CHEMISTRY AND AMERICAN INDUSTRY.*

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THE fact that chemistry is the real basis of human industry has been better advertised during the past two years and is now more fully understood by the general public than ever before in the history of the human race. Long before the word "chemistry" existed, prehistoric man began to practise the art, when he discovered, some time in the dim past, that the fires he built against the walls of cliff and cave changed the nature of the earthy materials with which he was familiar. Ceramics and metallurgy are the oldest of human industries, and none are more dependent upon obscure chemical actions and reactions. Although ancient as a practised art, chemistry as a science is no older than our own Declaration of Independence, and, indeed, may be said to have germinated from its seed in the bloody soil and under the murky clouds of war and revolution. Lavoisier, the great Frenchman, the father of the modern science of chemistry, was guillotined by the angry mob at the time of the Terror, but, like John Brown's, his soul goes marching on. It is curious that it should be reserved for this second time of Terror to give a new impetus to this most basic of all the arts and sciences. If war was destined to bring all evil and no good in its train, optimism would be impossible and race suicide excusable.

If American industry is to learn and benefit from the lessons of the past three years, it is necessary that the American people should realize more keenly and with a more active interest some of the facts that this paper will attempt to set forth. Either directly or indirectly, chemistry as applied to industry affects the conditions and well-being of every American home. The clothes we wear, the food we eat, the utensils we handle and prepare it with, the materials of construction with which we are housed or transported from place to place, the medicines which we depend upon in the struggle with disease and death, are all, in one way or another, dependent upon strictly chemical industries. It is

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chemistry that has made it possible to produce iron and steel on the enormous tonnage scale that makes modern civilization possible. It is chemistry that teaches us to make from ill-smelling, viscid coal-tar, the by-product of the gas and coke industry, thousands of beautiful colors and dyes, medicinals, and high explosives. The red silk parasol of a summer beach and the red wound of war have a common origin in that black, sticky mass. It is chemistry that has developed that wonderful structural material, Portland cement, that enables man to mould his building stone in the place he wants it so that in a few hours it attains the same condition of solidity and durability possessed by rock which Nature laid down and solidified in the course of geological epochs. Truly man takes upon himself the attributes of a creator when he learns to properly apply the principles and science of chemistry to the materials which surround him.

Our country, with its vast natural resources in coal, ores, and lumber, and with its extraordinarily diversified products of agriculture, has had special need to apply science to industry. Much has been done, but at best, except possibly in some exclusive lines, we have not heretofore kept pace with Europe in the application of chemistry to industry. It will do no harm and may do good to state very clearly that the apathy and careless ignorance of our people in regard to applied science in general have constituted a great hindrance to our progress along certain most important lines. George Washington, with the wisdom which was his, foresaw this national tendency, and his state papers constantly urged upon the Congress and the people that state of preparedness which depends upon the application of science to the arts of peace and war. Nevertheless, the great European war, with its consequent embargoes, found us terribly deficient in any preparation for an event that a wise government and people might have foreseen and anticipated as at least a dangerous possibility. And so for a long time after the outbreak of war there was a great scurrying about in our industrial ant hill, and great consternation over the question as to what some of our important enterprises were going to do without supplies of certain essential raw materials necessary to the arts, industries, and to the national defense. And now, as these words are written, with the world war threatening to engulf us also, great mills and factories in many sections of the country are shutting down and banking their

fires for the lack of cars to move fuel to the furnaces. It would seem that a wise government should recognize that in order to be an efficient people in peace or war the wheels of industry must be kept moving. The much-debated question of belated battle-ships that should have been building years ago is serious enough, but crippled industry is far more ominous, and its relief is worthy of the study and the helpful coöperation of government. The attitude of the great mass of the American people as expressed through its government has, however, for years past been one of passive indifference when it has not been one of active hostility, not only to the great chemical industries but to the railways which feed them and distribute their products.

