SCIENCE

FRIDAY, MAY 25, 1917

CONTENTS

ILLUSTRATED SUPPLEMENT

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

SOME RELATIONSHIPS OF CHEMISTRY AND LIFE[1]

ABOUT the middle of last century Huxley and his co-workers clearly recognized the place of science in education, and the relation of both to life, and urged upon the world the necessity of scientific knowledge. Meanwhile, the schools and colleges have tried the experiment and have been convinced, but it has taken the present war with its terrible toll of death and destruction to focus the attention of the masses in a way which a century of reasoning has failed to do. This is not the place to discuss either of these experiences in detail, and I shall content myself by giving the conclusions of one competent witness who has watched the entire progress of the experiment.

After more than fifty years of continuous study of the education problem, Ex-President Eliot, of Harvard, concludes that the present generation is characterized by two strong desires. The first is a desire for a sound knowledge of the facts, and the second is an intense desire to be of service to mankind. If these conclusions are well founded, education must provide for their realization if it is to be successful in the broadest sense. This program, of course, is but another way of stating the scriptural text, "Know the truth, and the truth shall make you free." For the purpose of this address no better text could be found, for these words sum up as clearly as can be done the place of the scientific method in the learning process, and the relation of science to life as a whole.

[1] Address delivered on the occasion of the dedication of the chemical laboratory of the University of Oklahoma, January 26, 1917.

The necessity of realizing these relationships in everyday life has been persistently urged for two generations by men of science, but it has taken the present world crisis and its consequent interruption of our commercial relations to show how much more should have been done. The preparedness programs of this and other nations, as well as the utterances of thoughtful men in responsible positions in various walks of life, bids us hope that the lesson has now, in a measure, been learned. In a recent address before the British Association for the Advancement of Science an able chemist says:

The press bears witness through the appearance of innumerable articles and letters that the people of this country have begun to perceive the dangers that will inevitably result from a continuance of their former attitude, and to understand that in peace, as in war, civilization is at a tremendous disadvantage in the struggle for existence unless armed by science; and that the future prosperity of this empire is ultimately dependent on the progress of science and very especially of chemistry. If, as one result of the war, our people are led to appreciate the value of scientific work, then perhaps we shall not have paid too high a price. (The same view has been expressed by many eminent American chemists.)

A similar note of warning is sounded by a continental writer in discussing the question of whether we shall have a precarious or a lasting peace. He says:

It would be a dangerous mistake to suppose that any readjustment of frontiers could afford a sufficient guarantee for future peace, or that war indemnities, protective tariffs and the like could oblige the peace-breakers to renounce their schemes. . . . At the future (*peace*) congress, among the seats reserved for the delegates of the Great Powers, one seat should remain vacant, as reserved to the greatest, the most redoubtable, though the youngest of Powers: Science in scarlet robes.[2]

Before taking up a discussion of the relationship of chemistry and life, it may be worth while to inquire as to the general attitude of the public toward the work of the chemist. If you ask the first person you meet, or if you get the opinion of the newspaper man or other influential citizen, about the work of the chemist, he is apt to tell you that the chemist is a man who can analyze substances, and detect falsification in them; but he is not likely to tell you that the chemist has any important relationship to the commercial development of the enterprise in question. How many in this audience, for example, think of the chemist when they pour their ''Karo'' on their hot cakes at breakfast, when they read the headlines of the daily paper and learn that a wireless message has been flashed across the ocean; when they step into an automobile to start the day's work, or when, the work completed, they while away the time of the evening watching the screen in some motion picture show? Nevertheless, in the successful working out of each of these the chemist has played an important and, in some cases, a vital part, but I have not time here to give particulars.

