepted. Arthur Amos Noyes, aged thirty-seven, became the director of the first Research Laboratory for Physical Chemistry in America.

His scientific career began in 1886, when he completed under the guidance of L. M. Norton his bachelor's thesis in organic chemistry at the Massachusetts Institute of Technology. The results were published with Professor Norton under the title, "The Action of Heat on Ethylene." In the following year he completed and published his master's thesis.

He then went to Leipzig intending to pursue graduate work in organic chemistry under Wislicenius. While at work in this laboratory he attended lectures by Ostwald in the newly created field of physical chemistry. Quick to grasp the great opportunities afforded by this rapidly growing subject he made the momentous decision to transfer to Ostwald's laboratory.

Research in physical chemistry of that day was largely influenced by two very recently advanced theories, the van't Hoff theory of osmotic pressure (1886) and the revolutionary Arrhenius theory of the dissociation of electrolytes into ions (1887). The Arrhenius theory especially was being subjected to quantitative test by pioneers in this field the world over, but Leipzig, due to the fame of Ostwald, had become the center of such activities.

In the year 1890 Noyes published three papers which led to the doctorate. In the first were discussed, from a theoretical view-point, causes for the deviations of non-electrolytes at higher concentrations from van't Hoff laws of solutions. In the second were presented the results of experiments made to test the validity of the constant solubility-product principle, which had been just formulated by Nernst, then a young privat-dozent in the laboratory. The third paper was published with LeBlanc and dealt with solubility and freezing-point determinations.

Enthused by his Leipzig training, tremendously inspired by Ostwald, Noyes returned to America, where his influence upon education and science constantly increased in scope and in importance. The establishment of the Research Laboratory of Physical Chemistry (1903); the acceptance, somewhat reluctantly, of the acting presidency of Technology (1907); the resumption of control of the Research Laboratory after his successor was chosen (1909); the assuming of concurrent control of two laboratories, his own and the Gates Chemical Laboratory in Pasadena (1916); the selection as acting chairman of the National Research Council (1918), were important points in his career. The most far-reaching change, however, came in 1919, when he definitely decided to sever connections with the Massachusetts Institute of Technology in order to devote his undivided effort to the new California Institute of Technology. This decision was a very difficult one for him to make.

During the period preceding the establishment of the Research Laboratory, Noyes taught successively *analytical, organic* and *physical* chemistry, publishing in each subject a book: "Qualitative Analysis of Inorganic Substances" (1895); "Experiments on Class Reactions. The Identification of Organic Substances," with S. P. Mulliken (1899); and "The General Principles of Physical Science" (1902).

His "Qualitative Analysis" received immediate recognition, and its wide acceptance did much to familiarize chemists of that day with the ionic theory and the laws of chemical equilibrium. The original scheme of analysis was incomplete in the sense that it provided for the separation and detection of the common elements only. Many of the omitted elements were, however, of common occurrence in nature, and each year new uses were being found for them. Furthermore, the scheme provided no satisfactory tests for estimating, even approximately, the relative quantities of the elements qualitatively detected.

Foreseeing future needs, Noyes initiated an extensive research project to devise a complete scheme of analysis which would include the so-called rare elements and would put qualitative analysis on a semi-quantitative basis. In 1902 he wrote in a personal letter: "Sammet and Ober are working with me on rare metal—qualitative analysis. We have lately been working on a *general* method of preparing the solution for analysis by using hydrofluoric acid in various ways, but have met a great many very trying difficulties. But I think in the end we shall succeed."

This marked the beginning of a long series of investigations carried out with the help of W. C. Bray and many other skilful collaborators. These investigations were published from time to time as the work progressed. There was finally published with Bray, after a quarter century of effort, a monumental treatise of over 500 pages entitled, "Qualitative Analysis of the Rare Elements." Noyes himself regarded this as his most important contribution to chemistry.

The second book marked the conception of a bold plan, wonderful if successful, to systematize the complexities of knowledge of the empirical properties of organic compounds. This extremely important systematization was subsequently developed by Mulliken, but Noyes always retained a deep interest in it.