The past two years have seen a better appreciation by the layman and the press as to the place chemistry really occupies in the national life, but even now people who are not technically trained do not realize that certain minor constituents which enter into the production of the necessities of life and national defense are quite as important factors in our political and economic salvation as the main-line raw materials. With all the wood, wool, cotton, coal, copper, and iron in the world in our possession, our mills and factories would stand idle if certain needed chemicals, whose very names are often unfamiliar to the man in the street, were unobtainable. Dr. George D. Rosengarten, a member of this Institute, in a presidential address before the American Institute of Chemical Engineers, has strikingly pointed out that had it not been for the discovery of sulphur in Louisiana and the economical method of mining it, devised by a famous chemist, in 1891, the balance of trade would not now be on our side to-day, and untold millions of dollars that have come to this country would have stayed at home or have gone elsewhere. How many people realize that the quantity of sulphuric acid consumed by a nation is a measure of its industry, that a large part of the great iron and steel mills would have to shut down for lack of it, while not a pound of powder to serve the guns could be made without this corrosive liquid?

As an interesting instance of the influence of more or less obscure minerals and chemicals on the destiny of nations, I wish to refer to a speech before the Parliament made by the British Minister of Munitions, the Rt. Hon. Edwin Montague, on August 15, 1916. In describing one morning's work, he recites how he

began his day completing arrangements for the transport from near the Arctic Circle to a neutral country of a mineral, the name of which was unknown to him, but which he understood was the limiting factor in the output of certain indispensable munitions. He next took up the question as to whether a certain railway must be constructed in a remote part of India to obtain strange supplies of material wanted for munitions. Next came a discussion and decision as to the allocation of a certain chemical, very limited in quantity, to meet the competing needs of the army, the navy, and the air service. After this, a conference on certain contracts in America valued at over £10,000,000 sterling. Next, an inspection of new inventions in artificial legs. And so on and on through a hundred-and-one topics which, as the Minister says, must confront any body of men who spend their whole days watching curves which ought always to go up and figures which ought always to swell; confronted always with the cry, "More, more, more!" and "Better, better, better!"

Returning to our own problems, let me recite a few cases of industrial unpreparedness that come prominently to mind at this time.

Before men can fight they must be fed. How few people realize that the feeding of a great people, either in peace or war, is largely a metallurgical problem with which the steel industry is primarily concerned! Not only much of our harvest yields but also the major portion of our annual sea food must be packed and preserved in tinned cans. A "tin can" is really made of sheet steel covered over with a thin wash of tin, and no other metal known can be used as a substitute. In spite of the fact that a tinned can carries only a small weight of tin, so great is our canning industry that in 1914 we imported from overseas 52,919 tons of this metal, valued at about \$33,000,000. Tin is not found in paying quantities in the United States, and in 1914 only 157 tons were produced in Alaska. The principal world source is in the East Indies and the Malay States, and is controlled by Great Britain. Tin ore is also found in Bolivia and is at present being imported and smelted in New Jersey, but thus far tin from this source is only a small factor in a great industry. As has been shown, the question of our tin supply is a most important factor in our food supply. This subject, according to the daily press, is now receiving the anxious attention of our government. Had

this been the case three years ago the probabilities are that any present and pressing emergency could have been forestalled.

Much of the world's supply of iron ore and coal lies right at our hand. According to the general idea, all that is necessary is to bring these things together in order to produce steel, the main prop of nations, whether in peace or war. But, among other things, steel cannot be manufactured without manganese, although this element is only a minor constituent rarely present in steel to the extent of more than one-half of one per cent. Shortly after the outbreak of the war ferromanganese was so scarce and so difficult to obtain that some steel manufacturers become panicky and the price is said to have reached the phenomenal figure of \$1000 a ton for a material which in 1913 sold for about \$60 and which is now quoted at \$300. In the decade from 1903 to 1914 we imported from overseas over 1,300,000 tons, or about \$51,000,000 worth, of this essential of our greatest industry. In the report of the Mineral Resources of the United States for 1913, published by the U. S. Geological Survey, we read that "Manganese ore mining in this country can hardly be said to have been a profitable industry. The causes are probably numerous, some of the more common being failure to explore the deposits sufficiently in advance of installation of washing equipment, lack of familiarity with the common features of the deposits in general, and possibly lack of high degree of technical skill on the part of operators."