Let me give you a concrete example of what I mean. Whenever one thinks of the Panama Canal one's thoughts turn at once to the chief engineer, Col. Goethals. He is the one to receive the medals, the honorary degrees, the thanks of Congress, the promotion to higher rank in the army, and finally to be named governor of the Canal Zone. Do not misunderstand me: I am not complaining of this recognition of the man's undoubted merit, because Goethals was unquestionably the moving spirit in the undertaking, and certainly worthy of all the honors that have come to him. But when we come to survey the case a little more closely, we see that there are at least three other factors for neither of which Goethals was personally responsible, but without the support of any one of which he

[2] Reinach, S., *Nation*, June 15, 1916.

would have been absolutely helpless. The first of these is the health of the laborers. The French undertook to build the canal years ago, and while their failure was brought about by several causes perhaps one of the most important was the fact that the men could not live in that part of the world and retain their health. Yellow fever and malaria were everywhere, and it was but a matter of time when one must be attacked by one or both of these infections. It has been stated that the building of the railroad across the Isthmus meant the death of a man for every tie that was laid. But man can live in Panama now with perfect safety, so far as yellow fever is concerned, and this is due entirely to discoveries with which Col. Goethals had nothing to do. Dr. Gorgas was in immediate charge of the work of sanitation, but it was kerosene, the product of the chemist, which was sprayed on the stagnant pools, and which checked the development of the mosquito.

In the second place, the penetration of Culebra, as well as the remainder of the blasting necessary, would have been impossible without the powerful explosives of the chemist. The gun-powder, dynamite, blasting gelatin and similar substances are all products of the chemical laboratory.

In the third place, let us suppose that the development of the mosquitoes has been checked, that Culebra has been pierced—the work is only half done. It is necessary to control the level of water in the canal, and this, under the conditions imposed, can be done in only one way, namely, by the construction of locks and dams. For these some material stronger than wood and less easily corroded and destroyed than iron must be used, and this is found in the chemist's cement. As is well known, thousands of barrels of this material were used in the work.

Finally, when the canal is complete and ships are passing back and forth through it, there is comparatively little safety until it has been fortified. The chemist's powder and steel must stand guard over it as they do over every treasure we own, or we should not be able to retain it as a national possession.

Cases of this kind could be multiplied indefinitely, but I must not take your time to do so. On the other hand, the Panama Canal is so remote that many persons do not think of it as having any bearing whatever on their daily lives. But the question of food and war munitions at this time can hardly be misunderstood by any, and it remains merely to show the relations of chemistry to these to convince the most indifferent. A detailed discussion of even these would tax your patience, I fear, therefore I shall limit myself to the consideration of a single element, viz., nitrogen.

It has long since been proved that nitrogen is an essential constituent of the food of all living beings, and that, in general, it may not be assimilated if taken directly from the air where it is present in the free form. It must be combined with one or more other elements. As one begins the study of nitrogen in a chemical laboratory, he finds what at first sight appears to be a relatively uninteresting element. It has neither color, odor nor taste, is but slightly soluble in water, and does not readily combine directly with other elements. But in combination it is a constituent of many different substances of the most varied characters. It is present in some of the most delicate of perfumes as well in substances whose odors suggest utter vileness. It is a constituent of various fibers (wool, silk, artificial silk) used in our clothing, and also of the aniline dyes which enhance their beauty and value. It is present in the most potent of medicines and in the most deadly poisons. As gunpowder it drives our bullets, as dynamite it explodes our mines, and as cyanide it extracts our gold. Under the general name of protein it is an indispensable element of animal food, and as animal waste, it is returned to the soil as food for plants. Thus, nitrogen not only gives life, health and prosperity, but it is the most terrible element of death and destruction known to modern warfare.

In considering nitrogen as an element of food, we may note in passing that the normal adult human body requires a certain amount of the element every 24 hours, and that this must be supplied in the form of meat, eggs and various vegetables, all of which are either directly or indirectly products of the soil. Now, every one knows that continual cropping causes a soil to become poor, and chemical analysis shows that the change is due, in part, to the loss of nitrogen. Fertilizers are applied to the land to increase the yield.

