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THE FUNCTION OF CHEMISTRY IN THE CONSERVATION OF OUR NATURAL RESOURCES.[1]

BY MARSTON TAYLOR BOGERT.

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Fellow Members, Ladies and Gentlemen:

At the first conference on Conservation of our Natural Resources, held at the White House, May 13–15, 1908, a most admirable Declaration of Principles was unanimously adopted by the assembled governors, part of which runs thus: "We, the governors of the states and territories of the United States of America, in conference assembled, do hereby declare the conviction that the great prosperity of our country rests upon the abundant resources of the land chosen by our forefathers for their home, and where they laid the foundation of this great nation........ We agree......that the great natural resources supply the material basis upon which our civilization must continue to depend, and upon which the perpetuity of the nation itself rests.... We declare our firm conviction that the conservation of these natural resources is a subject of transcendent importance which should engage unremittingly the attention of the nation, the states, and the people, in earnest co-operation."

The appeal to us is not alone because we happen to be experts in an important branch of science, but because we are more than this—we are patriotic Americans who are deeply interested in everything that concerns the welfare of our country, and such an appeal to the ten thousand chemists of the United States will not be in vain. The dignity and honor accorded a profession depend largely and properly upon the extent to

[1] Presidential address delivered at the Baltimore Meeting of the American Chemical Society, December 30, 1908.

which it ministers to the needs of the community. President Roosevelt has well said, "The life of the nation depends absolutely on the material resources which have already made the nation great."

In considering the matter, the first thing needed is a clear understanding of the nature of the problem so that the chemist can see for himself where he can be of service. I shall, consequently, endeavor to state the case as fully as my time will allow, pointing out incidentally where chemistry is likely to be or has already been helpful. I have no apology to offer if much of the material presented appears to touch chemistry but remotely or not at all. The important thing is that the issues, in their larger aspects at least, should be before us all, for the subject is greater than any one science.

It would be strange indeed if the science which deals with the ultimate constituents of our material universe, their combinations and transformations, could not offer any assistance in the solution of the problem as to how our natural resources may be conserved. It is chemistry that has determined the composition of those materials which make up the earth upon which we live, the atmosphere which surrounds it, and the heavenly bodies beyond. Chemistry studies the properties of the elements and their various compounds and upon these fundamental data our industries rest.

The transformation of the raw material into the finished product consists usually either in changing its external form, as in wood and metal working, weaving, and the like, or there is involved a chemical change, as in metallurgy, fermentation industries, the manufacture of glass, soap, cement, chemicals, etc. Practically all of our manufacturing processes are therefore primarily either mechanical or chemical. In the production of a metal from its ores, or of indigo from coal tar, it is chemistry that points the way, and the more complex the problem the greater the dependence upon this science. In devising new processes and in the discovery of new and useful products, chemistry is again the pathfinder. The community is apt to overlook the extent and diversity of the services rendered by the chemist because of the quiet and unobtrusive way in which the work is carried out.

The measure of a country's appreciation of the value of chemistry in its material development and the extent to which it utilizes this science in its industries, generally measure quite accurately the industrial progress and prosperity of that country. In no other country in the world has the value of chemistry to industry been so thoroughly understood and appreciated as in Germany, and in no other country of similar size and natural endowment have such remarkable advances in industrial development been recorded, and this, too, with steadily increasing economy in the utilization of the natural resources.

That our government realizes the importance of chemistry seems evident from the fact that six of our nine Federal Departments already maintain chemical laboratories where they handle both their own chemical work and that of the Departments of State, Justice, and Post-office, which as yet have no chemical laboratories.

The question confronting us at the outset is: What are the material resources upon which the existence of the human race and its advancement in civilization depend? Suppose we divide them into Extraterrestrial and Terrestrial.

In the former would fall the most important resource of all—the sun, our great reservoir of light and heat. According to Dr. Pritchett, the sun on a clear day, well above the horizon, delivers upon every square acre of earth exposed to its rays, the equivalent of 7,500 horse-power working continuously. And yet but little of this enormous energy is ever harnessed commercially. The day of the solar engine has not yet come, and, as in the case of our other natural resources, instead of using our income, we are making heavy drafts upon our capital—the solar energy of by-gone ages stored up for us in coal.

The possibilities in utilizing the sun's heat were indicated by the Portuguese priest's heliophore at the St. Louis Exposition, in which, by concentration of solar heat, a temperature of over 3,000° C. was obtained—a temperature at which a cannon ball would evaporate almost like a snowball on a red-hot stove.

We have, to be sure, made use of the sun's light in photography, but we have not yet satisfactorily solved the problem of color photography, while the all-important photo-syntheses accomplished in plants are still but very imperfectly understood. In fact, it is but just beginning to dawn upon us that in the varied and profound chemical and physiological changes brought about through the agency of sunlight, there lies a field for research almost unexplored.

Our terrestrial resources can be conveniently discussed under the headings: I. Atmosphere II. Water. III. Land.

I. Atmosphere.

In the words of Professor Chamberlin: "By a profound regulative system of adjustments and compensations, not only the general temperature of the earth, but the composition of its enveloping atmosphere, are kept relatively constant and within the narrow limits necessary for the existence of animal and vegetable life." Any extensive local pollution of the atmosphere cannot but result disastrously to both vegetable and animal life. The prevention of such pollution is therefore a measure of conservation—conservation of the health and working efficiency of the human being, of other animal life, and of the surrounding vegetation—and one which can often be accomplished to the financial benefit of the offender. The Bureau of Chemistry of the Department of Agriculture has been for some time investigating the effect of smelter fumes and other trade wastes upon agriculture and forestry.

One of the most frequent pollutants of the atmosphere, particularly in smelting regions, is SO_2. In presence of much humidity, 0.003 per cent. SO_2 in the air is injurious to trees and plants. When oxidized to SO_3 and carried down by rain as sulphuric acid, it materially hastens rock disintegration and soil erosion. There is little excuse for this waste of SO_2, with consequent poisoning of the surrounding air, for, by the older chamber process or the more modern contact process, it can be readily converted into sulphuric acid, that foundation-stone of so many chemical industries. In the manufacture of synthetic indigo, for example, over 50,000 tons of SO_2 which formerly went to waste are now annually reoxidized to SO_3 by the contact process.

At Ducktown, Tennessee, the fumes of SO_2 from the roasting and smelting of the copper ores, together with flue dust, have killed all vegetation for miles around, and the land thus denuded has eroded with startling rapidity. The Secretary of Agriculture cites it as "a striking illustration of the completeness of destruction that may result from erosion in this region when the protecting forest cover is once removed." I am happy to state that the operating company has recently installed a sulphuric acid plant to utilize this SO_2. A similar destruction of surrounding vegetation is now going on in the mining regions of Montana.

In the Rio Tinto mining district of Spain, the lower grade pyrite, in order to partially sulphatize and render the copper soluble, was for years roasted in heaps, with the usual destruction of all neighboring vegetation. It has since been discovered that by keeping moist the heaps of crude ore fines, a slow oxidation and lixiviation of the copper occurs, leaving a pyrite slightly richer in sulphur than before. In the Rio Tinto Company's yards are about 20,000,000 tons of badly roasted pyrite which should have yielded 7,000,000 tons of sulphur of a total market value of $70,000,000. The new process means a saving to the world of about 1,000,000 tons of sulphur annually.

The power latent in the movement of winds is utilized in propelling our sailing vessels and windmills, but the amount thus consumed is but a very small fraction of that available.

II. Water.

Rainfall.—Second only to the sun in importance as a great natural resource is the rainfall, for without an adequate water supply neither vegetable nor animal life can exist. In addition to supporting life, the rain also assists in soil formation by rock disintegration, tempers the climate, and supplies power and navigable streams. The average annual rainfall of 30 inches upon the mainland of the United States is equivalent to

200 trillion cubic feet, or an amount equal to about ten Mississippis. Over half of this enormous total is evaporated and tempers the air, one-sixth is absorbed on the earth's surface, and the remaining third flows off to the ocean. Of the seventy trillion cubic feet annually flowing into the sea, less than one per cent. is utilized for municipal or domestic supply, less than two per cent. for irrigation, perhaps five per cent. for navigation, and less than five per cent. for power. It is estimated that from eighty-five to ninety-five per cent. is wasted in freshets or destructive floods.

