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THE USEFULNESS OF CHEMISTRY IN THE INDUSTRIES[1]

ONE month ago I had the pleasure of addressing the University of Illinois section on the subject, "Chemistry and Industry." On that occasion I departed somewhat from the orthodox position of loyal chemists, which is that manufacturing industry could not long survive in the absence of chemists and a science of chemistry, and that manufacturing industry owes a large debt of gratitude, if not of worldly goods, to the chemical profession; and I endeavored to show how, long before a science of chemistry developed, a sufficient amount of chemical knowledge and a sufficient number of chemical facts were accumulated by the earliest civilizations of which we have a record, to enable them to establish and conduct chemical manufactures in a rather creditable manner. I felt it was necessary to emphasize this fact, which is frequently lost sight of in the pursuit of laboratory chemistry, in the interest of a fair understanding of the relationship between the science of chemistry, and manufacture, and in the interest of fair play, too, because I should not care to give chemistry more than its due.

There are, broadly considered, but two kinds of manufacture; one of them is concerned with those processes which change the form of matter only, mechanical manufacture, and includes such industries as the founding, metal-working, wood-working

[1] Address delivered before the Indianapolis Section of the American Chemical Society, March 20, 1908.

and weaving industries; the other is concerned with those processes in which the composition of matter is changed, chemical manufacture, and includes metallurgy, clay burning, glass making and the heavy chemical industries. By far the greatest number of industries partake of the nature of both these branches—in other words, are both mechanical and chemical—and in this way chemistry has a greater or less importance in connection with all industries. Students of the development of the human race find that the mechanical arts develop first; but not long afterwards and long before recorded history, are found evidences of a knowledge of metallurgy and of ceramics in the remains of iron and bronze implements and of earthenware utensils. Metallurgy and ceramics are both chemical industries, and they both presume a knowledge of chemical facts, that is, they presume a knowledge of the properties of certain substances, the ores in one case, clay in the other, and of the changes in composition which those substances undergo. If we turn to ancient Egypt, which is unique in having developed a somewhat advanced civilization in an early period and in having preserved by monument, picture, scroll and ornament a record of that civilization, we find that the people of that country, in addition to a knowledge of metallurgy and ceramics, were also informed in the arts of dyeing, pigment manufacture, varnish making, plaster making, paper making and the fermentation industries—all chemical manufacture—and most interesting of all, they were well versed in that distinctly chemical and not altogether simple industry—glass manufacture. Five thousand years ago they made a glass which approximates closely in composition the common glass, so-called soda-lime glass, of to-day. Now glass making is interesting from a number of standpoints. It did not develop as many other chemical industries did, apparently, in a number of localities widely separated, but in one, and that Egypt, and thence it spread throughout the world. So it is comparatively easy to trace the spread and the growth and the historical development of glass-making. On the east the Babylonians, the Assyrians, the Chaldeans, the Phœnicians learned the art; on the north the Greeks and Romans; China probably learned the art from Egypt by way of Ceylon, to which place adventurous merchants journeyed; India learned it later; Byzantium learned the art from Rome, and through Rome, too, the knowledge filtered and spread into Italy, beyond the Alps, and into the Rhine country. In the seventh century the Arabians, in their rise as a conquering nation, overran Egypt, learned her arts and carried the glass industry into Spain, where it flourished. Finally the industry centered in Bohemia, which is preeminent in this industry to-day. And thus the history of glass making can be traced from the most ancient times down to the beginning of modern history. Nor is this all, for in tracing the history of one chemical manufacture, one inevitably comes in contact with others. An industrial people is seldom satisfied with one industry and so where glass making flourished, as a rule other industries flourished also. Nobody knows how glass making was first discovered. Ordinary glass is composed of silica, lime and soda and can be made by melting together sand, limestone and soda in the proper proportions and at a sufficiently high temperature. The Nile valley is cut through limestone rock and this is the common building stone of the region. Soda occurs there, as it does in the arid regions of this country, as an incrustation on the surface of the soil—*alkali*, to use the common expression; and sand is, of course, abundant. It would be hard to find a place better supplied with the raw materials of glass making, and possibly this will account in some degree for the development of the industry there. But not entirely. And so we have various explanations of its origin. The ancient Egyptians were skilled metallurgists and smelted copper, iron, lead and tin and also refined the noble metals. One hypothesis says that the Egyptians first became acquainted with glass owing to the accidental similarity of the slag from one of their furnaces with that product. Another states that the burning of piles of straw frequently results in the production of glass because the potash in the ash combines with the sand and lime of the ash or of the soil beneath, in the heat of the conflagration. And you are all probably familiar with the old story accrediting the discovery to the Phœnicians, those bold seamen and traders of ancient times. This story, which is told by Pliny, that old Roman, than whom I suppose no man ever recorded more truth and untruth, relates how a certain Phœnician ship laden with soda was moored off a sandy shore, and how the merchants came ashore from the ship to cook their evening meal. There were no stones at hand on which to rest their pots and so they brought ashore some lumps of soda from their ship. As their fire grew hotter, the soda and sand fused and they were surprised to behold transparent streams (molten glass) flowing forth and consisting of a liquid previously unknown. The tale is interesting, for any tale is true as long as the telling lasts, but we know that the Phœnicians learned the art of glass making from the Egyptians.