The third book was the first step in the pedagogical development of what became later an exemplification of Noyes's conception of an ideal method of instruction in physical chemistry. The purpose of such a course was to give the students an intimate knowledge of fundamental chemical principles and a training in *logical, scientific* thinking such as would enable them to attack effectively the practical problems arising in their subsequent educational or professional work in any of the branches of chemistry or the related sciences. He proposed to accomplish this purpose through the use of a text interspersed with problems which would prevent the student from memorizing the principles or complacently believing that a formal knowledge constituted a real understanding of them. He believed it desirable to supplement the classroom exercises (preferably of the recitation type) with a brief laboratory course, or with lecture experiments, whose primary purpose should be to give concrete illustration to the basic phenomena under consideration.

It was my privilege, from 1905, to aid in the development of this course. After years of experience with our own classes Noyes and I published in 1922 "An Advanced Course of Instruction in Chemical Principles," in which these ideals were embodied. Noyes was also largely responsible for the experiments described in the supplementary laboratory text published by me. Since 1922 further development of the course has been continuous. At the time of Noyes's death a substantial part of a rewritten and rearranged second edition had been completed and printed for the use of classes at C. I. T. and M. I. T. This course in chemical principles is the main contribution of Noyes to pedagogy.

Noyes, through his research in physical chemistry, championed the cause of the ionic theory when many chemists sought to discredit it. He instigated an extensive research program for the systematic study of the nature of electrolytes by precise measurements of the *solubility* of various types of electrolytes in the presence of others; of *transference numbers;* of *electrical conductivities* covering a wide range (0° to 306°) of temperature; and of *chemical equilibria* and *electrode potentials.* Such investigations supplied a comprehensive knowledge of the ionization relations of different types of electrolytes upon which their chemical behavior in solution depends. Though the results confirmed the ionic theory in its more general aspects, the strong electrolytes showed puzzling anomalies.

In 1904, Noyes, after a critical analysis of all data then available, concluded that the ionization of salts is not primarily determined by chemical affinity, but by the magnitude of the electric charges on the ions. He was *almost* convinced that salts are completely ionized up to moderate concentrations, and that the decrease in conductivity is due merely to a change in migration velocity.

When Debye and Hückel, in 1923, advanced their theory of complete ionization of salts and of interionic attraction to explain the changing migration velocity with dilution, and the abnormal chemical behavior of ions, Noyes immediately became deeply interested. He published (1924) a long article giving (1) critical presentation of the theory; (2) testing of the theory with experimental data. These data were obtained for the most part from his own earlier investigations. This article was soon followed by two more, one of which tested the theory in alcoholic solutions and the other applied its principles to evaluate from conductance and transference data the ionization and ionization constants of moderately ionized substances.

When Noyes became convinced that the basic ideas of the ion-attraction theory were correct, he considered his own contributions to the theory of electrolytes as finished, and gave his whole-hearted interest and support to the newer lines of physico-chemical research—*rate of reaction, crystal structure, photochemistry, application of quantum mechanics to chemistry*—conducted by the various members of his staff. Personally, however, he continued to investigate with his *Honors* students the equilibrium conditions of oxidation-reduction reactions; and, in spite of great physical suffering he published during the last two years of his life several articles in this field. His final paper on strong oxidizing agents in nitric acid solutions was submitted for publication about one month before his death on the third of June.

The active participation of Noyes in the affairs of the American Chemical Society furnish the first concrete evidence of his leadership in science. In 1895 he published the *Review of American Chemical Research* as a part of the *Technology Quarterly,* of which he was editor. In 1897 this review was incorporated in the *Journal* of the American Chemical Society, Noyes continuing as editor until 1902. It was replaced by *Chemical Abstracts* in 1907. Thus Noyes inaugurated the first abstract journal covering American chemical research, the precursor of *Chemical Abstracts.*

Noyes also took an active part in the organization of the Northeastern Section, and in February, 1898, became its first president. He presented to the section, over a period of seven years, five papers—two illustrated by experiments and all related to his own work or that of the Research Laboratory. In 1904 he was honored by the presidency of the parent society.

A similar account might be recorded of his participation in the councils of the American Association for the Advancement of Science and of the National Academy of Sciences. In 1927 he was elected to the presidency of the former organization.