Unless properly controlled, therefore, that which is one of our greatest blessings may prove quite the contrary. This control consists in collecting and storing the water during heavy rains, releasing it later as it may be needed. There are two kinds of reservoirs for this purpose, natural and artificial. By the former, I mean the forests, which, like huge sponges soak up the rain and give it out again gradually; by the latter, the dams erected in the hills at the headwaters of our streams.

The damage caused by heavy rains upon land unprotected by forests or storage reservoirs is enormous, including as it does the loss of human lives, destruction of houses and similar property, the washing away of some of the most valuable portions of the soil, the covering of fertile fields with sand and débris, the clogging and rendering unnavigable of our streams and harbors, necessitating expensive dredging operations, the covering of the spawning grounds of fish with silt, and the loss of enormous water power, the saving of which would also mean the conserving of a considerable amount of our fast disappearing fuel supply. The direct yearly damage from floods has risen from $45,000,000 in 1900 to over $238,000,000, while the indirect loss from depreciation of lands and interference with navigation and business is probably far greater. As the water runs off bare and denuded land almost as rapidly as it would from a roof, drought, with all that it entails, quickly follows the cessation of the rains.

The future of all other terrestrial natural resources depends upon the proper conservation and utilization of the rainfall. It is the one vital, underlying problem upon which all others rest, and the chief methods of conserving our water supply—forests and reservoirs—are therefore matters of paramount importance. Forests cannot be grown without water, and the chief factor in the soil problem is also that of water supply. On the other hand, water is of but little service for power purposes or navigation unless the supply is relatively constant and the flow regular, and it is chiefly upon the development of water power that the conservation of our fuel depends.

Purity.—The quality, as well as the quantity, of our water supply is of grave concern. The purity of our drinking water is of vital interest to all of us, and it is to the chemist and bacteriologist that we must appeal for assurances on this point. The character of the water used is also of very great moment in many industries.

The chief industrial use of water is for the production of steam, but if the water employed is rich in mineral salts the formation of scale will proceed rapidly. Hence, even in such a fundamental engineering operation as steam-power generation the engineer must first consult the chemist as to the quality of the fuel and water to be used. In the United States the average thickness of locomotive boiler scale is 1/16th of an inch. This means a loss of at least 13 per cent. in fuel efficiency: for an eighth inch scale this mounts to 25 per cent., and for a half-inch scale to 60 per cent. Taking 1/16th inch then, as the average boiler scale, this means for our 51,000 locomotives alone, a total annual loss which may be estimated conservatively at 15,000,000 tons of coal. The use of pure water in the boilers reduces the coal consumption and, by decreasing the amount of repairs and prolonging the life of the boiler, reduces also the demand for iron.

In those operations where pure water is indispensable, the cost of impure water is the cost of purification, and it is to the chemist that the manufacturer must generally turn for instruction as to how this purification may best be accomplished. For some uses, as for boiler supply and paper making, the percentage of mineral matter is of moment, whereas in such industries as brewing, distilling, and ice manufacture, freedom from various micro-organisms must also be taken into account. Impure water means additional cost of production also to bleacheries, dye works, canning and pickle factories, creameries, abattoirs and packing-houses, nitroglycerin factories, woolen and straw-board mills, tanneries, chemical works, and factories for the manufacture of starch, sugar, glue and soap.

A serious problem arising in this connection is the steadily increasing pollution of our streams and tidewaters by sewage, factory waste, and refuse of all kinds. Practically all of our city and town sewage is disposed of in this way, together, often, with such other refuse as ashes, cinders, garbage, and trash of every variety. In drainage and sewage there is considerable loss of valuable fertilizing materials, the annual loss in phosphorus alone being estimated as equivalent to 1,200,000 tons of phosphate rock. Few people have any idea of the vast amount of solid waste regularly removed and disposed of in our great cities. In New York, excluding sewage, snow, street sweepings and dead animals, the solid refuse (ashes, garbage and rubbish) amounts to over 3,000,000 tons annually, or about 1450 lbs. for every man, woman and child in that city. This huge amount if piled together would occupy over 8,000,000 cubic yards. The removal of that volume of material between here

(Baltimore) and New York would build a canal connecting the two cities 27 feet wide and 10 feet deep. Yet that volume of solid refuse is handled every year by the New York Street Cleaning Department in addition to the items excluded above.

Sawmills, pulp mills, wood distilling plants, tanneries, starch factories, cheese factories, sugar refineries, gas works, chemical works, glass works, dye works, oil refineries, distilleries and breweries, smelters, mining plants, and many other industries pollute the streams with their wastes until the once crystal-clear brook becomes a mixture of water, particles of wood, earth, dust, cinders, fat, oil, soap, coal, wool, hair, refuse of all kinds and different chemical ingredients and colors—a blue-black, sluggish fluid. The waste from sulphite pulp alone in the United States is estimated at over 1,000,000 tons per year, practically all of which finds its way into the streams, although it contains substances related to the sugars and the tannins which might no doubt be recovered with advantage.

Here is a most promising field for the chemist and one in which he has already accomplished much. The manufacturer turns his waste into the stream for the same reason that the smelter allows his furnace gases to escape into the air—because he thinks that it is the cheapest thing to do. If the chemist can show him how he can make more money by saving these by-products and using them, either for the production of heat and power, or for the preparation of valuable commercial substances, he will no longer dump them into the streams.

The Water Supply Branch of the U. S. Geological Survey analyzes river waters to ascertain their potability, their suitableness for manufacturing operations and irrigation, or in relation to soil erosion. Recently, in co-operation with the Rhode Island State Board of Health, it has been making an investigation of various factory wastes now polluting the streams, and it has been found not only that all those so far studied can be satisfactorily purified at a reasonable expense, but also that in many cases it can be accomplished with substantial profit.

The poisoning of our streams and coastal waters also affects that portion of our food supply derived from these sources by either killing off all fish and molluscs or rendering them unfit for food. Inland streams alone provide $21,000,000 worth of fish annually. Brooks in the coal-mining regions once well stocked with fish have become blackened mine drains in which life of any kind is impossible. Although we are annually planting probably six billion fry in our inland and coastal waters, an amount greater than all the rest of the world put together, those best qualified to judge state that the maintenance of fish life in this country is fast becoming impossible. Hence, if the chemist can bring about a cessation of this pollution, he will be assisting directly in preventing the loss of this food supply, to say nothing of the debt of gratitude which all disciples of Izaak Walton will owe him.

It should not be forgotten that fish supply us also with oil and fertilizing material, as well as substitutes for isinglass, gelatin, and glue.

Although approximately two-thirds of the surface of our globe is covered by water, less than 5 per cent. of our food supply is drawn from the sea. As it seems not unlikely that by 1950 the population of the United States will be at least two hundred millions, the possibility of the sea's contributing more largely to our support is worth considering. Professor Bonnycastle Dale predicts that seaweed will some day be largely used for human food. Seaweeds have, to be sure, been used as food for ages, and in certain parts of the Orient constitute staple articles of diet, but the actual amount so used is at present relatively small. It has been calculated that enough proteids are lost annually in the decay of seaweeds on the sea beaches of the United States to take the place of the total product of our Northwestern wheat fields. In the great Sargasso Sea sufficient nutritious vegetation flourishes and decays to support the entire population of Europe if harvested and prepared in a form suitable for human consumption.

Water-power.—Water constitutes one of our most important sources of power. In the motion of the waves, the rise and fall of tides, and in running streams, vast power is available. The power latent in wave motion and tides is essentially unused at present. The problem is for the engineer.

The United States has now thirty-seven million horse-power available in its streams at a cost comparable to that of steam installation, an amount exceeding the total horse power at present utilized for all forms of production and transportation throughout the country. To develop thirty-seven million horse power in the ordinary steam engineering plant over eight hundred million tons of coal would be necessary. The theoretical power of all our streams is over two hundred and thirty million horse-power, of which probably one hundred and fifty million could be made available at reasonable cost. If we figure water-power as worth $20.00 per horse-power per annum, one hundred and fifty million horse-power would mean a yearly income of $3,000,000,000.

Of the water-power now available, only about five and a quarter million horse-power is in use and even this is perhaps not used in such a way as to give its maximum efficiency. Every year one million six hundred thousand horse-power wastes over Government dams.