But in whatever manner the ancient peoples learned the art of making glass and other chemical arts, it is certain that as one age succeeded another, the information spread and was handed down from father to son, from generation to generation. The arts were improved and a considerable store of chemical facts were acquired, in a practical way, concerning practical chemical processes. And I endeavored to show, besides the fact that chemical industries were established so long before the science of chemistry, the further fact that the science of chemistry owes a great debt of gratitude to manufacturing industry. In this way: If the chemical knowledge of the ancients could have been transmitted to the middle ages and the modern world only by books, we would know little or nothing of the facts which they slowly and laboriously acquired. Ancient records and books are extremely few in number, and worse than that, the scientific writings, when they are not purely speculative, are quite unreliable. The Greek and Roman poets recorded quite as many facts as did the philosophers and prose writers, and strange to say, the student of ancient knowledge refers as frequently to the ancient poets as to others. I repeat then, that if the world had been dependent upon written books for the transmission of chemical knowledge for, say, from 5000 B.C. to A.D. 1200, it would have fared poorly. There were two methods by which that knowledge was transmitted. The first, the alchemistic writings of the Egyptians and the Arabians; and second, the traditional knowledge of the chemical industries. The laboratory chemistry of the period I have mentioned was, in the early part of it, somewhat alchemistic in its tendency and in the latter part avowedly and emphatically so. Now all alchemistic records must be taken with plenty of seasoning, and are rather poor and unnutritious chemical food at that. And so I say that the principal means by which the chemical knowledge of the ancients was transmitted to the modern world was by means of the traditional method, from the elder to the younger generation working in the chemical industries. So for the old chemical industries we chemists should be thankful.

But some of you may ask: What of the great philosophers of Greece—what did they do for chemistry—Empedocles, Democritus, Aristotle and the rest? There is nothing like going to original sources for information and correct impressions, and therefore in answer I shall ask you to read from one of these philosophers—Empedocles. You all remember what sort of a man Empedocles is reputed to have been. He lived in Agrigentum in the island of Sicily to the south of Italy from 490 to 430 B.C. He was at once statesman, prophet, poet, physicist, physician and reformer. The few remains of his numerous writings are in verse—the classic hexameter. Imagine Sir Wm. Ramsay chronicling the discovery of argon in hexameters! Empedocles came of a proud family, was austere, august, studious, silent, and when he walked abroad in his purple robes bound by a golden girdle, a garland bound around his long hair, with brazen sandals on his feet and his retinue of slaves behind—for Greece and the Grecian colonies were slave-holding countries—he excited the wonder and the admiration of the populace. If you will read Empedocles you will see that he considered that all things are composed of four "elements" so called, earth, water, air and fire, and that the two forces, love and strife, or as we should say, I suppose, attractive and repulsive force, by acting upon these elements, caused changes in the composition of matter.