It is all very well to accept praise where praise is due for the phenomenal growth of American industry, but none the less the government report above quoted is fairly indicative of some of the careless, slipshod methods in vogue in this country. Four years have elapsed, and a prominent New York daily paper of February 15, 1917, announces in headlines: "English Makers of Manganese Withdraw from the Market. Steel Companies Alarmed by the Serious Outlook for Ferromanganese are Feverishly Buying Manganese at Rapidly Advancing Prices."

As a matter of fact, there is ferromanganese enough in this country at present to supply our steel industry on a hand-to-mouth basis, but it is difficult to prophesy what the immediate economic effects of a stoppage of this important substance would be, especially in the event of actual warfare.

The same daily paper quoted above contains the report of the

leading company of a great American chemical industry—one on which the American people would have to very largely depend for the national defence in case of war. From this report I take one brief paragraph, as pertinent to the subjects I am here discussing :

“ It is regrettable that the United States Government has made our stockholders victims of excessive taxation. Under the corporation tax and ammunition tax laws, the tax levied against our company for the year 1916 alone will result in our paying to the United States Government an amount equal to the entire profit made on sales of military powders to the United States Government by this company and its predecessors since the inception of the industry about twenty years ago. To state it another way, the tax levied against our company for 1916 under these laws will aggregate an amount equal to 170 per cent. of our entire net earnings for the year 1912, in which year we had the largest earnings in the history of the company prior to the war.”

As this paper is being written the United States Government is pleading before the Supreme Court for a dissolution of the great Steel Corporation, which ought to be one of our greatest assets, whether in peace or war. Where the governments of other great nations offer coöperation and even financial assistance to the great industries on which their national safety depends, our government sees fit to oppose obstacles and discourage growth by excessive taxation. What the effect of such policies will be, should we ever be forced into a condition more serious than a mere state of war or armed neutrality, is a question which we can only hope will not have to be put to test by the final and awful eventuality.

Although awake at last, Great Britain has suffered from the same national complaint, and Dr. Alexander Findlay, in his book on “ Chemistry in the Service of Man,” has used words which apply quite as well to America as they do to England. They will bear repetition :

“ The crisis through which this and other European countries are now passing has brought home to us how greatly we, as a nation, have hitherto failed to recog-

nize the intimate and vital dependence of our social and national prosperity on a knowledge and appreciation of the facts and principles of science, and not least of chemistry, and on their application in industry. All the industries of the country on which not only the comfort, but even the life of the people depends—the great manufacturing industries and agriculture, the greatest industry of all—claim tribute of chemistry. And yet we, as a nation, have done much less than the responsibilities of our civilization demanded to promote and encourage the development of chemical knowledge; we have even, indeed, largely failed to avail ourselves of that tribute which science is so willing to pay. To the work of laying the foundation of pure science, on which the superstructure of successful industrial achievement must be raised, British chemists have, according to the measure of their numbers, contributed an honourable share; but the people as a whole, being ignorant of science, have mistrusted and looked askance at those who alone could enlarge the scope of their industries and increase the efficiency of their labours. And so we have witnessed in the past an appalling and needless waste of our national resources, and in too many cases industries have languished and succumbed, or, even when born under conditions of great promise, have remained dwarfed and stunted in growth. In 1862 the German chemist, Hofmann, at that time a professor of chemistry in London, could utter the prophecy: ‘England will, beyond question, at no distant day, become herself the greatest colour-producing country in the world; nay, by the strangest of revolutions, she may, ere long, send her coal-derived blues to indigo-growing India, her tar-distilled crimsons to cochineal-producing Mexico, and her fossil substitutes for quercitron and safflower to China, Japan, and the other countries whence these articles are now derived.’ But alas! that prophecy has not yet been fulfilled, and the industry of synthetic dyes, an industry which above all others depends on the fostering and encouragement of chemical research and on the highest scientific efficiency, has

found a home elsewhere amid more congenial surroundings.

