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THE EDUCATION OF INDUSTRIAL CHEMISTS.[1]

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THE vast domain of chemistry is now divided into a number of fields, worked by different men, and according to methods differing widely from each other. It has not always been so. Berzelius, Dumas, Liebig, and some of the minor stars shining at the same time as these great luminaries, combined the mastery and leadership in inorganic and organic chemistry as a pure science, with applied chemistry in all its branches. In no case, perhaps, has this widely embracing spirit been more clearly exhibited than in that of Liebig. I will not dwell for a moment upon his immortal achievements in pure chemistry; these are, after all, the central tower of the vast building which he has reared, and they form the foremost title to his being classed as the greatest of all the chemical giants our century has produced. But hardly, if at all, inferior to this are his achievements in applied chemistry. Need I remind my hearers where Liebig found those two immensely important fields, agricultural and physiological chemistry, and where he left them? His merits with respect of industrial chemistry are perhaps less generally known and appreciated, but they are also sufficient to warrant the assertion that during the first half of this century no teacher of chemistry, except, perhaps Dumas, occupied so high a place in technical matters, and was more

[1] Read before the World's Congress of Chemists, August 26, 1893.

frequently appealed to for assistance and enlightenment by chemical manufacturers than Liebig. It was probably not a mere accident that one of the very first men who occupied a chair entirely devoted to technological chemistry in its stricter sense, Friedrich Knapp, was Liebig's brother-in-law. It will not be disputed that the teachers of industrial chemistry of this day, if they look for their spiritual ancestors of half a century ago, can find hardly any men of mark who were at that time mere specialists in technology, but they must and can lay claim to being the humble successors of those grand heroes of pure science of whom I have spoken at the outset, and who have combined excellence in theoretical and in applied chemistry.

It is very different to-day. Hardly one of the men whom we are now proud of revering as our leaders in pure science, is intimately connected with industrial chemistry. The last of the great men of whom that could have been said, August Wilhelm Hofmann, has passed away from us; and he had about thirty years ago ceased to be productive in that specialty. Of course, a good many other first-class theoretical chemists have some connection with industrial pursuits; some of them have even taken out patents, and devote part of their time to the "business" element of applied chemistry. But no one of them occupies himself with teaching industrial chemistry, or working, or writing in that field; and few of them have any extended knowledge or interest in that domain. Industrial chemistry in that respect is exactly on the same ground as pharmaceutical, or agricultural, or physiological chemistry. All of them have branched out too far and have become too closely intertwined with other sciences to be embraced by the same men whose life-work lies in pure chemistry; all the less as the latter have been compelled long ago to parcel up their own field among various workers. It is now quite an exception for the same man to pursue more than one of these three directions: General and physical, inorganic and analytical, and organic chemistry. Nay, the time seems near at hand when the organic chemists will be divided into fatty, aromatic, and pyridine chemists, and perhaps some further shades. It is, of course, indispensable for every chemist to be acquainted with all the branches of his profession, and for the

elementary grades even the teaching of those various branches may be and generally is still left in a single hand. But the creative work is now distributed among quite a number of classes of chemists; and in the highest grades the teaching must be similarly divided among specialists. Thus at the Zurich Polytechnic School there are four full professors for the various departments of pure and applied chemistry, with four assistant professors, and a fifth chair has just been founded.

Since industrial chemistry has become an entirely distinct department of science, and since the instruction therein has naturally been entrusted to separate teachers, it is important, both to those who intend to study industrial chemistry as a profession, and to those who have to employ the men educated for that pursuit, that it should be taught in the best possible manner. This is so self-evident that it sounds almost like a commonplace to speak of it; and yet it is far more difficult than it looks. Whilst the teaching of pure chemistry is carried on very much the same lines all over the world, it is certainly not a settled question how chemical technology is to be taught, and great differences of opinion exist in that respect, among the leaders in that branch of science, the governing boards of technical schools, and the practical manufacturers who look for the best possible preparation of their employees.