Another philosopher, Democritus, who lived about 490–390 B.C., in Abdera, in Thrace, made another guess at the secret of chemical composition. His hypothesis concerning the composition of matter considered that there were in all the universe but two entities—vacuum and atoms. Vacuum represented void, interplanetary space. All material things were composed of atoms. All spirit, too, was composed of atoms as well. They were invisible particles, extended, heavy, impenetrable, of various shapes, uncaused, eternally-existent and in ceaseless motion. This hypothesis bears a striking resemblance to the atomic theory of to-day. You see men, like children, have in all ages asked the questions: "What is this made of? What is that made of?" and have endeavored to answer these questions.

You will have guessed already the difficulty with the chemistry of the Greeks. It amounted to nothing more than speculation. The hypotheses were never tested in the workshop of science—the laboratory; they remained at the last what they were in the beginning—unproven products of the imagination. And I think I may safely say that all the Grecian philosophy, as a means of developing and preserving chemical knowledge, was worth less than one factory engaged in chemical manufacture—let us say a factory engaged in the manufacture of glass.

So, on the last occasion on which I spoke of "Chemistry and Industry" I emphasized, and indeed over-emphasized for the sake of the argument, the debt of gratitude owed by the science of chemistry to the manufacturing industries. To-night I wish to take the other view-point and show what the science of chemistry has done and can yet do for manufacture. In truth, manufacture and chemistry must be considered as close partners in the affairs of to-day and neither could well be deprived of the other.

In ancient times and during the middle ages progress in both manufacture and chemistry was slow. That progress goes on in an ever-increasing ratio, and very suggestive of the great progress that has been made is the fact that accuracy, and certainty in application, have increased to as great an extent as rapidity of discovery.

I would like to think of chemistry as an essentially practical science—one which can be directly applied to supplying the wants of mankind. Let us not forget, in our admiration of the brilliant researches of an Ostwald, a Van't Hoff, or a Ramsay, that in the judgment of time even the greatest and most brilliant feats of the mind must be accorded a mediocre place if they are not ultimately practical.

As I have said, there are two classes of manufacture—the mechanical and the chemical. This means that two classes of men have been mainly instrumental in developing manufacture—the mechanical engineer and the chemist. I should not give either class preeminence in industry. I should not say that either one was more necessary to the proper conduct of a manufacturing business than the other; *both* are essential to the highest development of industry. Once in a long time it happens that a man is born with a sufficiently broad conception of science and art, with sufficient industry, and with a sufficiently tireless mind and body that he can pursue both callings. Need I say that such a man is unusual, that he is possessed of unusual talents? Indeed, I might say, if the term genius were ordinarily applied to those who devote their lives not to the fine arts and literature, but to the more lowly calling of fashioning material things with their hands, that he is a genius. Ordinarily we must be content to have the chemical engineer embodied in two individuals—one of them an engineer and the other a chemist, and these men by cooperation and by combination of their separate talents, must develop the manufacture of the future. I can not refrain at this juncture from indulging in just a word of caution to those institutions of learning which offer the degree C.E.—chemical engineer—at the end of a four years' course, possibly with the proviso of one or two years' successful work, after leaving school, in some industrial laboratory. Let me say that a degree in itself means nothing, and the degree of chemical engineer should by all means be a post-graduate degree equivalent to the doctor's degree and should be reserved for exceptional, and not given to ordinary, students. A degree in itself means nothing and may be no more appropriate to the individual than the degree given by some sophomores to the boastful freshman. They painted the letters on his back—A.S.S., which they said stood for astonishing smart scholar.

Let us understand clearly that progress in the manufacturing industries which make use of chemical processes will be uncertain and slow, or altogether impossible, without a well-developed chemical science to furnish new ideas. Let us remember that chemical manufacture has developed more in the period from 1850 to the present time than in all the previous centuries and millenniums of mankind's earth. And while we may well be astonished at the chemical industries which developed when there was no science of chemistry, they were as nothing compared with the chemical industries which have been and are developing in our own time.