Thirty per cent. of all the horse-power now used is used electrically. At the present rate, it will equal or exceed power mechanically applied by the year 1920. As has been said before, we are entering the Age of Electricity, which means the Age of Water-power and the Age of Electrochemistry. The electrification of our railroads will result in the disappearance of one of the most frequent sources of forest fires—hot cinders from locomotive stacks. As the chief use of coal is for the generation of power, the more water-power used the less the drain upon our coal resources.

Navigation and Transportation.—In the United States there are 282 rivers navigated for an aggregate of 26,115 miles, and this amount could readily be doubled by improvement. Our domestic commerce equals in value the foreign trade of all nations combined, and yet we apparently fail to realize the importance of our inland water-ways to this commerce, for instead of developing them we have the spectacle of their ever-increasing disuse. This has been ascribed to railroad competition, involving reduction of rates when competing with water routes and control of river lines and of terminals, to inadequate river improvement and to the fluctuation and silting up of streams formerly navigable. A little over a year ago the railroads of the country were complaining that it was impossible to handle the amount of freight awaiting shipment, and Mr. James J. Hill was quoted as saying that an immediate expenditure of at least $5,000,000,000 would be necessary to equip the railroads so that they could properly handle the freight presented. And yet the expenditure of one-tenth this sum, or half a billion dollars, would suffice to rehabilitate our inland waterways.

Water transportation generally costs only about one-quarter that of rail transportation. As our railways' freightage in 1906 reached 217,000,000,000 ton-miles, at an average cost of 77 cents, the shipping of even one-fifth of it by water would have saved the producer and consumer over $250,000,000. The consumption of coal, iron and wood per freight-mile is also much less. Dr. McGee states that but one-tenth as much iron and one-eighth as much coal is needed as for rail transportation. The stimulating effect upon production and commerce of cheap transportation is obvious, while the existence of independent and competing water routes might react favorably upon railroad rates.

Irrigation.—The reclamation of our desert lands by irrigation proceeds apace. Up to date about eight million acres have thus been made available, and the lands thus recovered are among the most productive in our country. Yet in the western half of the United States there is said still to be sufficient fertile land now barren from lack of water to support probably 50,000,000 people who might, in turn, raise enough to support another 50,000,000 in the East. The Reclamation Service believe that in the next twenty-five years it will be possible to develop water supplies sufficient to irrigate twelve million acres more, thus providing farms for about two million people.

The use of water for irrigation does not necessarily interfere with its use for other purposes also. It may, for example, represent the impounding of heavy rainfalls or melting snows which would otherwise have rushed down the valleys in devastating floods, but which may now serve as a domestic or municipal water supply, or be gradually liberated for the creation of valuable water-power on its way to irrigate lands at a lower level, finally escaping into streams which may thereby be rendered navigable.

Chemistry's services in this field include the furnishing of the necessary explosives for rock blasting, cement and concrete for the dams, the analysis of the water, and the determination of the kind of fertilizers needed on land thus reclaimed. The Bureau of Soils of the Department of Agriculture has been investigating the availability of mine runnings and various waste waters for irrigation.

III. Land.

Amount Available.—Of the three million square miles of mainland of the United States, a little over 1/5 is under cultivation, less than 2/5 is wooded, and 2/5, or an area greater than that of the ancient Roman Empire, is arid or semi-arid. Four hundred million acres of this lie west of the Mississippi River. In 1906 our remaining stock of unoccupied arable land consisted of fifty million acres surveyed and thirty-six and a half million acres unsurveyed, and of this total twenty-one million acres were disposed of in 1907.

The chief means at our disposal for adding to our productive land are by irrigation of regions where the rainfall is insufficient and by drainage of swamps and overflowed lands. In the arid and semi-arid regions only certain areas may be rendered productive by irrigation, while vast tracts, aside from mineral resources, are valuable only for grazing.

Swamps, until recently, covered seventy-seven million acres of our country, or an area equal to all New England, New York and New Jersey combined. Twelve million acres of this have already been drained and are now used for agricultural purposes, and it is estimated that twenty million acres more may be reclaimed—an amount sufficient to support perhaps ten million people. It might be recalled that drainage of the swamps means also the obliteration of the breeding places of disease-carrying mosquitoes.

The engineer may recover arid land by irrigation and swamps by drainage, but the yield from such reclaimed land will depend primarily upon the manner in which it is tilled, and the foundation of modern scientific agriculture is chemistry. But the chemist can do some land reclaiming on his own account. Whenever he shows how agricultural products can be obtained more cheaply in other ways, from industrial wastes, for example, the land devoted to these particular crops is released for the cultivation of other crops. By the discovery of commercially profitable methods of manufacturing alizarin and indigo from coal tar, hundreds of thousands of acres have been set free for other crops. The amount of synthetic indigo now prepared from coal tar is equivalent to considerably over a quarter of a million acres of indigo plants.

Soil.—The action of water and air in producing soil from rock is partly physical, partly chemical. Certain of the rock constituents are made soluble and become plant food or plant poison, while others remain practically insoluble and are reduced to a finely divided state and then constitute the earthy portion of the soil. Hence the salinity of the soil will depend upon the rainfall. If insufficient water passes through the soil, plants will suffer from saline excess; if too much, from saline deficiency. The mean rate of soil formation has been calculated as probably not over one foot in ten thousand years, so that the waste should not exceed one inch in a thousand years, and yet we are informed by the Secretary of the Inland Waterways Commission that over a billion tons of our richest soil, valued at not less than a billion dollars, is annually washed away to clog our rivers and harbors. That amount represents about half a ton per acre, or if placed in one pile, would make a block a mile square and a thousand feet high. It seems certain that the amount of soil carried into the sea by winds is very much greater than this. Dust from the Sahara Desert is occasionally carried as far north as the Baltic Sea. As Professor Chamberlin so aptly puts it: "When our soils are gone, we too must go unless some way is found to feed on raw rock or its equivalent."

Soil fertility is affected not alone by erosion and soil-wash, but also by bad agricultural methods (single cropping and no fertilization), and by the general conditions of rural life. Soil erosion may be prevented by proper reservoirs or forests, by a cover of mulch or humus, by deep cultivation, or by terracing and contour cultivation. Bad agricultural methods are being gradually improved through the labors of the Department of Agriculture; and its Bureau of Soils, in addition to the routine examination of soils, fertilizers, irrigation and drainage waters, has been occupied in applying methods of physical and organic chemistry to soil problems, and in making a special study of the solubility of the various constituents of the soil, the physical-chemical character of the resulting solutions, their absorption and toxicity, the iron constituents of the soil, and the humus. It should not be assumed that the addition of fertilizers is all that is needed to give large crops. There is no more important problem than that of the character and function of the organic constituents of the soil. The popular term "humus" is but the title of a whole volume of organic chemistry but few pages of which have as yet been accurately translated. The chief differences in soils are not in their mineral, but in their organic constituents.

Agriculture—Agriculture still remains the world's most important industry. Nearly thirty-six per cent. of our people are directly engaged in it and all the rest depend upon it. As Mr. James J. Hill well says: "In the last analysis, commerce, manufacturers, our home market, every form of activity runs back to the bounty of the earth by which every worker, skilled and unskilled, must be fed and by which his wages are ultimately paid." The value of our farm products last year (1907) was about eight billion dollars. We supply one-third of the corn, one-fifth of the wheat, and two-thirds of the cotton consumed by the whole world. Our farms furnish fifty-eight per cent. of our total exports ($919,000,000 out of a grand total of $1,578,000,000), manufactures furnishing 33 per cent., the forests 4.6 per cent., and our mines 2.8 per cent., and 42 per cent. of all the material used in our manufactures comes from the soil. Yet only half our farm land is improved and even this portion yields but a fraction of what it should, and this fraction would be still smaller were it not for the labors of our Department of Agriculture and of its 61 experiment stations (the majority of whose directors, by the way, are chemists) distributed throughout the length and breadth of our land.

We are too prone to gloat over the enormous totals of our crops instead of considering the much more significant item of yield per acre. Were we to examine the latter we should find small cause for pride. On soils originally of high fertility we raise from 12 1/5 to 15 bushels of wheat per acre, while England, Belgium, Holland, and Denmark have averaged over 30 bushels per acre for the last five years. To quote again from Mr. James J. Hill: "In no other important country in the world, except Russia, is the industry that must be the foundation of every state at so low an ebb as in our own. According to the last census, the average annual production per acre of the farms of the whole United States was worth $11.38, an amount that is little more than a respectable rental in communities where the soil is properly cared for and made to give a reasonable return for cultivation." That this is not due to any general loss in the fertility of our soils seems borne out by the fact that our yield per acre for most crops is greater than it has been, rather than less. It is more probably referable to the high price of farm labor in comparison with the price of land. With the exception of our intensively farmed fruit and truck lands, known methods of soil and farm management could double the net profit per acre within five years.