A few years ago public discussions on the best way of educating young men for the profession of technical chemists took place very extensively, both in Germany and England. The societies of chemical industry in both countries, a number of private gentlemen, and in Prussia even the State Department of Education took part in those discussions. I myself have borne a good share in them, and whilst standing up for what both experience and common sense induced me to maintain, I have given due weight to the arguments brought forward from other sides. I have also had a good opportunity of carrying out at least a good portion of those views which I then felt bound to take, in one of the most flourishing centers of technical instruction. As far as I can judge, only a faint echo of those discussions has reached the country in which I have now the honor of speaking. But it cannot be indifferent to this great nation

how its young men are to be fitted out for carrying on the pursuit of technical chemistry. Indeed, metallurgy, assuredly one of the greatest American industries, is nothing but a special case of technical chemistry, and any remarks made upon the latter apply to a great extent also to the former: but my theme is too large to take notice of the special requirements for the instruction in metallurgy to-day.

I hope, therefore, to be excused, if I touch briefly on the main points of these discussions on the education of technical chemists, so far as they may seem to possess interest for this country. I shall confine my remarks exclusively to the highest class of teaching, such as is practised at universities and polytechnic schools; both because time would not permit me to discuss the lower grade schools as well, most useful though these are in their way, and because I do not possess the necessary personal experience and competence for dealing with that part of the subject.

Before entering upon the course of instruction to be followed at the colleges themselves, we must necessarily look to the foundation of that edifice; that is the previous training of the young men who are to enter a college of which technical chemistry forms one of the principal branches. I am not sufficiently acquainted with the various classes of schools existing in this country to tread upon this ground; but so many of my hearers have been in Europe, or at least know European institutions, that I may take it for granted that I shall be understood when speaking of the various systems prevailing in Europe. I shall venture even further, by speaking chiefly of the German and Swiss schools, which are generally acknowledged as being among the best of their kind.

In these countries two systems of education are found side by side, and often in tacit or outspoken opposition to each other, *viz.*, the classical or humanistic, and the modern or realistic system. The former, as embodied by the German gymnasien, the English grammar schools, and the French Lycées, builds up the whole of education on the foundation of Latin and Greek, devoting but little time to modern languages, including the mother tongue, about as much to mathematics, and very little

indeed to natural sciences. Youths brought up under this system have very frequently turned out splendid men in all walks of life, and many savants of the first order have sprung from such classical schools. The devotees of this system are not tired of repeating, with that dogmatic tone fostered by itself, that higher mental culture cannot be brought about by any other means. A man, they say, who knows Latin and Greek, or who at least has known something of these languages at a former period of his life, has thereby trained his mind in such a wise that it is open to receive knowledge of all kinds, whether philological, or historical, or mathematical, or belonging to the realm of natural science. But they go much further; they boldly say that nothing but this classical training enables a man to thoroughly grasp even the inductive sciences in their highest ramifications. Others may grub about in the lower regions; they may do useful work in chemical analysis, in collecting plants or beetles, or stones, and the like; but the fundamental discoveries, the grand generalizations, all the higher attainments in science are reserved for those who have drunk from the fountain of classical studies. Nor are the men who speak in this way shaken in their belief, which with them amounts to a dogma, by the hard fact that many men of the highest order, of whom I will only mention Faraday and Liebig, do not conform to the rule of the exclusively saving power of classical education.

In this practical country such views are probably very rarely met with, and many of my hearers may think that any discussion about them is like fighting with shadows. But in Europe, at all events, they are realities. Men like Hofmann and Dubois Reymond (of whom the second later on withdrew from that position) have pronounced in their favor, and probably the majority of German university professors still adhere to them, more or less outspokenly. Up to this moment in Germany the majority of those entering college for the purpose of devoting themselves to the study of pure science, and all those who enter for medicine, come from the classical gymnasien, where Latin and Greek are the central pillars of education; even for the polytechnic schools the classical gymnasien enjoy the same privileges as the realschulen, where only Latin or no classical language at all is

taught, but in lieu of that far more of modern languages, of mathematics, chemistry, physics, drawing and so forth. It will be perceived from this that in Europe it is not yet a waste of time and energy to stand up publicly for the conviction that the classical languages, so far from being helpful in the pursuit of scientific and especially technical studies, are most decidedly *injurious* to it, both directly and indirectly, by blocking the way for other matters of far greater importance. I speak feelingly on this point, for I received a thorough Latin and Greek education, and my original intention was to devote myself to the study of the science of language. I cannot, therefore, be upbraided with talking about matters of which I know as much as a blind man of colors, when discoursing on the value of a training in the classical languages, which I have loved dearly, and in which I have worked with far more than the ordinary zeal of a collegian. But I am bound to say, as a chemist, that I have bought my whistle far to dear. It would not be becoming, if I went any further into personal matters, but thousands are in my position, and most of them will, like myself, say that, if we have done our little share in some theoretical or practical branch of natural science, it has most assuredly not been in consequence, but in spite of our classical training, which taught us to esteem words more highly than things, and book-learning as the only kind of knowledge worthy of a noble and really cultivated mind.