“ But there are now welcome signs that the country is awakening to a sense of past deficiencies, and already the government has taken a first short step in the direction of encouraging and assisting scientific and industrial research. But if the national effort is really to become effective and to exert a lasting influence, something more is necessary, something which is, perhaps, more difficult of achievement than governmental aid. The mental outlook and the attitude of the people as a whole towards science must be changed, and the scientific habit and a spirit of trust in science must be cultivated; and we must also attract in much larger numbers into the ranks of scientific workers men of equal mental calibre to, and capable of taking the same wide outlook as, those who are at present attracted into the higher ranks of the legal profession or into the civil services. Science stands for efficiency *in all the activities of life*, and the neglect of science spells waste and industrial decay. It is for the country to choose the path which it will follow.”

A year ago I published a paper in the JOURNAL of this Institute on “ The Rôle of Chemistry in the War.” This paper, which was reprinted by the U. S. Senate as Senate Document No. 340, attempted, among other things, to set forth the great importance of studying methods of fixing atmospheric nitrogen for the production of fertilizers and high explosives. In that paper the effort was made to explain in simple language the absolute dependence of our people on an adequate supply of fixed nitrogen, and the danger that would ensue if war or embargo should interfere with the importation of fixed nitrogen from the nitrate beds of Chile. The air we breathe consists of nearly four-fifths of nitrogen gas, or equivalent to a weight of 33,880 tons upon every acre of land. The land needs nitrogen for the production of crops, but, except through the agency of bacteria which, curiously enough, are associated only with the root systems of beans, peas, and clovers, vegetation cannot make use of the free nitrogen of the air. Also, before it can be used for making high explosives, nitrogen must be fixed to some other element. Once

thus fixed, it makes little difference to the chemist what it is joined with, as he can by one method or another manipulate it to any end product desired. Nitrogen may appear combined with other elements as a simple fertilizer for your lawn; as a deadly, treacherous explosive, an ounce of which is sufficient to wreck a building or a battleship. It may take the form of a deadly poison, cyanide, which is used to extract gold from its ores. It may be a principal constituent of a beautiful dye or a beneficent medicine. It is a constituent of the wool we wear upon our backs, of the leather on our feet. Joined with oxygen, it forms the corrosive nitric acid which dissolves nearly all metals; joined with hydrogen, it forms the familiar pungent alkali, ammonia, which neutralizes all acids. Fixed nitrogen in the form of protein makes the principal strength and value of the food we eat. Animals having absorbed it in part excrete the remainder in a different combination, and the manure goes back to the land to be used in part again. But there is always waste, and a large portion gets free and escapes back into the atmospheric ocean from which it originally came, hence the call upon the chemist to devise methods for its fixation.

During the past year there has been much discussion and agitation over the question of nitrogen fixation. Many of the great steel and smelting companies have invested large sums of money in the installation of by-product coke ovens. One of the by-products of coke making is ammonia, and it is claimed that the fixed nitrogen from this source alone would supply all the reasonable needs of the nation. Large quantities of ammonia are, however, needed for the cooling and refrigeration of the enormous meat supplies of the world, while the chemical methods used in changing ammonia to the much-needed nitric acid state of fixation present certain difficult problems which have not yet been fully worked out in this country.

By a method which is worked on a large scale at Niagara Falls, Canada, nitrogen is fixed to carbon to form a chemical compound known as cyanamide. If carbon in the form of ground coal or coke is mixed with lime and heated in an electric furnace, a carbide is formed. If air nitrogen is conducted into this substance in another furnace, the mass is converted into calcium cyanamide (CaCN_2), an excellent fertilizer under certain conditions. Treated with steam, this compound yields ammonia.

Nitrogen can also be fixed by passing huge electric arcs or sparks through air which is conducted between terminals enclosed in furnaces of a special type. Congress has within the past year appropriated \$20,000,000 for the installation of a government nitrogen fixation process, but no announcement has yet been made as to what method the government's advisers intend to select, and it is exceedingly doubtful whether the appropriation will be large enough for the purpose, or whether, under our American conditions, such a government plant could be operated except as a losing venture.