The problem will become clearer if we take another view. There was a time when fewer people lived in cities, and when this depletion of the soil was largely restored by the refuse from farm animals and even from man himself, from which it follows that the greater portion of the nitrogen removed as food for animals was returned to the soil in some other form available for plant growth.

We may next consider the complications that arise in dealing with such aggregates of population as our large cities. Sustenance must still be drawn from the soil, and since nitrogenous waste is no longer returned to the land it is clear that the latter is continually being depleted. A single example will illustrate the point. The sewage of the city of London has an estimated annual value of $100,000,000 as fertilizer, and that of any other city would represent an amount corresponding to its population. These drains, of course, must in some way be accounted for if the soil is to continue to produce. What, now, has science done to relieve the situation?

When chemical analyses of soils and crops had clearly defined the problem and had told the story of nitrogen, a search was made for some material that could supply the deficit. First, natural guano, as it is called, deposits consisting largely of the dried excrements of birds, and found in such arid districts as Peru, was obtained in as large quantities as possible. But material of this kind was limited in amount and is now practically exhausted.

Next, the chemist saw that the waste liquors of the gas works contained combined nitrogen that could serve as plant food, and we are now using in the United States $20,000,000 worth of ammonium sulphate as fertilizer per year. This, again, is limited because in this country about 80 per cent. of the coke is made in the wasteful "beehive" oven in which the vapors are simply burned on the spot. The ammonium sulphate derivable from those vapors in 1911 could have been sold for $24,000,000, to say nothing of the other compounds present. But gas plants can not be operated economically for the ammonium sulphate alone, and our coal beds are not inexhaustible, which shows that some other nitrogen supply must be found.

The third source of plant nitrogen is the Chile saltpeter bed, from which millions of tons of sodium nitrate have been taken as fertilizer to different parts of the world. This supply, also, is limited. Indeed, conservative estimates indicate that the deposits will be exhausted within a relatively short time, which means that man must solve the nitrogen problem in some other way, or he must eventually starve. The necessity for research in this field has been urged for many years, and it is now in order to ask what chemistry has done to relieve the situation.

It has already been stated that nitrogen does not readily combine with other elements, and that animals and plants, with very few exceptions, can not use free nitrogen as food. But the free form is plentiful, since it makes up about four fifths of the atmosphere, while the greater portion of the remainder is oxygen. The specific problem, then, is to cause those two gases to unite, or to find some other way of "fixing" the nitrogen. This has been accomplished, and while the history of the commercial process now in use is full of interest, it must be passed here with mere mention. It should be noted in passing that Cavendish, an English chemist, showed as early as 1785 that nitrogen and oxygen could be made to unite under the influence of the electric spark, and that the product would react with water to give nitric acid. At that day, however, electricity was regarded as a mere toy, and no one dreamed of the possibilities locked up in that interesting though, to the average person, seemingly useless, laboratory experiment.

In 1898, Sir Wm. Crookes aroused interest in this problem again by calling attention to the future exhaustion of the Chile saltpeter beds, and urged a study of methods for fixation of nitrogen. In 1902, Bradley and Lovejoy, two American chemists, published an account of the commercial application of the Cavendish experiment mentioned above, while to-day the manufacture of nitric acid by that process in Norway is a business in which more than $30,000,000 is invested. Immense sums have been spent in its development in Germany and elsewhere.

At present, the manufacture of calcium carbide, so largely used in the production of acetylene for lighting and heating purposes, offers an important method for fixing nitrogen. The manufacture of the carbide was begun in this country several years ago and is now one of the leading industries of Niagara Falls. Frank and Caro, German chemists, found that the carbide could be made to combine with nitrogen in such a way as to produce a valuable fertilizer. The nitrogen it contains can readily be converted into ammonia, and from the latter nitric acid can be prepared. As a matter of fact the Germans are now producing 600,000 tons of the carbide annually in order to supply, through the reactions indicated, the nitric acid required to make explosives for the war.