Losses to live stock, grain, etc., by injurious mammals (wolves, rats and mice) exceed one hundred million dollars annually, while insect damage to crops, orchards, grain in storage, etc., is not less than six hundred and fifty million dollars annually. Most of these losses are preventable.

What, then, is the relation of chemistry to this important industry? Liebig, in the preface to his "Chemistry in Its Applications to Agriculture and Physiology" (1840), says: "Perfect agriculture is the true foundation of all trades and industries. It is the foundation of the riches of states. But a rational system of agriculture cannot be formed without the application of scientific principles, for such a system must be based on an exact acquaintance with the means of nutrition of vegetables, and with the influence of soils and actions of manure upon them. This knowledge we must seek from chemistry, which teaches the mode of investigating the composition and of studying the character of the different substances from which plants derive their nourishment."

The chemist's services have included the fixation of atmospheric nitrogen, the elucidation of some of the ways in which atmospheric nitrogen enters into organic combination and of the methods whereby organic nitrogen is prepared for plant food, the analysis of soils and the determination of their relation to plant growth, the analysis of plants and agricultural products and a study of the influence of environment upon their composition, the manufacture of fertilizers and their adaptation to the needs of special soils or crops, the protection of the farmer, by analytical control, from fraud in purchasing the same, methods of utilizing plant food and of conserving it for future use, the establishing of the general principles of plant growth and the chemical changes involved, the replacing of natural dyes and drugs by synthetic articles, the preparation of artificial silk, the mercerization of cotton, the saving of many crops from threatened annihilation by providing effective insecticides and fungicides, the production of valuable substances from former wastes (cottonseed oil, corn oil, gluten from starch factories, cream of tartar from wine lees, etc.) and of industrial alcohol from crop refuse. In the words of Dr. Wiley: "The application of the principles of chemical technology to the elaboration of raw agricultural products has added a new value to the fruits of the farm, opened up new avenues of prosperity, and developed new staple crops."

More than this, the Bureau of Chemistry of the Department of Agriculture, through its chief, Dr. Wiley, was largely instrumental in securing the introduction and enactment of our Pure Food and Drug Laws, and it is the chemist who protects the consumer from adulteration and fraud in his food and drink.

The three substances essential to all plant growth, in addition to water are nitrogen, potash and phosphoric acid. The total value of these substances in our annual crops is estimated at over three billion dollars, to assist in replacing which we manufacture over three million tons of fertilizer per annum. The phosphoric acid needed is obtained from mineral phosphates and phosphatic slags; the potash from the great deposits at Stassfurt, from feldspar, and other sources; the nitrogen, from ammonium salts, animal wastes, Chili saltpetre, and the air. The supply of Peruvian guano, a former source of nitrogen, is already exhausted, and the production of Chili saltpeter is now slightly over two million tons per annum. How long the Chilean deposits can stand the drain is a matter of uncertainty. The fixation of atmospheric nitrogen is therefore one of our most important agricultural problems, and as there are about 34,000 tons of nitrogen over every acre of ground, a commercial process for obtaining nitrogen from this source will forever remove the danger of a nitrogen famine. Much has already been accomplished in this direction, and the basic calcium nitrate and cyanamide processes appear very promising. Uneasiness over the adequacy of our supply of plant food has lately been transferred from nitrogen to phosphoric acid, as our Government experts have reported that the present known supplies of high-grade phosphate rock are likely to be exhausted by the middle of the century.

Among our important agricultural chemical industries are fertilizer manufacturing, wine-making, brewing, distilling, sugar production, cottonseed oil and its products, starch and glucose. In 1907 our brewing and distilling establishments consumed thirty million dollars' worth of barley, fifteen million dollars' worth of corn, and four million dollars' worth of rye, or forty-nine million dollars' worth of grain in all. The beet sugar industry is due to a German chemist, Marggraf by name. By scientific agriculture the sugar content of the beet has been raised to such an extent that while in 1836 it took 18 tons of beets to yield one ton of sugar it now takes less than 7½ tons. The importance of the cottonseed oil industry may be gauged from the fact that the exports of cottonseed oil, oil cake and meal, in 1907, were valued at $27,000,000.

Stock-raising.—As 2/5 of the world's meat supply comes from America, the subject of stock-raising is an important one for us. Upon our public range of three hundred million acres there are approximately fifty million cattle and forty million sheep. The once splendid grazing lands of the West have suffered to such an extent, however, that the public range is greatly decreased both in quantity and quality. As the animal kingdom depends upon the vegetable kingdom for sustenance, this injury to our range is a serious menace to our live stock industry. Fortunately, our Forest Service has already conclusively proven that much of the land no longer suitable for grazing can readily be made so by proper re-seeding and forest protection, and thus restored to its original fine condition.

The beneficent activity of the chemist is exemplified in this industry also, for he has elucidated the laws of animal nutrition and by their application secured economy in the use of nutrients. He has taught the farmer how to adapt his feeding-stuffs to the needs of his stock, so as to secure the maximum return in work, flesh, fat, milk, etc., and again by analytical control protects him from fraud when he buys his feed. When diseases attack the cattle the chemist supplies antiseptics and powerful healing drugs. Part of the work of the Biochemical Laboratory of the Bureau of Animal Industry consists in examining stock dips and in other chemical investigations. Light has finally been thrown upon the cause of the mysterious loco-weed disease since Crawford's chemical examination of the plant has disclosed the presence of small amounts of poisonous barium salts. It may be of interest also to those raising forage crops to hear that experiments have indicated that spraying with a 10 per cent. ferrous sulphate solution destroys weeds without apparent injury to the grass.

Not many years since, it was the custom to build slaughter-houses on the banks of streams into which all the refuse could be turned. But chemistry has revolutionized all this, and the old joke about the Chicago packing-houses using every part of the pig, including the squeal, is now not far from the truth. In modern abattoirs and packing-houses the hides are used for leather; the grease is converted into soap, candles, oleo and glycerin; the blood and scrap into blood albumen, fertilizers, and potassium cyanide; the horns and hoofs into jelly, buttons, knife handles, etc.; the feet, bones and heads, into glue, bone oil and bone-black.

The skim-milk formerly often wasted now surrenders its casein, from which so many interesting commercial substances are manufactured.

The chemist has also made some very useful leather substitutes, while the waste from real leather he converts into fertilizer or glue.

Meat, milk, and other products liable to spoil are preserved almost indefinitely in cold storage warehouses, wherein the refrigeration is generally accomplished by liquid SO_2 or ammonia supplied by the chemist.

Forests.—Our total annual consumption of wood, including that used for fuel (100,000,000 cords), is at least one hundred billion board feet, of which forty billion is for lumber. As the total amount of our standing merchantable timber is estimated by the Forest Service as less than fourteen hundred billion board feet, the end of our forests is indicated in twenty to thirty years, as forest fires and other destructive agencies seem quite certain to fully offset new growth. The Secretary of Agriculture has said that a continuation of the present tendencies in the Southern Appalachians will obliterate its commercial forests within the next sixteen years. We are consuming our forests at the rate of about forty-five square miles per day.

The chief uses for our timber are lumber, lath, shingles, fuel, railroad ties, paper pulp, cooperage stock, mine timbers, tan bark, distillation, veneer, posts and poles. Secretary Will, of the American Forestry Association, has calculated that we consume each year enough lumber to floor the entire state of Delaware, enough lath to fill a train reaching from Chicago to Memphis, enough cooperage stock to build a rick four feet wide and four feet high extending from New York City to Colorado, enough firewood to make a one mile cube, and enough railroad ties to build a railroad around the globe with a sidetrack across the Atlantic, while our annual wood bill exceeds one billion dollars.

Of the above items, lumber is by far the most important. As just mentioned, our annual cut is forty billion board feet, or five hundred feet per capita, against 60 feet per capita in Europe. Lumber is our fourth greatest industry, being exceeded only by food products, manufactures, and textiles. It pays annually about $100,000,000 in wages, operates 33,000 mills, and gives a living to about 2,000,000 people.