To come down to details: As I see it, the chemist may be useful in the manufacturing industries in four different ways:

1. In the buying and selling of materials according to analysis.

2. In the chemical control of manufacturing operations by analyzing raw, intermediate and final products.

3. In a consulting capacity, interpreting chemical process, terms, and operations to the administrative heads of the business.

4. In the improvement of plant and processes, including the working up of by-

products, cheapening of operations, and turning low-grade products into high-grade ones.

I shall take up these four different lines of work, one after another, somewhat in detail.

First—The buying and selling of materials according to analysis. I take it for granted that no modern manufacturing plant can run without power—power is indeed the chief distinguishing characteristic of modern plants as contrasted with ancient ones—and the principal source of power still is steam under pressure, and the heat necessary to generate steam is derived from burning coal. In very recent months plants have been constructed which derive their power from gas engines operating on producer gas, blast furnace gas, etc., and such plants may operate entirely without steam power. The demands made upon the world's coal supply for power have increased greatly in recent years; the coal supply can not last forever; and so, means must be devised for making the coal supply last longer either by utilizing more of the energy or by working out methods for substituting other sources of energy for heat energy. The gas engine is the result of efforts in the first direction and the conversion of the gravitational energy of falling water into electrical energy is the result of the second. In spite of the efforts now being made to conserve the coal supply, the heat from burning coal applied to steam boilers is still the universal way of producing power. To operate a boiler plant a good water supply is necessary. There must not be too large a quantity of incrusting substances in the water, or scale will form in the boiler; the water must not be too alkaline, or it will prime or foam in the boiler. If only a poor water supply is to be had, then the chemist must provide a purification plant or boiler compound which will prevent or minimize the formation of scale. The coal received at all large plants is regularly analyzed and by many the coal is contracted for and bought on analysis. Thus for the very fundamental process of generating power for operating purposes, the manufacturing plant must call in the services of the chemist.

But every plant buys large quantities of supplies besides coal and water. For construction work there is Portland cement, which must be analyzed and tested; and lime and sand are frequently examined by the chemist. The railroad buys its iron and steel, bronze and babbitt, brass and tin according to analysis; the packing-house buys its salt, sugar and vinegar in this way; the soap factory buys oils and tallows, caustic soda and soda ash, essential oils and artificial perfumes entirely according to composition and purity; the sulphuric-acid plant buys its pyrites; the fertilizer plant its potash salts; the glass factory its sand, its lime, its soda; the explosive factory its glycerine and nitric acid, all according to the chemist's certificate. The analytical chemist has come to be a factor of enormous importance in the affairs of the commercial world. The very standard of the basis of exchange is determined by his assay; he analyzes every product from stone and iron to food and spices.

Of course, the thought will occur to you: How was manufacture and exchange conducted at all in the days before chemistry and chemists became so important? How did manufacturers and business men get along at all? Well, they got along fairly well then, but to-day I am afraid their difficulties would be many. The keen competition of to-day and the more elaborate working up of by-products, yes the greater complexity of modern society, have brought about the change. Still, even to-day there are plants of fair size which are operating without chemists. I know of a soap factory, for example, in which the fats are bought on inspection, the alkalies on the seller's analysis, and no control whatever is exercised over the chemical process of soap-making excepting that afforded by the sense of taste which is used in determining when the boiling soap is approximately neutral. The soap lyes are not refined, but are shipped in drums to the refiner.

Somebody may ask: How can a small plant afford to employ a chemist and so increase its pay-roll by a greater or less sum? My reply is that it is not necessary for the small plant to employ a chemist on the spot. At all the large commercial and industrial centers will be found commercial chemists who will make yearly contracts on the basis of the output, to handle all analyses and serve in a consulting capacity as well, in the interest of the plant. I have in mind one such laboratory in Chicago, which serves in an analytical capacity for about four hundred small and large foundries at a moderate compensation for each one. Each day the foundries send in their samples and these are analyzed at night; in the morning the various foundries are notified by telegram or letter as to whether their mixtures are right or wrong, and if wrong they are told how to correct them.