In this brief and superficial fashion, I have tried to make it clear that the preparedness which the nations demand is twofold—agricultural as well as military—and that, in essence, both are largely chemical. Cheap fertilizer must be furnished in times of peace, and nitric acid and other materials for explosives in times of war. So much for the formulation of the demand. The real problem is to furnish the means by which this program can be successfully carried through.

So far as the chemical part of the program is concerned, two specific requirements must be met. First, there must be adequate training in the fundamentals of chemistry, and second, there must be opportunity for chemical research. The first is conceded by everybody, but many highly intelligent educated people do not understand research, and therefore call it theoretical and impractical. The cry is for applied science, for something practical. They fail to recognize the fact that there can be no applied science until there is science to apply. It is not strange that Huxley, with his extraordinary precision of thought and remarkable command of language, long ago pointed out that what people call applied science is nothing more than the application of the methods of pure science to particular classes of problems. Some one must patiently and laboriously determine the facts and formulate the principles before there can be any commercial application of them; and, whether we recognize it or not, the world is waiting on the research worker.

If time were available it would be easy to show that practically all the great commercial successes rest upon principles formulated by research workers who, in many cases, labored solely for the love of truth, without any expectation that their work would immediately benefit mankind. But no one can tell at what instant some such observation may become of immense importance. I beg your indulgence to call attention to a few cases. Was Röntgen thinking of the extraction of bullets, the reduction of dislocated limbs or the setting of broken bones when he discovered the X-rays? By no means. Or Helmholtz, did he have in mind the prevention and cure of eye diseases when he worked out the principle of the ophthalmoscope? Not at all. Was Cavendish, to whom I have already referred, thinking of providing food and war munitions for the future when, 132 years ago, he read before the Royal Society his paper on the fixation of nitrogen? I think not. No one will doubt the great practical value to the human race of Pasteur's researches, but it is proper to point out here that he began by the study of the asymmetry of crystals, and that he became a bacteriologist through his attempts to disprove the doctrine of spontaneous generation. Scores of cases could be cited to illustrate the point, but the lesson is, learn the facts, and the applications will be forthcoming.

The expenditure of public money for the erection of the splendid building we are assembled to dedicate is an expression of continued confidence in the leaders in charge of our educational interests, and a pledge that the necessary equipment for the future shall be provided.

It is a pleasure to me to come here to-day and have a part in the dedication, not merely because of my interest in the educational welfare of our state, as a whole, but more particularly because of the opportunity it gives to emphasize the claim of science in general and chemistry particularly in connection with the problems now confronting the world. Interest in the study of chemistry has been steadily increasing for many years, but its importance has been emphasized by the war in a way that could not have been done otherwise. The University of Oklahoma is to be most heartily congratulated on having completed at this time a laboratory so carefully planned and so well equipped, as well as upon the work of its department of chemistry in the past. With the extra space and facilities offered by the new building, both the university and the state may confidently look forward to greater things in the future.

L. Chas. Raiford
Oklahoma Agricultural and Mechanical College

SCIENTIFIC EVENTS

ENGLISH VITAL STATISTICS

The annual report of the registrar-general on births, deaths and marriages in England and Wales for 1915, as summarized in the London *Times*, is remarkable for the number of previous "records" which are broken. Thus the marriage rate was the highest on record; the birth rate the lowest on record; the death rate from typhoid fever was the lowest on record; that from influenza the highest since 1900; and that from measles the highest since 1896. Again, the age rates of bachelors marrying spinsters and spinsters marrying bachelors were both the highest on record. Finally, the increase of boy babies over girl babies from July, 1915, to June, 1916, was the highest on record for 50 years. The estimated infant mortality rate for 1916 is the lowest on record.

The marriage rate was 19.5 per 1,000, being 3.6 above the rate in 1914. The provisional figures for 1916, however, indicate that what has been described as the "boom" in marri-