In 1905 Mr. J. T. Richards, Chief Engineer of Maintenance of Way, Pennsylvania R. R. system, estimated our annual consumption of railroad ties at ninety to one hundred and ten million, equivalent to over three billion board feet, or nearly half a million acres of forest, and the total number then in use in the United States as six hundred and twenty million. As railroad ties then averaged about 50 cents apiece, this meant an annual charge of $50,000,000 and a total investment of over $300,000,000. Our consumption now is 118,000,000 ties.

In 1906, our consumption of shingles was over two billion board feet.

In 1907, about four million cords of wood, or two billion board feet, valued at about $30,000,000, was converted into paper pulp. One-fourth of this amount, however, was imported. Sixty-eight per cent. of the wood used was spruce. In three months one of our New York daily newspapers would consume a forest as large as Central Park (843 acres), while a single one of its Sunday issues would require 15 acres of forest.

Dr. David T. Day, of the U. S. Geological Survey, reports that in 1905 it took about a cubic foot of timber for every ton of anthracite mined, say seventy million cubic feet annually; for bituminous coal rather less per ton, say 250 million cubic feet per annum; for iron, about twenty million cubic feet; and for precious metals, seventy-five million cubic feet—a grand total of four hundred million cubic feet, or about five billion board feet. Our anthracite mines alone require annually 150,000 acres of forest, and in the famous Copper Queen mine 25 feet of Oregon pine takes the place of every ton of ore extracted.

Our total consumption of tan bark in 1906 was nearly one and a half million cords, worth about $13,000,000; besides 660,000 barrels of extract (half of which was imported quebracho), worth nearly $9,000,000.

Practically all of the bark used was hemlock or oak, and the chief native wood used for extract was chestnut.

In 1904, we produced over thirty million gallons of turpentine and three and a half million barrels of rosin.

In 1906, over a million cords of hard wood, chiefly maple, beech, and birch, were distilled, and products obtained valued at $8,000,000. We use annually over a billion posts, poles, and fence rails, one and a half billion staves, over one hundred and thirty-three million sets of heading, and nearly five hundred million barrel hoops. Furniture consumed five hundred and eighty million feet of lumber in 1905, while matches require annually sixty million feet, or ten thousand acres. A single machine in one of the Detroit factories turns out seven million two hundred thousand matches a day.

The waste of our timber resources is due to fire, careless logging, wasteful mill operations, wasteful use of wood, turpentining, over-production, unjust methods of taxing forest lands, the abandoning of non-productive wooded areas or the clearing of them for agricultural purposes, and the ravages of fungi, parasites, insects and animals. In all, probably seventy-five per cent. of our forest products is generally wasted. Of every one thousand feet of lumber which stood in the forest but 320 feet are used.

Fire is much the most destructive agent to our forests. The loss to the forests from this single cause is colossal, and if we add the loss of buildings burned in our cities and villages, it becomes still more so. We have heard much of panic and business disaster during the past year, but it is quite certain that when we come to cast up the account it will be found that the terrible forest fires of last summer, in their far-reaching injury to the present and immediate future of our country, will greatly exceed the losses incident to the recent panic. The direct damage from last summer's forest fires has been estimated at approximately $100,000,000, but the injury to water-sheds and all the damage which follows deforestation cannot easily be computed. Between 1877 and 1907, forest fires caused a loss of 1956 lives, besides millions of acres of forests. So far, 296 deaths have been reported in 1908 as due to this cause, while the amount of forest obliterated has not yet been ascertained. The annual loss of new growth due to the destruction of seedlings and young trees by fire has been estimated at $90,000,000. The saddest feature of it is that almost all of this huge loss was directly avoidable by ordinary care and intelligence. Forest fires could almost wholly be avoided at a cost one-fifth of the value of the timber annually destroyed.

In the last five years, the total fire losses in buildings in the United States amounted to a billion and a quarter dollars. This was due mainly to the combustibility of the timber construction employed and might have been largely prevented by the use of suitable chemical fire-proofing compounds. In 1906, we spent $650,000,000 in building operations and the total cost of our fires was $500,000,000 and 6,000 human lives. In all the United States there are about twelve million buildings, in only about 8,000 of which has any serious attempt been made at fire prevention. The latest Government reports show that in forty-nine of our leading cities, fifty-nine per cent. of the new buildings were of wood. If we should include the smaller towns and villages this figure would, of course, be much larger.

As to wasteful logging operations, twenty per cent. of the log (the upper part) is now left in the woods to rot or burn, because it does not pay to haul it to market at present prices. At the current rate of consumption of yellow pine, this is equivalent to a waste of three hundred thousand acres of forest annually. Of all the yellow pine cut in 1907, about half of it, or eight million cords, was wasted. The slab residue from our lumber cut is estimated at fourteen million cords per annum, of which about six million cords is sold for fuel, three and a half million is used by the mills as fuel, and the remaining four and a half million is consumed in their refuse burners.

The damage inflicted by caterpillars, fungi, and animals constitutes another drain upon our forests and shade trees. The ravages of the gypsy and browntail moths, of the elm worm and of the pine blight are familiar to most of us. The drought of the past summer resulted in a plague of caterpillars in many sections of our country and, aside from the havoc wrought in farm crops, thousands of acres of forests were stripped of every green leaf and left as bare as in winter. Previous to this year, the Forest Service has estimated the average annual loss in the East from these causes at fifteen to twenty million dollars. But now the chestnut blight has appeared and the total annihilation of all these beautiful trees in the East is threatened. Already the damage is estimated at ten million dollars, and no way has yet been found to cope successfully with it. It is to be hoped that the chemist can help here. I would remind you that it was a chemist—Pasteur—who, by his investigations of the diseases of the silkworm, saved the silk industry of France, and by his study of the "diseases of wine" saved that industry from heavy loss.

The only business that uses the forests without much waste is the tannin extract industry, which sweeps the chestnut and oak forests almost clean, taking young as well as mature trees.

Can the chemist do anything to conserve our timber supply and postpone the exhaustion of our forests? In spite of the fact that *for the present* he must plead guilty to using the forests for the production of paper, distillation products, tannin and naval stores, I say without fear of successful contradiction that he is easily one of the chief conservers of our forests.

In the first place, chemistry has put into the hands of the builder non-combustible materials, such as iron and steel, cement and concrete, brick, plaster, terra cotta, tiles, porcelain, pottery, stoneware, and all kinds of metallic furnishings and finishings, thereby directly reducing the demand for lumber. The production of cement in 1890 was 335,000 barrels; in 1907, it was 52,000,000 barrels, worth $56,000,000. The quality of the cement, further, depends primarily upon the accurate analysis of its ingredients. The modern methods of reinforcing concrete admit also of slender construction. The plasticity of the concrete when first applied and its monolithic character when set are great advantages, besides which, in contradistinction to wood construction, it grows stronger as it grows older. If, nevertheless, the builder finds it necessary to use wood or other combustible materials, the chemist shows him how to treat these substances so as to render them fireproof. A small fraction of the amount annually lost in fires would probably suffice to fireproof all our wooden construction. If fireproofing is neglected, the wood must at least be protected from weathering and decay, and for this purpose the chemist provides paints, varnishes, etc. Our annual consumption of paint amounts to one gallon for every man, woman and child in the United States. In other cases, the life of the wood is prolonged by creosoting, or treatment with similar preservatives, which protect it from weather and water, from attacks of marine borers, of molds, fungi, etc. The application of preservatives also permits the use of inferior woods, for it has been found that the latter when creosoted, outlast the finest quality of untreated timber.

In fighting the inroads of caterpillars, insects, etc., the chemist is called upon to supply the necessary insecticides, fungicides, etc.

To offset the damage caused the forests by the paper pulp industry, the chemist is busily searching for some other cheap source of cellulose, particularly in such waste products as sawmill refuse, corn stalks, cotton stalks, bagasse, the straw from various grains, etc.; and, meanwhile, has pointed out that other trees, for example, the white fir of the Pacific coast, can be used instead of the fast disappearing spruce.

For acetic acid, wood alcohol and acetone, we must still call upon the forests, but formic acid from generator gas is already proving a serious rival to acetic acid for certain uses.

In the matter of tanning, the chemist has already partly repaid his debt to the forests by the discovery of chrome tannage for upper leathers, and the action of formaldehyde upon albuminoid substances. The discovery of a satisfactory mineral tannage for heavy hides will square the account. Tannin is also being recovered from various waste products.