Recently an American scientist, Prof. J. E. Bucher, of Brown University, has announced a new process by which sodium carbonate, the chemical familiar to every household under the name of washing soda, is mixed with finely-ground iron ore and coke dust and the mixture heated in a current of air to a moderate temperature. Nitrogen is fixed in the form of the poisonous sodium cyanide (NaCN). As has been pointed out, nitrogen once fixed lends itself to the chemist with great adaptation. From cyanide, ammonia and an astonishing number of useful chemicals, both of an organic and inorganic nature, can be made. The chemical changes which are proposed are too complicated for discussion in this paper, but it is interesting to note that one of the compounds which can be readily synthesized by this process is urea, a metabolic product of animal life. As urea contains 46 per cent. of fixed nitrogen and is soluble, it should be and is an intensive fertilizer. Its cost heretofore has alone excluded it from use for this purpose. Bucher's researches, which have persisted through a number of years, have been carried out with fascinating simplicity and ingenuity. It is as yet too soon to venture a prediction as to the economic and commercial success of this new method of attacking the nitrogen fixation problem, but while awaiting the verdict of the future we may be permitted to hope that this fine example of persistent American research will prove to be at least one useful way of tapping the inexhaustible treasure of the air.

The potash situation in this country since the war has been an interesting one, and, while the scarcity of this important chemical has crippled some American industries, chemists in some lines have been stimulated to work out methods of getting on without it. Before the war certain grades of glass, such, for instance, as are

used for making electric-light bulbs, were potash glass. Now it is quite certain that better glass is being made in America than ever before, in spite of the potash famine. Potash, however, like fixed nitrogen, is a necessary plant food, and intensive agriculture cannot get on indefinitely without it, unless potash or the lack of it is to become a very important factor in the much-discussed high cost of living. As sold on the basis of fertilizer value before the war, potash was worth about \$34 per ton. It is now quoted nominally at \$400, though, owing to its practical absence from the market, sales are rare occurrences. It is perhaps needless to repeat here that practically all the normal world's supply of potash has heretofore come from mines controlled by Germany. We have unlimited quantities of potash locked up in an insoluble form in our feldspathic rocks, but it costs more than \$30 per ton to get it out, so that fear of German competition after the war has prevented capital from developing the processes that American chemists have worked out for treating these potash ores. A certain quantity of potash is collected as a by-product in the manufacture of some few types of cement, and to a certain extent it is being extracted from sea-weed on the Pacific coast and from a potash-bearing mineral known as alunite, which is found in Utah. It is also, with a good deal of trouble, extracted from the brines of some of our western salt lakes, and from hardwood ashes. In all, our domestic production from all sources in 1916 was less than 9000 tons, while our yearly need at present is probably greatly in excess of 300,000 tons. The fact remains that up to date there is no potash industry in America at all commensurate with our present or future needs.

The chemistry of coal-tar has been tremendously stimulated in America within the last three years, and the manufacture of many beautiful dyes and useful chemicals and medicinals from this source, which used to come exclusively from Germany, is now firmly established in this country. The dyestuff situation has been much discussed in the daily press, and many wrong impressions have been disseminated in regard to it, in spite of the fact that a number of papers containing the simple truth have been published by chemical experts. I touch but briefly on this phase of chemistry in American industry, as the subject is one that can be discussed far better by others and is worthy of a paper by itself.