The trek to Noyes's first Research Laboratory began immediately after its establishment. The roster of these youthful investigators—"which now reads like a membership list of the National Academy of Sciences"—has been too often cited to require mention here. Through this distinguished group Noyes's influence spread in ever-widening circles.

It was, however, George Hale who first fully appreciated the potentialities of Noyes as a leader in education, and solicited his aid in the reorganization of Throop College in Pasadena. In securing also the cooperation of Millikan he brought together with himself two men whose combined qualities were ideal. Under the guidance of this trio has been created one of the greatest research and educational centers of the world.

Here Noyes brought to fulfilment some of his most cherished ideals of education. To cite but one, he introduced as a general policy his own life-long practice of *selecting* the ablest students, of *interesting* them in discovery and of *training* them in research early in their undergraduate course. The yield of effective research men obtained by this treatment of so-called honors students was a matter of great significance to him.

The last, and almost the greatest departmental interest of Noyes was the development of a division of bio-organic chemistry. Realizing that the applications of chemistry to biological problems would become more and more important, he became deeply interested in the study of chemical compounds having biological import. He published with H. W. Estill (1925) a paper on "Effect of Insulin on the Lactic Fermentation," and sponsored the extensive work on insulin conducted by J. J. Abel at the institute. (R. C. Tolman writes that it is the hope of the department to develop further this last-mentioned interest of Noyes, when the Crellin Wing of the Gates Laboratory is completed.)

During the years spent in California, Noyes's interest in science in general widened. He was devoted to Hale and to the success of the 200-inch telescope. He was a member, not only of the executive council of the institute, but of the observatory council, which has direct responsibility for the telescope. In his quiet and unobtrusive way, he exerted a profound influence in all departments. The educational policies, both graduate and undergraduate, were largely due to him. As Millikan has said, "he spent more time than any other man on the campus trying to create here outstanding departments of physics, of mathematics, of the humanities, of geology, of biology and of the various branches of engineering, and what these departments are to-day they owe, more than they themselves know, to Arthur A. Noyes."

SCIENTIFIC EVENTS

THE CROCKER EXPEDITION OF THE AMERICAN MUSEUM OF NATURAL HISTORY

THE American Museum of Natural History, through the generosity and with the collaboration of Templeton Crocker, of San Francisco, is planning an expedition to Christmas Island, Samoa, and, incidentally, certain islands of Hawaii, to obtain material for new group exhibits for the Hall of Ocean Life and the new Whitney Memorial Hall of Pacific Bird Life.

Mr. Crocker sailed on the yacht *Zaca* from San Francisco on August 18 for Honolulu, where he will be joined by Dr. Roy Waldo Miner, curator of marine life in the museum, and his party, consisting of Chris E. Olsen, artist and modeler, and Wyllys Rossiter Betts, associate on Dr. Miner's staff. William F. Coultas, of the department of birds, will accompany the expedition and will have charge of the ornithological work. Mr. Crocker will be accompanied by Toshio Asaeda, a skilled artist and photographer.

Dr. Miner plans to collect materials and make observations for a pearl fisheries group, to be installed near the great coral reef group he has recently completed after twelve years' work and five expeditions to the Bahamas. The proposed new group will represent a pearl bed on the floor of the sea, with native divers engaged in collecting the pearl shell. For this purpose the expedition will visit Christmas Island, a large coral atoll situated about 2° north of the Equator and 1,200 miles south of Honolulu; it is about 40 miles in diameter, with a central lagoon where pearl shell grows in the midst of the coral formation. Paul Rougier, the owner, has put the island and all its facilities at the service of the museum for the purposes of the trip. Dr. Miner and his assistants will utilize diving helmets and undersea cameras to obtain motion and still pictures of the undersea life of the lagoon for faithful reproduction in the new American Museum exhibit. Oil-color sketches will be made under sea by Mr. Olsen on specially prepared and mounted oiled canvas, and wax models of the brilliant fishes of the region will be constructed as part of the group setting.

After completing this phase of the work the expedition will proceed to Samoa, where Mr. Coultas will make special studies of the birds of that region and