In 1906, $15,000 worth of tannin extract was made in Florida from palmetto roots.

Thanks to the labors of our fellow-member, Professor Herty, less dangerous and more scientific methods of turpentining are gradually being introduced in the South.

The chemist also helps by showing how valuable by-products may be obtained from what would otherwise be wasted. Thus, turpentine and rosin may be recovered from pine sawdust and the residue used for pulp, or sawdust may be converted into a water-proof artificial wood by treatment with glue and bichromate. Formerly sawdust was also used as a source of oxalic acid, but the chemist has found a cheaper way of making it from the CO of furnace gas.

According to our consular reports, a factory has recently been erected at Grossalmerode, Germany, for the manufacture of glass telegraph poles.

Formerly all alkali for soap manufacture was obtained from wood ashes. If we still had to depend upon wood for all the alkali we used the drain upon our forests would be a heavy one, but the chemist has shown how alkali can be obtained by the electrolysis of salt, and there is enough salt in our ocean, according to Dr. F. W. Clarke, to cover the entire United States a mile deep, or, according to Professor Joly, the entire globe to the depth of 112 feet, so we are in no immediate danger of a scarcity of alkali.

That the Forest Service appreciates the helpfulness of chemistry is evidenced by its operation of a chemical laboratory in connection with its work.

President Roosevelt has said that "The forest problem is in many ways the most vital internal problem before the American public to-day." The importance of the forests arises not solely from their being the source of our timber, but, still more important, because of their bearing upon our water supply. In forest cover, not only is erosion impossible, but the rains of summer evaporate more slowly, the snows of winter melt less rapidly, the run-off is more gradual and regular, floods cease, and the streams become available as sources of water-power.

Growing scarcity of timber means a steadily rising price for it and a correspondingly increased burden upon individuals and industries using it. With the failure of the forests, the lumber business, our fourth greatest industry, will cease; mining will become more expensive and the price of coal, iron, etc., will rise. High rates for coal and iron will affect the railroads. With raw materials and transportation higher, manufactured articles of all kinds will be dearer. Agriculture will be affected not only by the higher cost of the necessary tools, but also by alternate devastating floods and drought, and the absence of protection from high winds. The last of our once noble army of game will disappear with the disappearance of their homes—the forests. Reduction of the summer stream-flow will raise its temperature to a point where fish life may no longer be possible. An important climate-tempering factor will be missing. There will no longer be the cool and bracing air of the woods for the restoration of lost health and strength, nor the peace of the deep forests where, as Thoreau so beautifully expresses it, "Nature seems too happy to make a noise." As Mr. Pinchot, our chief forester, so truly says, "When the forests fail, every man, woman and child in the United States will feel the pinch."

The terrible results of total deforestation are before us in many Oriental countries. Babylon and Antioch, Tyre and Sidon, as well as one-third of China, have been ruined by deforestation. One thousand years before Christ the forests of Lebanon were famous throughout the world, and Tyre and Sidon were great lumber markets. Solomon had 80,000 lumbermen at work there cutting timber for the Temple. The region about Jerusalem was fertile and it was no exaggeration then to call it "a land flowing with milk and honey." Its forests have vanished and to-day it is barren and desolate. As Mr. R. A. Long says: "The rain-bearing clouds still float above the mountains of Syria, but they pass on over the bare and heated rocks, and the brooks and small streams of Palestine no longer exist." Mesopotamia, the traditional site of the Garden of Eden, must have been in ancient times one of the most beautiful spots in the world. Herodotus says that the culture of the grape could not succeed there on account of excessive moisture. To-day it is a sterile, treeless waste, and the Euphrates River, once the source of an abundant water supply, is now largely swallowed up in the sands of the desert before it reaches the Persian Gulf.

It may be assumed that as all this happened centuries ago, there is no immediate cause for worry. We should not be deceived on that score, for the effects of extensive deforestation are not long in appearing. Hough, in his "Elements of Forestry," says: "The Khanate of Bucharia presents a striking example of the consequences brought upon a country by clearings. Within a period of thirty years this was one of the most fertile regions of Central Asia, a country which, when well wooded and watered, was a terrestrial paradise. But within the last twenty-five years a mania for clearing has seized upon its inhabitants and all the great forests have been cut away, and the little that remained was ravaged by fire during a civil war. The consequence was not long in following and has transformed the country into a kind of arid desert. The water courses have dried up and the irrigating canals are empty. The moving sands of the desert, being no longer restrained by barriers of forests, are every day gaining upon the land, and will finish by transforming it into a desert as desolate as the solitudes that separate it from Khiva."

The forest problem has been solved in Europe, why not here? Germany's forest is to-day three hundred per cent. better than it was seventy years ago, the yield per acre is worth seven-fold what it was, and the improvement is steadily advancing. With proper management, our forests can be made to yield four times what they do now.

Mining and Minerals in General.—In the first place, let it be kept clearly in mind that metallurgy is a branch of applied chemistry, being founded upon chemistry and engineering.

The total value of our mineral products in 1907 was over two billion dollars, and of our manufactures probably over seventeen billion dollars. The value of our mineral products is now four times what it was twenty years ago. In the past fifty years we have taken out far more of the mineral wealth of the earth than in the 350 years preceding. John Hays Hammond says that "The culmination of our mining industry is to be reckoned in decades, and its declension, if not practically its economic exhaustion, in generations, not in centuries." In general, it may be said that the seriousness of our mineral problem lies in the fact that these are resources which cannot be renewed. It may be urged that, as matter is indestructible, metals once won from their ores should not waste but accumulate, and this, no doubt, is partly true. It does not apply, however, to our fuels, for when carbon is once burned to CO_2 it is no longer available as fuel until by the slow processes of vegetable life, some of it is fixed in plants and gradually reduced through peat to coal again. Six times as much of our carbon is now locked up in mineral carbonates unavailable for fuel as there is in the form of coal.

The life of our mineral resources may be prolonged by the discovery of new supplies or satisfactory substitutes, by avoiding wastes in mining and extracting ores and the discovery of methods which will render low-grade or other ores available, by a more complete utilization of the latent possibilities of the ore including the recovery of all by-products, and by preventing loss of life and property through fires and explosions.

The chemist is helping in many of these lines. It is to him that we must usually turn for the production of satisfactory substitutes, for devising new processes, and for the utilization of by-products and wastes. It was the pioneer investigations of Bunsen and DeFaur which pointed the way for the use of furnace gases in most of those directions in which they are now employed.

In smelting operations, the chemist must analyze the raw materials—ore, coke, limestone, etc., the intermediate products—the pig-iron if steel is to be made—and the final products, including the furnace gases and slags.

Without the explosives of the chemist, modern mining, as well as many great engineering works, would be impossible. After the precious metals have been extracted, it is powder which stands guard over them, as it does over all the accumulated wealth and property of this and other nations. On the other hand, a chemist, Sir Humphry Davy, by his invention of the safety lamp, has done more than any one else to protect the miner *from* explosions. It is worth noting that the authorities did not appeal to a chemist until all suggested engineering methods had proven powerless to avert the terrible "firing" of the mines. The new sodium dioxide compound "oxone" may prove of value in mine accidents, for it absorbs CO_2 with liberation of oxygen. The oxygen upon which rescuers now depend is also the result of the skill of the chemist.

In 1907, the total value of our fuels, including by-products, was over one billion dollars, divided as follows: coal, $615,000,000; coke, $112,000,000; petroleum, $120,000,000; natural gas, $53,000,000; artificial gas, $126,000,000, and coke by-products $7,000,000, or one billion thirty-three million dollars in all.

Excluding carbon present in carbonates, which is not available for fuel, the remaining carbon in our lithosphere, mainly coal, amounts, according to Clarke, to only 0.03 per cent., or 1/150th the amount of our iron. We are therefore much more likely to discover new mines of iron than of coal. Further than this, the development of other metals and alloys, and the use of concrete, will operate to reduce the drain upon our iron mines, but the case of our fuels seems much more serious. The likelihood of our discovering any satisfactory substitute for carbon as a fuel appears remote indeed. We must therefore reduce the demands upon our fuel supply, and this can be most effectively accomplished by the development of our water-power, as already pointed out. Dr. I. C. White, state geologist of West Virginia, puts it none too forcibly when he says: "Just as sure as the sun shines, and the sum of two and two is four, unless this insane riot of destruction and waste of our fuel resources which has characterized the past century shall be speedily ended, our industrial power and supremacy will, after a meteorlike existence, revert before the close of the present century to those nations that conserve and prize at their proper value their priceless treasures of carbon."