The second way in which I have said the chemist is useful in the modern factory is in following what we call the chemical control work of the factory. In brief, this means the analysis of the raw material, of the intermediate products and of the final products of manufacture. In blast furnace practise, the control work would include the analysis of the ore, of the coke, and of the limestone which go to make up the charge, of the pig iron produced in the operation, and possibly of the slag for cement-making purposes and of the blast-furnace gases. This is an old story to chemists and to those who are familiar with the chemical profession, but I would like to emphasize the fact, that this technical analysis or control work is, so far as the operative side of an industry is concerned, the vital and important thing. There is no doubt that analysis is the backbone of chemistry, and it is well to remember that analytical methods can not be made too exact. The business and commercial and manufacturing world to-day is scrutinizing intently the work of the analytical chemists, both in works and in commercial laboratories, and day by day is demanding more exact and carefully made analyses. I can see signs at the present time of demands in point of accuracy of analytical work which will tax to the utmost the resources of chemical invention. The question of accuracy and rapidity in technical analysis is a most important one and in the near future our great chemical society, through its division of industrial chemists and chemical engineers, must take up this question and by means of committees and cooperative work give the manufacturing world what it is demanding.

There is no factory engaged in the transformation of substances chemically which does not require this control work by chemists. In a soap factory, the raw fats and the alkalies are analyzed; during the process the product is examined for completeness of saponification; the lyes are analyzed for their glycerine content and for excess caustic soda and sodium carbonate; the crude glycerine must be analyzed and the chemically pure and dynamite glycerine after distillation. Finally the finished product must be analyzed from time to time, and the soap of other makers as well, for the sake of comparison.

The Portland cement industry has grown to enormous proportions in this country in recent years and in that industry, again, the turning out of strong and sound cement is a matter depending almost wholly upon the carefulness of the control exercised by the chemist. The limestone or marl and the clay or blast-furnace slag which go to make up the mix, must be analyzed with the greatest care, to insure a uniform product of high quality. I have mentioned the word "uniform." Probably no single thing in manufacture is more important than the turning out of a product which is of the same quality from day to day and from year to year. The public even to-day buys largely according to appearances, and, for example, if one lot of commercial fertilizer is gray and another brown, although of the same grade and composition, the farmer is very apt to have a strong prejudice in favor of one or the other.

The list of industries in which the chemical control work is vitally important might be extended indefinitely. I will only say that in every well-organized pottery works in the country, in every large brewery, in every oil works, gas works, wood distillation plant, varnish works, sugar factory, explosive plant, dye house, tannery, glue factory and fertilizer plant, not to mention those very modern lines of industry which are engaged in the manufacture of acids, alkalies and salts—the so-called heavy chemicals—there is a well-organized laboratory and chemical staff constantly engaged in this work of chemical control. It is hardly necessary, under these circumstances, to answer the question: Does it pay? if the question should be asked. I say unqualifiedly that not only does it pay, but it nets the industry the largest return on the investment of any branch of the establishment. I will go further and say that during the next ten or twenty years, where there is one chemist working at a given industry now, there will be two or three chemists working then. And that this great increase in the chemical forces of this country will mean more to the development of the manufacturing industries here than mere words can express. Germany's preeminence in certain large lines of manufacture to-day is freely acknowledged to be due solely to the contributions which her scientific men, and chiefly her chemists, have made to the cause of manufacture.