I have come to the conclusion that, taking men as they are, and looking at the fact that only a small minority are able to give an unlimited amount of time to their preparation for practical life, those who intend to embark in the career of natural science, in medicine, or in any technical line, ought to content themselves with only *one* classical language, that is practically with Latin, although some well-meaning enthusiasts would in this case plead for Greek. In my opinion a man may get on perfectly well in every one of the branches named before without knowing even Latin, and I make bold to say, he may also acquire a mental education as deep and real as that generally approached through the classical languages; but in Europe, at all events for the present generation, a knowledge of Latin is still desirable for those who move in the higher spheres of

society, whilst it is the merest sham to pretend that there exists in those circles, with trifling exceptions, more than a faint remembrance of the Greek with which they painfully struggled in their earlier years. The whole of the time given to Greek, and a good deal of that spent on Latin in the gymnasien, is in the realschulen devoted to modern languages, to mathematics, to natural science and to drawing, which subjects in my firm belief are not merely more useful for all practical purposes, but which form the youthful mind in a far healthier mould than the one-sided pursuit of classical studies.

I am afraid I have, after all, dwelt too long on the chapter of preparatory education, as I am speaking in a country where the immense prestige enjoyed by the classical languages in the greater part of Europe does not exist, and where the opinions which I have stood up for are taken for granted without any discussion. Let us, therefore, now enter upon our proper field, the special studies to be pursued at a university or technical college by those who mean to devote themselves to industrial chemistry.

It will be granted on all sides that at this time of day no technical chemist is worthy of that name who does not possess a sound and thorough knowledge of general chemistry. The time is past when the rule of thumb was paramount; when most factory managers recruited themselves from the ranks of "practical" men, understanding thereby mechanics, manual laborers, or business men, who looked down upon the chemist—if such a person was at all attached to the works—as a testing machine, to be kept in his proper place and to be mistrusted, whenever he ventured for a moment beyond the hole which was by courtesy styled the "laboratory." Nor were these "practical men" altogether wrong in their estimation of the "chemists" they came in contact with; for the majority of those chemists had started as bottle washers to a "chemist" similarly educated, and had at best acquired some smattering of chemistry at a night school or the like. These men were often qualified by natural quickness of intellect or by a practical turn of mind for better things, but science could not lead them on, for of that they were really almost innocent. This sort of works' chemists

lowered the standing of the whole profession. Even many so-called "analytical chemists" were only brought up to this profession as apprentices, as to an ordinary handicraft, and these were only a step or two more advanced in science than those who had commenced with the bottle-washing department. This state of things is not so far removed from the present time as some of my hearers may think. Thirty years ago, when I transferred my abode from Germany to England, I found it to a great extent prevailing in the latter country, and it was not altogether unknown in the former. Even then many scientifically educated chemists had been turned out, chiefly by the German laboratories; but they had mostly to accept positions and salaries corresponding to the low estimation in which the profession of chemistry was then held at most chemical works.

The time I mention, saw, however, the commencement of a better era. Just about that epoch the new industry of coal-tar colors, which had commenced with the discovery of Perkin's mauve in 1856, began to assume larger and larger proportions. It had become abundantly clear that that industry could be carried on and extended by none but scientifically trained chemists; more than that, it soon became apparent that an elementary knowledge of chemistry, such as had been thought quite sufficient for practical purposes, would not do here; that chemists were required conversant with every recess of their science, and trained not merely to receive what others had discovered, but to think independently, to strike out new ways, and to enlarge the domain of science. Men really capable of doing this found an abundant field at the color works, and naturally a demand for good chemists sprung up which was soon overtaken by the unremitting supply flowing from about thirty German and Swiss universities and polytechnic schools. The men who could not find places in the coal tar industry overflowed into other domains of manufacturing chemistry, and soon enough it was found that men of that stamp were after all far more valuable than the old "testing slaves," as they were sometimes ironically called. The operations of manufacturing chemistry in most of its branches assumed quite a different face under the light shed upon them by science, which transformed them from a string of

merely empirical rules into a carefully elaborated and constantly checked system. The difference, both in the quality of the articles and the quantitative yields between our time and thirty years ago, is simply marvellous in many branches of manufacturing chemistry, and nobody dreams of denying that this has been brought about by the firm hold science has now got over that industry.