Dr. J. M. Mathews, addressing a section of the American Chemical Society, recently made some comments on the public attitude towards applied chemistry which I shall take the liberty of repeating at this place, as in a way it serves to introduce the next phase of chemical industry which I have selected to discuss in this paper. Dr. Mathews said:

“The past two years, I think, have seen a better appreciation by the layman and the press as to just what the chemist is and what his profession consists of and can accomplish. There is still that idea, however, prevailing that chemistry is a hodge-podge of mysterious secrets, the discovery of which is made by accidental and haphazard methods. The popular mind has evidently not yet progressed beyond the age of the alchemist. In things chemical the public has still the innocently receptive mind of a child; it will accept as gospel truth the most absurd and illogical statements of supposed discoveries. Some so-called chemist announces the remarkable discovery that by the addition of a few drops of a mysterious green liquid to water he creates a perfect substitute for gasoline for use in automobiles. The daily press devotes column after column to this truly remarkable process, and the public evidences the keenest and most serious interest. The thing could not be more absurd than if a physician announced that he had discovered that he could make new legs grow where those members had been amputated, by rubbing a decoction of hen's teeth on the parts affected. I hardly believe either the press or the public would take this latter announcement seriously, and any editor would consider it too foolish to be printed. And yet how often have we been regaled at the breakfast table with glaring headlines announcing with all seriousness that Dr. So-and-So, a celebrated chemist (whom none of us had ever heard of before), had just discovered the *secret* of the German dyes.”

The war, as well as the enormous domestic growth in automobile traffic, with the inevitable rise in the price of motor fuel, has naturally stimulated the study by American chemists and

engineers of the whole motor fuel question. There are a number of different lines along which this problem can be attacked. Benzine, or benzol, one of the many by-products of coal-tar distillation already referred to, may some day be cheap enough in this country to use as a motor fuel, either alone or mixed with gasoline. Again, engines can be designed to burn denatured or industrial alcohol, and chemistry has already devised practical methods for making so-called grain or ethyl alcohol out of sawdust and other woody waste material. This presents an interesting possibility from the conservation standpoint, because when we use up petroleum or coal we have consumed just that much of a natural resource that will never come back to us again. But alcohol can be made from crops that are planted and thus renewed from year to year. Since alcohol can also be made from any starchy plant, it would not be impossible to contemplate at some future time growing our motor fuel each year, just as we now grow potatoes and corn. Moreover, in the making of alcohol, bacteria and other microscopic organisms are put to work in the service of man, a fascinating source of energy that will probably be exploited by our posterity to a much greater degree than it has up to the present time.

Whatever may be the final solution of the motor fuel question, it seems quite certain that for some time to come the natural petroleum deposits of the earth will continue to furnish the bulk of our liquid fuels. In addition to the large petroleum resources of North America, South American sources have not yet been fully explored, while the extraordinary petroleum wells in the Mexican field promise a practically inexhaustible supply of raw material.

The Mexican oil fields, however, though developed and owned by American capital, are left open and unpoliced by our government, ready to be grabbed by any foreign government or even any group of bandits strong enough to take possession. Such possession would constitute a very considerable balance of power in world affairs to-day, and the recapture would call for an untold expenditure of blood and treasure, perhaps to no purpose, as a retreating enemy can destroy oil wells, tanks, and pipe lines so that years must pass before they can again become available. This danger has been emphasized by the terrible destruction in the oil fields of Roumania and Galicia.

It is a fact not generally known that a great many of the

large petroleum deposits of the world contain little or no light-boiling constituents which we call gasoline or naphtha and which are known in Europe as petrol. The petroleum of the mid-continental field of the United States yield from eight to twelve or even fifteen per cent. of natural gasoline, but some of the California, Texas, and all of the Mexican petroleum contain very little of the lighter boiling fractions suitable for motor fuels. Now, to use an analogy, if we have large, heavy pieces of stone or other solid materials which we wish to make more conformable for certain purposes, we usually crack up the large pieces into smaller ones and then screen the pieces into lots of more or less approximately even size, and sometimes we wash the resulting materials to remove adherent dust and impurities. Now, this is precisely analogous to what chemistry is doing to heavy hydrocarbon molecules, of which natural petroleum, as it exudes from below the earth's surface, is constituted. By a process known as fractional distillation under pressure the heavy molecules vaporized and put into rapid movement by the heat might almost be said to crack themselves into pieces by violently colliding with each other and with the walls of the containing vessel. This is the process actually known as "cracking," by which the percentage of gasoline is artificially increased so that we obtain a greater yield than Nature had originally provided in the crude oil. But just as in our analogy the screens separated the cracked stone into various sizes, the distillation separates the oil into fractions, the dust of which appears as a permanent gas which cannot be liquefied and shipped, but must be locally burned as fuel or piped away. The next lot of fine screenings, say of sand-grain dimensions, might represent the ethereal liquids known as naphthas, petroleum ethers, or rigolines. Next come the analogues of the fine-grained gravel sizes used for gasoline motor fuels, next the coarser gravel size representing the kerosenes, then the still larger sortings corresponding to the lubricating oils, and finally the larger lumps—the axle greases, asphaltic pitches, and solid paraffins.