The third way in which I stated that the chemist is useful in the manufacturing plant was in the capacity of consulting man, interpreting chemical processes, terms and operations to the administrative heads of the business. In a large plant there is constantly coming up a host of new problems and suggested processes, as well as incidental questions, which can only be properly handled by a technical chemist. To him comes the manager, the president, the superintendent or other members of the executive staff, asking for information: And on these occasions, the chemist is the man of ready reference for everybody. When the questions are coming in thick and fast, his information must be practically all that is recorded in existing and non-existing scientific books and journals and his mind must be as well organized as a card index in a library. There is no question concerning force or matter on this earth, the heavens above or the waters beneath, that the manager or superintendent can not ask, or, I am happy to say, his chemist can not answer with equal facility. What is the difference between salt and sugar? If an iron pipe will rust, why will not a lead pipe? Have you got a good recipe for taking aniline stains out of a table cloth? What is the latest decision on the Board of Food and Drug Inspection? How much salt per day is the proper ration for draft horses? And the list might be carried on to infinity. All these questions, I say, the chemist can answer with as great facility as the layman can ask them.

The fourth sphere of usefulness which I suggested referred to the improvement of plant and processes, including the working up of by-products and cheapening of operations, and turning low-grade products into high-grade ones. Work of this nature is to be viewed in a different light from the other kinds of work which I have described. I should say that while all plants require analytical and control work and also consulting work, there are many plants which can operate, and operate successfully, without any of the research work implied in the present category. This fact is not to be taken as a criticism against the plant, but is to be accepted as a natural feature of industrial operations. Not all plants can lead. There must always be a considerable number which work along the accepted lines of their particular branch with no great desire to take the initiative in developing plant and process. The man who can invent, describe, work out in detail, instal and operate a new industrial process or an improvement on an old one, is an extremely rare person. He must have inventive ability, profound knowledge, keen insight, imagination, initiative, tireless energy and that wonderful faculty of elimination of the non-essential. One of the great mistakes of the present tendency in chemical education is, in my opinion, that every young student of chemistry is taught to believe, or at least is not taught to disbelieve, that on a modest or even a considerable foundation of chemical information he can become a research man in an industrial laboratory and an improver of processes in manufacture. This is a serious mistake. No amount of chemical training can change the nature or the talents of a man, and yet almost every young man who enters an industrial laboratory seems to have the idea that any work but research, or work of an executive nature, is not to be considered worthy. The simple result of this is that the men are failures as research or executive men if given an opportunity, and, further, because they do not regard as sufficiently important for their consideration that foundation of our science, analytical chemistry, they are bad analysts. It is an astonishing thing that the great rarity in an industrial laboratory is a first-class analyst. Most men, instead of looking upon skill in analysis as a desirable thing to attain, consider it as of secondary importance. To them, apparently, the work of Berzelius, of Stas, of Fresenius and of Hillebrand does not appeal, or does not influence them greatly. I believe that every chemist, no matter what line he may be working along, whether a teacher in a high school, a university professor, a consulting chemist or a chemical engineer, should be first of all a capable analyst.

These remarks are somewhat aside from the immediate topic. The chemical engineer—for by this much-abused name I prefer to call those chemists who are able to improve plant and process—has a high calling. Fortunate indeed is the establishment which possesses such a man. In my own limited experience, not more than one chemist in one hundred (and possibly the ratio is lower yet) is entitled to be called by that name. And the greatest of these, the Bessemers, the Solvays, the LeBlancs, the Chances, the Lunges, the Knietsches, stand out as notable landmarks in the course of the history of chemistry. Notice, I have given the names of the men who have *successfully* worked upon new processes. To indicate the difference implied in this statement between the unsuccessful and the successful workers, I shall say that in 1837 Gossage proposed reactions for the recovery of tank waste in the LeBlanc soda process. He worked on the process from 1837 until 1847; nor was he, like many inventors, without funds to carry on his work. He spent a considerable fortune in carrying on his researches, but failed. It was not until 1888 that the Chance-Claus process, simple and cheap, based upon Gossage's reactions, was successfully introduced. There are other examples identical with this one. The reactions in the Solvay process, the Hargreaves-Robinson process, the Deacon process, the contact sulphuric-acid process, were all known before the men were found who could successfully introduce them into manufacture.