There is no more need of preaching nowadays that a devotee of technical chemistry must be a good scientific chemist to begin with. True, not every student needs or will penetrate to the more profound depths of science; but so much is universally granted that during his college career he must enjoy the fullest opportunity for this, and that consequently not merely the universities, but the polytechnic schools, and other institutions of the same character, as they exist in this country under various names, must be furnished with first-class teachers and first-class laboratories for general chemistry. Nor can there be the slighest doubt that a good knowledge of physics, mathematics, mineralogy, and geology should be acquired by a technical chemist, not, of course, to the same extent as chemistry itself, but still in a sound manner, not as amateur work. The biological disciplines will never be wanting at such institutions, and a knowledge of them is certainly useful and becoming for every educated man, let alone a man of science, but it would be an exaggeration to say that they are indispensable to a technical chemist as such, and they are often entirely left out in his curriculum.

Strange to say, here many students and even many institutions stop. The young men leave college, well grounded in chemistry and the allied sciences, but entirely or at least almost entirely ignorant of technology, of mechanical engineering, and of mechanical drawing. This is the case at all German and at most other universities, from which we must here carefully separate the polytechnic schools, and at a number of special colleges of chemistry. Although at some of these institutions some little time is given to technology, it is so little that the results of teaching it are almost nil.

What that means, nobody knows better than I. My college

studies fell in a time when the polytechnic schools were still comparatively in their infancy, and although I had from the first intended to devote myself to industrial chemistry, I thought it most natural for that purpose, when I had finished the gymnasium in 1856, to go to a university, from which I came away without any knowledge of mechanical drawing, of engineering, or of chemical technology, apart from some meager allusions to it in the general chemical lectures. Even now, more than thirty-seven years after that time, hundreds of young men enter upon the same career in the same way. Those of them who either turn over to pure chemistry (whose number must always be very small) or who are lucky enough to find entrance in the scientific laboratory of a color works, or else who are content to be confined for ever in the laboratory of another kind of chemical works, without a chance of rising to the management, will have done quite right in having carried on their studies at a university. But those who ever mean to rise to the position of superintendent, and to get to practical manufacturing work as soon as possible, will meet with the same difficulties I did. They will soon become conscious of their utter ignorance of the means by which manufacturing processes are carried out on the large scale; they will be constantly put to shame by men or even youths of infinitely less learning, but familiar with the working process; they will commit blunder after blunder when left to themselves, and still worse ones when they try to realize improvements which they have conceived, and which may possibly be quite right in principle; they will not even be able to express what they want to an engineer or furnace builder, since they cannot make or even properly understand technical drawings. Some men, when thus thrown upon their own resources, by dint of natural ability and by long and painful labor, get the better of all these drawbacks; but many others do not succeed in their endeavors, and they have either to pass over to some other career or else they remain locked up in inferior places, no better than those of the "testing slaves" I have spoken of.

Far better on the whole is the lot of those young men who have acquired a knowledge of technology and engineering. It takes them much less time to be at home in any factory where

they may have found a position. No previous teaching at any technical school can get them far enough to enable them to instantly take the manufacture in hand and carry it on like those who are accustomed to do so. But they have been taught to *think* and to *see* matters in a technical light; they know where to look for important points essential to the success of operations on a large scale, and they know how to translate any ideas of theirs into reality by such means as are suitable for factory operations. They will, of course, not be entirely exempt from mistakes; but their blunders will hardly ever be so gross as those of their colleagues who have received an exclusively scientific teaching.

A training of the kind just sketched is not, and cannot be given at an ordinary university, but only at institutions set apart for that purpose, such as the polytechnic schools, in Europe, and the various institutes of technology existing in this country. Strange to say, the hitherto greatest of all industrial nations, England, is altogether devoid of efficient institutes of the kind; and although for many years past this deficiency has been clearly recognized, although the undeniable comparative decline of some important branches of industry, in England, has been traced to this cause, and although there has been no lack of royal or municipal commissions, of public discussions, and even of large expenditure for remedying this state of things, very little has been effected in that direction. Unfortunately for England, her splendid achievements in all realms of mind and matter have created there a feeling of innate superiority over all other nations of the world, more quiet than the loud self-assertion of the French as the "*grande nation*," which professes to march in the van of civilization, but perhaps even more deep-seated and resolute. This feeling produces a strong undercurrent in English thought which has hitherto paralyzed all useful action in the quarter I am speaking of. The majority of those who have ultimately to decide on matters of technical education have the quiet conviction that, in spite of all the lamentations about the decline of commerce and the uprising of other nations in industrial matters, it is quite sufficient to trust to English common-sense, pluck, and perseverance, which with certainty will tide the

country over any temporary reverses, and triumph over all these foreign shams.