The fuel oils on which the navies of the world are rapidly coming to depend may be considered as a mixture of all these fractions after the lightest or finest have been removed and the heaviest and coarsest left behind.

Now, no analogy is perfect, and the one used above must not

be pushed too far, but it serves a very good purpose in making clear to the general reader the answer to a number of questions which are constantly being asked.

If the supply of crude oil is so abundant and if the cracking process is efficient, why should not the supply of gasoline keep pace with the increased demand, however great that may become? Just as it is impossible to crack a stone boulder into pieces all of one desired size, it is impossible to carry on the cracking of petroleum except within certain prescribed limits. Moreover, a process which would crack up one kind of stone efficiently would fail entirely with another. Thus an oil-cracking process which might increase the yield of gasoline from eight to twenty-five per cent. on a mid-continental oil might not work at all on a Mexican or some other type of oil.

Why is it that some of the gasolines offered for sale to-day are degraded and will not start our engines in cold weather as well as used to be the case in earlier days? Simply for the reason that, as the demand grows more rapidly than the supply, the tendency is, following our analogy, to slightly increase the size of the holes in one of the screens so as to let more of the kerosene sizes mix in with the gasoline. If we want all fine screenings, we must so specify and pay the price, but gasoline is not manufactured to specification, and, so far as the public is concerned, it has nothing to say about the size of the holes in the screens.

In reality, of course, the distillation of oils has nothing to do with screens, but depends upon the temperatures at which the cuts on the different fractions are made. It is now clear, from what has been said, that when the chemist is through with the problem he turns it over to the engineer. If the engineer can design an engine that will start and operate as efficiently with a degraded gasoline, so much the better for all concerned. The producer will be helped out of many a trouble, and the consumer will get a cheaper fuel. But the chemist is not yet through with his end of the problem; he is beginning to find out that if he cannot simply crack up certain kinds of oils to make satisfactory motor fuel, he can first crack them up to the finest fragments and then put the fragments together again into new aggregated pieces or molecules which serve his purpose.

Since we have been dealing in analogies, let us suppose that a dairyman had been separating ten or twelve per cent. of cream

from his milk and making it into butter, getting whatever he could for the skimmed milk that was left. Then suppose that a chemist came forward and proposed to treat the skimmed milk in some manner so that another ten per cent. of cream could be separated, and the second crop of skimmed milk treated again to make a third lot of cream, after which two treatments the skimmed milk still remaining was at least as good for every purpose it could possibly be used for as it was at first. It is just this sort of thing the chemist is now at work on for the motor-fuel industry, viz. : to take the oil distillates, after all the gasoline has been removed, and treat them so that another crop of gasoline can be taken off, this treatment to be repeated as often as it pays to do so, the residue being still available as a fuel oil. At best such reprocessing could not go on indefinitely, for at each treatment of the oil distillates some free carbon or coke is split off from the molecules, and is a waste, so that such a method is by no means capable of getting something for nothing, although it has very practical possibilities. The daily press has from time to time got hold of a few details of the investigations of some of the workers in this field, and has reverberated with exaggerations of the wonders that have been accomplished.