I have now dealt at some length with the usefulness of chemistry in the manufacturing industries, but there are other applications of chemistry which I must mention or I shall not have presented my subject to you in the fullest extent. The science of chemistry has permeated every field and phase of modern life. Its growth has been so steady and so silent, and it has been developed on the whole by so few men and in the retirement of laboratories and studies, that the public mind has hardly yet awakened to its full significance. As to its possibilities, no men, not even its enthusiastic disciples and devotees, dare to predict. They only watch its growth and foster it as they would a child. I wonder how long it will take us to catch up with our own times. We live, it seems, half in the past and half in the future. We look back to our boyhood days with delight, and think, to mention only one example, of the good things we used to have to eat, and we look ahead to some future time when those conditions shall have been restored. How often do we seriously stop to consider that engineering and chemical science have made and are making possible better ways of living than were ever possible before? I wonder how long it will take us to realize that better butter can be and is being made in creameries than on the farm, that better hams and bacon can be and are being made in modern packing-houses than in the country butcher shop, that better bread can be and is being made in bakeries than in the home—not to mention the superiority of that distinctly modern invention—the breakfast cereal? Why should it not be true that the larger establishments are able to turn out better and more uniform goods than the smaller ones? In the large institutions formulas can be worked out scientifically by the experts employed there, whereas in the small institutions where the services of the expert are not afforded, that relic of a dark and barbarous age—the so-called rule-of-thumb—still holds sway. In all these developments, modern chemistry has taken a preeminent part. There is no home in this broad land of ours, no home in the whole civilized world, but is better ventilated, better heated, better lighted and supplied with better food and clothing, owing to the applications of the science of chemistry. A broad statement, you will say. Possibly. Take the question of lighting. Glass is a very old invention, but window glass is a modern one—for example; in Roman times, from the beginning of our era to the downfall of the empire, glass was extensively used for tableware (more extensively than it is to-day, in the better Roman families), it was used for ornaments, for mural mosaic work, for pavements in courts, but not for windows. Window glass is a modern invention. And I ask you, how would you like to substitute for the broad clear panes in your dwellings the translucent sea shells, the mica, the oiled paper and the other devices which have been used at various times and by various peoples to let in the light of the sun and shut out the cold of winter? But window glass has to do with natural light—what has chemistry done to improve artificial illumination? In ancient times animal and vegetable oils and fats, waxes and resins, were used for illumination in lamps, candles and torches. The flames must have been extremely smoky, odorous and generally disagreeable. It was in the early eighteen hundreds that the stearic-acid candle was introduced, following Chevreul's pioneer work on the chemistry of the animal and vegetable oils and fats. It was later still when crude petroleum was refined by the chemist and kerosene and gasoline came into general use for lighting and heating. Coal gas, the discovery of Clayton in 1675, was first used for illumination in modern times by Wm. Murdoch in 1792, who lighted his own house with it. Now illuminating gas of one kind or another issues from orifices in the earth in various places and the Chinese at an early day made use of this gas for evaporating salt brine and for lighting salt factories. But no general use was made of either natural or artificial gas until the early eighteen hundreds. In the United States at the present time more than $200,000,000 is invested in gas plants, and the gas industry is, of course, a chemical industry developed by chemists. But with gas flames as with other flames, more of the energy is dissipated as heat than is radiated as light, and for many years the problem of obtaining a larger percentage of the energy of combustibles in the form of light was an unsolved problem. It was known that certain oxides, such as those of calcium and magnesium, emitted a brilliant light when heated, but these oxides were brittle and a mantle made of them would crumble and fall apart. But with the discovery of new elements and the investigations of their properties, oxides were finally found which, when heated, emitted an intense light and at the same time were tough enough to construct a mantle of. Auer von Welsbach took out his first patents for glow lights or gas mantles made of thorium and cerium oxides in 1886. Edison constructed the first successful filament for an incandescent lamp out of a charred bamboo filament, but now the demand is for more light from the incandescent bulb, and the tantalum lamp and the tungsten lamp are already practically successful and others will follow.