Nobody can have greater admiration for the sterling qualities of the English character than myself. I have spent a dozen of the best years of a man's life in England. I have become a loyal British citizen, and an English author. But it is precisely my sympathy for my adopted second fatherland which makes me mourn that fatal blindness to the defects of English technical education prevailing in that country. I will not speak of the object lessons which this country is daily giving to England, for instance of the fact that the production of that specially British article, iron, is now considerably greater in the United States than in Great Britain, that coal will soon follow suit, and that American machinery of many descriptions has asserted its superiority over English machinery in many important cases. All this is well known and is, however reluctantly, conceded in England; but the English people comfort themselves to some extent with the idea that America, on the one hand, enjoys immense natural riches and facilities accounting for her most signal industrial triumphs, and that, on the other hand, the Americans are Anglo-Saxons like themselves, flesh of their flesh and blood of their blood. It is surely unnecessary to point out the fallacy of the latter argument in a city where born Americans form only a fifth or a sixth of the population, and only a minority of those born Americans are of purely Anglo-Saxon descent. It is very often forgotten on the other side of the ocean that community of language is something very different from identity of race, and just in commercial and industrial matters both the good and the less favorable features of the American and those of the English character are very different. But it is unnecessary to pursue this side of the question any further. Those Englishmen who hold to the firm belief in the innate industrial, colonizing, political, and even physical superiority of their race over all others forget that all this is of very recent date. The Anglo-Saxons had conquered Britain more than a thousand years, and the Normans more than five hundred years, before England possessed a mercantile marine or navy to speak of. Four hundred years ago the German Hanse-towns were im-

mensely superior to England as maritime powers, and much more recently this applied to the Dutch. The office of the Hanse-towns, in London, was called the Stahlhof, because in the middle ages no iron or steel was made in England, and the importation of those articles from Germany formed a very important branch of trade. The blast furnace and the cementation of steel have been brought into England from Westphalia, the textile industries from the Netherlands. It is barely 150 years since England has taken the lead in these industries. How can Englishmen be blind to the thought that that lead may pass away from them, unless they make the same efforts as other nations to keep abreast with all advances of science?

Allow me to give you a very striking example of the novelty of English superiority in the field which is most familiar both to my hearers and to myself; I mean the alkali trade. The name Leblanc at once recalls the fact that the manufacture of soda from common salt was invented in France, but few Englishmen will realize the further fact that it took thirty-five years before England entered the race in this field, while numerous alkali works had been erected in France and elsewhere in the mean time. It is true that in England the alkali manufacture was impossible, so long as an enormous duty weighed upon the salt; it is equally true that immediately after this incubus had been removed, the alkali manufacture sprang up in Great Britain, and in a very short time left all other countries far behind in that line; it is true that this was not merely due to favorable external circumstances, such as the cheapness of salt and coal, and the easy communication with the sea, but perhaps quite as much to the long string of English inventions which have made the English methods of alkali manufacture the pattern from which all other nations have immensely profited. Nobody will more heartily acknowledge than I how much honor and gratitude the whole world owes in that respect to British inventive genius and British enterprise. But that cannot obliterate the fact that, on the one hand, the first British alkali works is less than seventy years old, and that, on the other hand, new methods have already partly superseded those worked out in England, and partly threaten to do so even more in the

future. We behold here a strange turn of the wheel of fortune. The invention of a Frenchman, Leblanc, has laid the foundation of England's greatness in the alkali trade; but an English invention, the ammonia soda process, could not be worked out into a practical process in that country, in spite of many endeavors, and it was left to a Belgian, Solvay, to do this, and to reintroduce the process into England, where it is now carried on according to Solvay's method. It is notorious that the English alkali trade is no longer rapidly expanding, while that of the other industrial nations has made enormous strides. Customs' duties and other external circumstances partly account for this; but a very important part is also played by the more careful scientific training of the managers and chemists in the other countries, exceptions on both sides of course, notwithstanding.