It is one thing, however, to work on a problem of this kind on the laboratory scale of operation, and quite another to adapt a new process to the big commercial scale of operation, as those of us who have had experience along these lines can most keenly realize. In working out such difficulties, the chemist and the engineer must join hands or, better, must exist in one and the same person, a member of that most modern of all professions, chemical engineering. Very often metallurgy must be called upon to develop new alloy steels especially made to exhibit great strength at comparatively high temperatures, while quite new types of machinery must be designed and tried out in service. Sometimes mistakes will be made and discouraging setbacks will occur, but, however great the obstacles and discouragements, the work goes on, for it is mainly by his mistakes that man learns to accomplish results in a few minutes or hours that Nature has taken her time over for untold ages. How long it takes Mother Earth to make a ruby or an emerald we do not know any more than we know how long it took her to make gasoline. Given the raw materials, we can make all these and many other things in a few hours, but

chemists working in these fields have labored patiently and lain awake very many discouraged nights before success was achieved, and then nine times out of ten, yes ninety-nine times out of a hundred, the credit is given to some well-advertised worker who merely began from some vantage-ground that somebody else had painfully climbed to.

Although not the result strictly of American chemical research, I would like to include in this paper some account of the wonderful work of chemistry in making synthetically from well-known raw materials useful substances that have heretofore been extracted from the sap of trees and plants indigenous to tropical or semi-tropical parts of the world. Among such substances we may particularly mention indigo, camphor, and rubber. Man-made indigo is already an article of commerce, while the manufacture of the other two has already been accomplished. Dr. Duisberg, a German scientist, was already able to say in 1912:

“The end in view is this: that artificial rubber may soon play as important a rôle in the markets of the world as does natural rubber. The consumption of rubber is simply enormous. Finished articles to the value of three milliard marks are manufactured every year, and the raw material from which they are made, calculated at the present market price of 12 marks per kilo, costs one milliard marks. Other tasks which the chemist has on hand shrink into insignificance compared with this gigantic problem. The laurel wreath will not adorn the brow of the wild dreamer, but that of the scientist who, cool and persevering, pursues his way. The seed he sows ripens slowly, and though, according to the statements in the press, all this is mere child's play and the problem has been solved, I leave it to your judgment whether this is true or not, like much that printer's ink patiently transfers to paper. I am right in the midst of this excitement. I have employed articles made of synthetic rubber, and for some time I have used automobile tires made of this material. Yet, if you ask me to answer you honestly and truly when synthetic rubber will bring the millions which prophets see in its exploitation, I must reply that I do not know. Surely not

in the immediate future, although synthetic rubber will certainly appear on the market in a very short time. But I hope to live long enough to see Art triumph also here over Nature."

The subject of chemistry and American industry covers too wide a field to be treated more than sketchily in a single paper. I have no space to refer to many interesting chemical developments in the field of metallurgy, of textile manufacture, of food-stuffs and medicinals, and last, but not least, of photography and the moving-picture film, destined to have so profound an influence on the education of the people. If what I have here written will stimulate the slightest interest in an appreciation of the usefulness and place of chemistry in our national development, my time will have been well spent.

I have endeavored to point out a few of a great many needs on the chemical side of industrial development in America. I have also ventured to point out what seems to me to be a national shortcoming, in the lack of interest and prevision exhibited both by our people and our government in regard to certain important factors of industry. Whatever has been stated is said in no spirit of carping criticism, but with the purely patriotic hope that a new leaf may be turned in the study of reasonable preparedness, whether in peace or war.

If we can have a Federal Reserve for money, why not a Federal Reserve for the necessities of our people that we do not adequately produce within our own boundaries?

A former president of the American Chemical Society, Mr. A. D. Little, once used words to this effect:

"We have in this country the capital, the enterprise and the chemistry for great industrial achievements. That we cannot thus far point to them is due to the fact that with us chemistry is too often left like Cinderella sitting beside the ashes of the laboratory furnace, while her two haughty sisters drive away to the industrial ball."

The Fairy Godmother in this case must be an awakened and intelligent public opinion which will be reflected in government, to the end that chemistry, capital, and enterprise shall be treated with equal appreciation and a fair and just generosity.