So much for the contributions of chemistry to the art of illumination. I might take the matter of food chemistry and show some most interesting developments. How larger and better corn crops are now produced than formerly, due in part to the application of chemistry to corn breeding; how the sugar beet has been raised from 6 per cent. to 8 per cent. of sugar content, to 18 per cent. or 20 per cent.; how the sugar cane and the cereals are being improved; how the scientific application of fertilizers is maintaining soils in a state of fertility; and how the great science of soil chemistry is developing with enormous rapidity. Think what that means. It means the food-supply of future generations and life and health to them. Agriculture is fundamental in human affairs, and chemistry is fundamental in scientific agriculture.

In every branch of human knowledge and activity, the influence of chemistry is making itself felt. Under its influence the people are beginning to note that it is the composition of things, not appearances and not names, that is important. I am as great an admirer as any man of the human imagination in science and in art. I am capable of appreciating keenly the romance in literature and impressionism in painting, and I can enjoy, too, that combination of romance and impressionism which the advertising man places before our vision in vending his wares. I am capable of enjoying these things, I say, as fiction. Imaginative advertising, as advertising, has delighted me from the start. I have read them all from "Sunny Jim" to the "Gold Dust Twins." But, after all, could we not purchase more intelligently if we were better posted on composition and less on catch-phrases and cartoons? Is it too much to hope that chemical composition will one day be the public's guide in matters of this sort? Carnation milk, Violet wafers, Butternut bread, Bullfrog beer, Buttermilk soap and Grapenuts! I can see an opportunity for chemistry here!

In conclusion, there may be some present who will think I have praised chemistry and chemists too highly. Some may say that important matters speak for themselves and need no praising. I am not in the least of the opinion that chemistry needs praising; what it does require in this country is, calling the public's attention to its importance.

W. D. Richardson

SOME RESULTS OF THE MAGNETIC SURVEY OF THE UNITED STATES[1]

The United States of North America, embracing nearly one fifteenth of the entire land area of the globe, or an area about equal to that of Europe, constitutes at present the largest land area for which a general magnetic survey, in sufficient detail and of the requisite accuracy, has been made. The three magnetic elements: the magnetic declination, the inclination and the intensity of the magnetic force, have been determined at about 3,500 fairly uniformly distributed points. Of this number of stations about two thirds were occupied during the seven years the speaker had charge of the magnetic operations of the United States Coast and Geodetic Survey, viz., 1899–1906.

[1] Presented before the National Academy of Sciences, Washington, D. C., April 22, 1908.

The stations are, on the average, thirty to forty miles apart, or we may say there is, on the average, one station for every 900 or 1,000 square miles. Of course, in some states, *e. g.*, in the coast states, the distribution of stations is somewhat denser than in some of the interior western states, because the early magnetic work of the Coast Survey was largely confined to the Atlantic and Pacific coasts. However, before many years the distribution for all the states will be practically the same. When this has been accomplished, the plan is to multiply stations in the regions of manifest irregularities. (Two slides were exhibited, one showing the distribution of the stations up to 1899 and the other up to January 1, 1907.)

Because of this large amount of accurate magnetic data now available for the United States, I was enabled to construct the magnetic maps of the United States, for the first time as based upon strictly reliable and homogeneous data. My predecessor, the late Charles A. Schott, who had been a member of this academy, was obliged to base his isogonic maps or "lines of equal magnetic declination" very largely upon surveyors' data, owing to the paucity of data, whereas his isoclinic and isodynamic maps had to rest upon even more slender material. In the present instance, however, the charts of the various magnetic elements all depend upon practically the same number of observations made at the same points. They are, hence, strictly comparable and we may, therefore, pursue our investigations respecting the irregularities in magnetic distribution much more successfully than hitherto.

Mention should also be made that during the period 1899–1906 special attention was paid to instrumental errors—more frequently inherent in magnetic instruments than generally supposed. All instruments were therefore studied care-