How the Germans have wrested the most brilliant of all chemical industries, that of the coal tar colors, out of the hands of the English, in whose country the first discovery of these colors was made, and which had to supply all the raw materials for them, is an often told story, which I need not repeat here.

All this (I could give many more examples of the same class) further confirms my opinion that no nation, whether the American, or the English, or any other, has a right to boast of being forever in the van, and to look down upon other nations as innately inferior to itself. Natural advantages of situation, mineral wealth, inventive genius, accumulated capital, an enterprising spirit, are all enormously important factors in creating and extending industries, but they are not omnipotent, not even if all combined; the victory over all these accidental or inarticulate forces will ultimately fall to the scientifically trained human mind; just as the engineer in charge of a large steamer holds in subordination not merely all the brute powers of fuel, furnaces, and machinery, but also a large number of human beings, immensely superior to him in bodily strength, but inferior in knowledge.

Well, how is a first-class engineer brought up? Merely on a knowledge of the physical and mathematical theorems concerning the action of steam and the laws of motion? Certainly not. Nobody would expect such a man to be able either to

build or to work an engine. He must be brought face to face with the hard facts of reality; he must know all about casting, forging, and other ways of shaping metal; he must know a great number of practical points indispensable for designing machinery, and too many other matters to enumerate here. And it is just the same with a manufacturing chemist. If he enters practical life, trusting merely to theoretical knowledge, and to such practice as he has gained with glass, porcelain, and platinum vessels in a laboratory, he is at first as helpless as a child, and he must begin at the beginning, picking up what he can on his way. Some people manage to do this very fast, and it is just to this "practical sense" that the English system of education leaves the students of chemistry; but, I say it with the fullest conviction, it is decidedly wrong there. The time is past when the crudest of all machinery would do for chemical purposes, and when chemists could try to translate their laboratory operations into manufacturing work by merely magnifying the apparatus and substituting one material for another, in which attempt they only too frequently broke down. All this has become the subject of special studies. A manufacturing chemist of first-class standing must nowadays know almost as much about the strength of materials as an engineer, and he must add to this a knowledge of the behavior of all sorts of metals, stone, earthenware, wood, of various coatings, of joints made in different ways and so forth, against the action of ever so many chemicals under varying conditions of concentration, temperature, and pressure. He must know how to produce heat, and in many cases cold, to the necessary degree in the most efficient and economical way. The construction of furnaces of all kinds belongs to his special domain. He must know how to design large vessels of various materials, both open and closed, with or without agitating machinery adapted to special requirements. He must employ presses, pumps, drying apparatus, having regard to what will answer not merely in the engineer's workshop, but under the special conditions of chemical attack and of high temperatures. The arts of disintegration, evaporation, filtering, distilling, fusing, the action of gases upon liquids and solids, the heating under pressure and other operations con-

stantly carried on in chemical works have been so thoroughly developed as to amount almost to special sciences. One of the most distinguished men in the domain of chemical technology, who at the same time would have done honor to any chair of pure organic chemistry, and who more than any other living technical chemist represents the theoretical element in technology, Heinrich Caro, formerly director of the Badische Anilin und Sodafabrik, in Ludwigshafen, in a lecture delivered last year before the Berlin Chemical Society, distinctly declares that chemists for the actual work in a chemical factory (Betriebs Chemiker) cannot receive their training for the above requirements at the Universities, but only at the polytechnic schools, and this judgment has all the greater weight, as Dr. Caro was formerly of the opposite opinion, *viz.*, that at least at such large works as theirs it was best for the chemists to receive a purely scientific training, leaving the constructing work to the engineers appointed at the same works, an opinion which he has seen reason to change after prolonged experience with a large number of chemists from both universities and polytechnic schools.

Nobody indeed who looks at the present state of chemical industry with an unprejudiced eye can deny that a mere training in theoretical chemistry is as unable to cope with the competition to be met with in the rest of the world, as is the formerly universal rule-of-thumb management. We must needs teach our future chemical manufacturers how chemical operations are and ought to be carried out on the large scale. To accomplish this, we must approach the subject from various sides. We must in the first instance teach our students at least the elements of mechanical engineering, of building construction, and of furnace building. This supposes a much better knowledge of mathematics than chemists formerly used to possess, as well as some practice in mechanical drawing. We must further introduce them to a description of the various classes of work they meet with in their career. This should be done in different ways. At all events the leading chemical industries ought to be described, going into all essential details of apparatus, and thus serving the double purpose of a preparation for those in-