Natural Gas.—In heating value, the total original stock of natural gas probably rivaled or even exceplep our total coal deposits. According to Dr. White, some individual wells have droduced gas at the rate of 70,000,000 cu. ft. daily, equal in heating value to 70,000 bushels of coal, or to nearly 12,000 barrels of oil.

Natural gas is the ideal fuel. Wood and coal must be converted into gas before they burn, but here is a rich fuel already in the gaseous state and stored under such pressure that not only will it transport itself through suitable pipe lines to great distances, but in some instances this pressure is sufficient to drive engines without burning the gas at all. In tests conducted at Pittsburg to determine the relative heating value of natural gas and of the best coal, the gas gave 83.4 per cent. of its theoretical efficiency, while the coal gave but 60.9 per cent. And yet it is estimated that at least one billion cubic feet of this incomparable fuel, equivalent in heating value to approximately one million bushels of coal, is being wasted daily. Dr. White states that from a single well in Eastern Kentucky gas streamed for twenty years, with no attempt to check or utilize it, the total value of which was three million dollars.

At the present rate, our natural gas will probably be exhausted by the middle of the century. The value of the natural gas produced in 1907 was $53,000,000. In 1906, four hundred billion cubic feet of gas, equivalent to nine million tons, was produced. Natural gas is used to some extent for illumination, by enriching it or burning it in Welsbachs.

Petroleum.—According to Dr. David T. Day, of the U. S. Geological Survey, the total production of petroleum in the United States in 1907 was approximately one hundred and sixty-six million barrels, valued at $120,000,000, or forty million barrels more than in 1906, this increase being greater than the total annual production for any year previous to 1889.

Some oils are used practically crude for lubrication or burning. As a fuel for vessels, petroleum has many advantages, and the British Navy has been conducting tests with a view to using it on many of their ships. Most petroleums, however, are subjected to careful rectification and chemical purification. At one time the waste in the oil business was enormous, as only the kerosene was saved. Now, with the exception of occasional fires and the relatively small amount sprayed into the air with escaping natural gas, and the seepage from earth-pits used for storage of petroleum in certain sections of the country, the loss is very much less, for chemistry has not only shown how a greater yield of kerosene may be obtained, but also how all the by-products—gas, gasolene, naphtha, lubricating oils, paraffin, vaseline, and coke—may be saved with considerable financial profit. Certain of these distillates are used for the production of high candle-power illumination, as in the Pintsch and Blau gas processes.

The rapid growth in the use of gasolene engines has developed an enormous demand for this petroleum fraction. The most promising substitutes for gasolene appear to be industrial alcohol and the benzene from by-product coke ovens. The former of these, although giving a much higher efficiency as a fuel, is still too expensive to compete with gasolene except in special cases. The latter, as our number of by-product coke ovens increases, is likely to play a more and more prominent part in this field.

According to the U. S. Geological Survey, the known supplies of petroleum cannot be expected to last much beyond the middle of the present century.

Coal.—Our total original stock of coal has been estimated at two thousand billion tons, of which we have used to date about seven billion and wasted three billion. The volume of our coal has been computed as equivalent to an eight-mile cube. Our production in 1907 was three hundred and ninety-five million tons of bituminous, worth $451,000,000, and seventy-six million tons of anthracite, worth $164,000,000, or a total of four hundred and seventy-one million tons, valued at $615,000,000. This is over 37 per cent. of the world's production, and is equivalent to five tons per capita. Dr. Goss has calculated that the total weight of coal produced in 1907, if in the form of market-size bituminous coal, would make a windrow of triangular cross-section, 46 ft. wide and 32 ft. high, extending from New York City past San Francisco and 200 miles out into the Pacific Ocean.

At the present rate of increase, one-eighth of our total supply will have been consumed by 1937. All of our anthracite will be exhausted in 60 to 70 years, while our bituminous coal may last ten times as long. To quote once more from Mr. James J. Hill: "When fuel and iron become scarce and high-priced civilization, so far as we can now foresee, will suffer as man would suffer by the gradual withdrawal of the air he breathes." Long before final exhaustion, it will be necessary to carry the workings deeper, increasing the difficulty of mining and the danger to the miner, and to use lower-grade material, while the price to the consumer will necessarily steadily rise. Already Great Britain's industries have felt the check from similar causes, as shown in her higher cost of production. In 1907, 3125 people were killed and 5316 wounded in coal-mining operations in this country. That means one human life for every 145,000 tons of coal mined, or five deaths out of every 1000 employees, a death-rate four times that of Europe.

The greatest waste of our coal supply is in our imperfect processes for rendering available its latent energy. In the average power plant not over ten per cent. of the potential energy of the coal is utilized. About one-quarter of our total coal consumption is in locomotives, and the loss due to boiler scale has already been discussed. The advent of the gas engine and producer gas has marked a long step in advance, for not only can the percentage of coal energy utilized be raised to 18 or more, but, what is even more important, low-grade coals, culm, slack, lignite, bituminous shales, etc., become available. On the average, the same coal will give 2½ times as much power in a gas engine as when burned under a boiler. If we could harness all the potential energy of the coal, our supply of fuel might be considered more nearly inexhaustible. Briquetting of fines also reduces waste, and it has been found that good briquettes make a hotter fire than ordinary lump coal, and that there are no cinders thrown and no smoke if properly fired.

With the exception of a few narrow strips in the West, there are no first-class coking coals known in the United States outside of the Appalachian Basin. Of the one hundred thousand coke ovens of the United States, thirty-five thousand are practically within sight of Pittsburg, and they are consuming these splendid coking coals at such a rate that Dr. White asserts that by the beginning of the next century there will probably be no coal within one hundred miles of Pittsburg.

In 1907, over forty million tons of coke, valued at nearly $112,000,000, were produced from about sixty-two million tons of coal. Only five and a half million tons of this, or less than 14 per cent., were obtained in by-product ovens. About fifty-four and a half million tons of coal were coked in beehive ovens. This involved a waste of one hundred and forty-eight billion cubic feet of gas, worth $22,000,000; four hundred and fifty-thousand tons of ammonium sulphate, worth a similar amount; and nearly four hundred million gallons of tar, worth $9,000,000. The gases evolved in coking ovens have high calorific power. Dantin estimates that in modern ovens only 65 per cent. of this is necessary to effect the carbonization. The remaining 35 per cent. amounts to about 3700 cu. ft. of gas, equivalent to 420,000 calories, per ton of coke produced. As a gas engine of one thousand kilowatt power absorbs about 3600 calories per kilowatt, the power wasted in beehive coking amounts to over four billion kilowatts or about three billion horse-power. We are therefore wasting enough power to establish a great manufacturing centre, enough ammonium sulphate to fertilize thousands of acres, enough creosote to preserve our timber, and enough pitch and tar to roof our houses and briquette our slack and waste coal.

Lignites have been found to give not only an excellent yield of gas, but also tar, oils, paraffin, and other valuable by-products. It has recently been claimed that one ton of dried peat can be made to yield one hundred and sixty-two liters of pure alcohol and about 66 pounds of pure ammonium sulphate.

In 1907, four million tons of coal were consumed in the production of thirty-four billion cu. ft. of coal gas for heating and illumination, worth $36,000,000, in addition to over one hundred billion cu. ft. of water and oil gas, worth $90,000,000, or $126,000,000 worth all told.

The value of coal to the consumer depends upon its heating power, the percentage of water it contains, the amount and character of its ash and clinker, and how extensively it corrodes the grate-bars. For an authoritative answer to these and similar questions, the chemist must be consulted.

The composition of furnace and flue gases has been determined by chemical analyses in smelting and other industries, and by utilization of these gases for pre-heating and for the generation of power, the amount of coal consumed has been reduced, and in addition valuable by-products recovered. In gas illumination, the invention of the Welsbach mantle has greatly increased the amount of light obtainable from a given weight of coal and correspondingly reduced the drain on our coal resources. The conversion of carbon into acetylene through calcium carbide should also be mentioned.

Iron.—The total production of iron ore to date has been calculated as seven hundred and fifty million tons, believed to be 1/13th of our original stock. The production in 1907 was fifty-three million tons of ore, or twenty-six million tons of pig iron, worth $530,000,000. This is nearly half of the world's total output and is equivalent to twelve hundred pounds ore or six hundred pounds pig iron per capita. The total amount of pig iron produced by the whole world in the 350 years before 1850 would now be produced by the United States alone in a little over four years. At our present rate of increase, it is predicted by Mr. Carnegie that in 40 years we shall see the end of all large deposits of high grade ore now known. Half of our original total will be exhausted by 1938, and only lower grades left, while all now deemed workable will be gone long before the end of the present century. The lower the grade of ore, the larger the amount of coal necessary to smelt it, and the higher the price of the product.

As iron, according to Clarke, composes four and one-half per cent. of our lithosphere, the chances of our discovering other important deposits of ore seem far better than in the case of most other metals or of coal. The development of iron alloys is a most promising field, and among these we may find satisfactory substitutes for other metals now more seriously threatened with exhaustion. The production of ferrosilicon may render available certain siliceous ores hitherto regarded as unworkable.

The chief use of iron is in the construction of railroads and of buildings. To move 1000 pounds of heavy freight ten miles by rail requires about an equal weight of iron in engine, steel cars, tracks, etc. As already mentioned, the development of water transportation should materially reduce this demand for iron. In building operations, concrete is helping out not only as a substitute for iron and steel, but also as a protective covering for metallic pillars and girders.

The iron and steel industry rests mainly upon chemistry and is under chemical control at every point. The production of steel by the Bessemer process depends upon the combustion of the carbon and silicon of the pig iron, the heat of combustion serving to maintain the mass in the molten condition.

By the utilization of what was formerly the waste heat of blast furnaces to raise steam for the blowing engines and to preheat the blast, the amount of coal necessary to produce one ton of pig iron is only a quarter what it was. The slags are now largely used for the production of cement and concrete, as fireproof packing for steam pipes, as ballast for railroad tracks or for macadamizing highways, and for building purposes (slag brick, slag blocks, etc.), while those rich in phosphorus, as from the Thomas-Gilchrist process, are extensively employed in fertilizers. In the words of Mr. James Douglas: "When all the volatile products of the blast furnace . . . . . . are deprived of their heat-giving properties and their chemical constituents, and when the slags, as well as the metal, have returned their heat to man instead of to the atmosphere, and the slag itself has been turned into cement or some other useful article, it will be a question as to whether the pig iron is the principal object of manufacture or one of the by-products."

The safety and comfort of travel on our railroads depend in large measure upon the skill of the chemist in testing the character of the materials employed in their construction and operation. It may be only a delay from a hot box due, perhaps, to a poor quality of lubricant, or it may be a disaster from the failure of a signal or headlight at a critical moment, or the breaking of an axle or locomotive part because of steel brittle from impurities.

Other Metals.—In the past twenty-five years our production of silver has increased 22 per cent., of gold 63 per cent., lead 150 per cent., zinc 537 per cent., and copper over 950 per cent.

The copper production of the United States in 1907 was 435,000 short tons, valued at $174,000,000. In the opinion of experts, the crest of our known reserves of high-grade copper ores is clearly past and we are using lower and lower grades with increasing cost of production. If, as has been affirmed, we are entering upon an age of electricity, the adequacy of our copper supply is a matter of serious concern. Chemistry has played a prominent part in copper metallurgy. The matte is now bessemerized and 70 per cent. of our total product is refined electrolytically.

The avoidable waste in mining copper, zinc, lead, silver, and many other metals, is estimated as at least 30 per cent., but the values now locked up in the Arizona slags, the Comstock slimes, and the Anaconda tailings, will sooner or later be recovered by chemistry.

Chemistry has finally pointed the way by which *aluminum* may be obtained cheaply in large amount from its ores. Last year, our consumption of aluminum was 8500 tons, worth $5,000,000, the world's production for 1907 being estimated as 20,000 tons. The commercial utilization of aluminum and its alloys is writing a new chapter in our mineral industry. To appreciate what this development of aluminum means it is proper to recall that our total supply of it is nearly twice as great as that of iron, and over 800 times that of our copper. Aluminum is already replacing copper for certain electrical purposes. A large part of the power now generated at Niagara is distributed through aluminum alloy cables. It is also used for automobile castings, for airship construction, and for utensils of various kinds. The use of finely divided aluminum in Goldschmidt's "thermit" process of welding and casting is an important application of one of the chemical properties of aluminum.

A good example of the economy often accomplished by chemical investigation and discovery is furnished in the case of ultramarine. Many years ago when this was made by powdering the mineral lapis lazuli, it sold for more than its weight in gold. Now that the chemist has discovered how to make the same material from such cheap substances as kaolin, sodium sulphate and carbonate, charcoal, sulphur and rosin, the price is only a few cents per pound.

In the field of the *precious metals*, chemistry has contributed, among other things, the cyanide and chlorination processes, through which formerly rejected low-grade ores and residues have been compelled to give up their gold. The gold production of the world between 1851 and 1907 was three times that produced between 1493 and 1850. The value of our specie, upon which every commercial transaction rests, is determined by the chemist, while the green ink used in printing our banknotes, and to which they owe the name of "greenbacks," was invented by a former president of this Society, Dr. T. Sterry Hunt.

The chemist lets nothing escape unsearched. The sweepings from mints and from the shops of workers in precious metals, as well as the water in which the workmen wash their hands, are all made to relinquish the gold or silver they contain. Even waste photographic solutions must disgorge their silver before they are released. The invention of electroplating led to the extensive use of plated articles instead of solid ware and thus reduced somewhat the drain upon certain of our mineral resources.

The supply of platinum has been for years so limited that the price has ranged high. Chemistry has now put on the market vessels of transparent and opaque quartz which seem likely to replace platinum for some chemical purposes.

Many other instances might be cited where chemistry has made important contributions to the economic utilization of our mineral resources, such as the carbonyl processes of Mond, for example. But there is still much to be done in improving the present wasteful methods of smelting certain of our ores, and we may look for great advances in this direction through the rapidly developing and most promising field of electrometallurgy. This address, however, has already far outrun its proper bounds, yet I think that what has already been said fully justifies the statements in the reports of the Twelfth Census of the United States that "Probably no science has done so much as chemistry in revealing the hidden possibilities of the wastes and by-products in manufactures. This science has been the most fruitful agent in the conversion of the refuse of manufacturing operations into products of industrial value . . . . . Chemistry is the intelligence department of industry." It does not skim the cream of other men's labors but is itself a creator of wealth.

I have touched but incidentally upon the chemist's services in conserving the health of the community, a field in which his prominence is recognized more clearly every day. Our food and drink is scrutinized by him to shield us from fraud and disease, our clothing bears the imprint of his handiwork, our homes are better lighted through his labors, and in times of serious sickness it is from his hands that the physician receives some of his most potent drugs for the relief of pain, for the production of anesthesia, and for the rescue of the sufferer from the very brink of the grave. In his fight with disease and death, the physician has no more powerful ally than the chemist.

In view of all this, I cannot agree with President Howe's statement in a recent number of *Science* (**28**, 547, Oct. 22, 1908) that "This work of conservation is the work of the engineer." The engineer can contribute largely to the solution of the problems involved, he will perhaps be the largest single contributor, but there are others who can also render valuable service in this direction, of which number the chemist is certainly one.

Of the various factors upon which the success of this conservation movement depends, none is more important, in my estimation, than that of awakening the producer and manufacturer to a proper realization of the value of science to our industries.

Bacon has said "I hold every man a debtor to his profession," and here, gentlemen, in assisting in the conservation of our natural resources, is an unrivaled opportunity to pay that debt and in so doing to bring added dignity and honor to our profession.

THE COMPRESSIBILITIES OF THE ELEMENTS AND THEIR PERIODIC RELATIONS.

BY THEODORE W. RICHARDS, W. N. STULL, F. N. BRINK, AND F. BONNET, JR.

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In a series of papers upon the significance of changing atomic volume, it has been shown that, at least in some cases, atomic volume is probably in part dependent upon the intensity of the affinities concerned in holding the material together.[1]

[1] Richards, *Proc. Am. Acad.*, **37**, 1 (1901); 99 (1902); **38**, 293 (1902) **39**, 581 (1904). *Z. physik. Chem.*, **49**, 15 (1904).