tending to enter that special field, and of giving to all others important suggestions how the appliances invented for one manufacture may be used in another, possibly entirely different from the first. Many of my former students who are now employed in the industry of coal-tar colors, or in dyeing and tissue printing, have told me how useful to them has been the description which they received as students of the apparatus employed in the manufacture of heavy chemicals. The reverse is just as possible, and actually met with. Thus thirty or even twenty years ago the use of centrifugal machines and filter presses was almost unknown in the alkali and chlorine manufacture; nowadays it is quite common. For another very practical reason it is necessary to offer at a technical college instruction in all the more important branches of technical chemistry, *viz.*, because such a college should enable all its students to take situations wherever they find them open. This applies to the great majority of students, although there is always a number who go to college with a specific purpose, principally those connected with manufacturers whose works they are destined to enter after finishing their studies. I cannot therefore approve of the plan proposed by an Austrian professor, according to which each polytechnicum is to cultivate a separate specialty—say sugar making, or brewing, or alkali making, or dyeing, or color making, and so forth—with the idea that a youth of eighteen years, before entering on his academical career, should absolutely fix what special manufacture he is to devote himself to afterwards. Suppose he has studied four years with the entire object of becoming a sugar manufacturer, but at the end of that time it is seen that that trade is declining, or has migrated elsewhere, or that the supply of sugar chemists is largely in excess of the demand. What can he then do but throw up all he has studied and begin over again on a different line? If he has prepared himself less specially, but more universally, he will probably not be quite so useful at a sugar works for the first few months, but he has the chance of taking to any other manufacture where there is a vacancy, and to pick up whatever situation comes in his way.

I certainly cannot approve of the other extreme, introduced at the Ecole Centrale in Paris, where all the students, whether

they mean to follow the profession of civil engineering, of mechanical engineering, or of industrial chemistry, are taught exactly in the same way and receive instruction both in mechanical and chemical subjects. I do not know whether that system produces good engineers; but I am told it does not produce good chemists, and I can readily believe it.

I should also like to correct a mistake, not infrequently met with, *viz.*, that the teaching of chemical technology is of comparatively little value, because the professors themselves generally are not acquainted with the very last phases of progress made in the manufactures, seeing that there are constantly new inventions made, many of which are kept secret, or are very imperfectly described by patents. This is perfectly true, and yet it is of very little importance. No teaching of real or imaginary trade secrets would enable a mere book or laboratory student to carry on real work on a large scale; only practice itself can do that. But that practice will be all the more quickly and thoroughly acquired, the more the student has heard of technology generally and of the special branch to which he devotes himself afterwards. Any fresh improvements he finds applied when entering a manufactory will be quickly grasped by one who enters upon his practical work, armed with such general preparation as has been described above, which has taught him to think and see matters in a technical light, as I have expressed it above.

There are some subjects which are common to all chemical operations on a large scale, and which ought to be learned by every student. The technology of water and of fuel are the principal subjects in question, and the latter especially opens out a large field, embracing the construction and working of heating appliances of all kinds. These, together with the elements of engineering and building construction on the one hand, and with the thorough study of theoretical chemistry and the concomitant sciences of mathematics, physics, mineralogy, and geology, and lastly with practice in the chemical and physical laboratory and at the drawing board, ought to fill the first years of the study at a technical college. The last years ought to be devoted to chemical technology proper, and to a special study of

such subjects as have not been sufficiently mastered before, or as are likely to form the main occupation of the student in later life.

The whole study is generally crowned by the obtention of a degree, in Germany either a "diploma," or the title of Ph.D. The latter, owing to the jealousy of the old universities, cannot yet be conferred by the polytechnic schools themselves, but it is very frequently earned by their students afterwards. I have found the greatest possible benefit to arise from this system of "diploma examination." A student, instead of losing himself in a specialty, and being too much absorbed thereby, to the detriment of his general scientific and technical culture, or of falling into habits of laziness and dissipation, or else of becoming an exclusive devotee to athletic sports, is compelled to concentrate his energies once more on all the more important branches of his life-studies, and to carefully rehearse what he has once learned, but much of which he will have forgotten. Taking human and especially youthful nature as it is, there is no denying that mere abstract considerations of what may be good for a man's future are not sufficiently powerful to counteract the forces, both good and bad, which tend to draw a student away from his work, and that it is immensely better to hold out to him an immediate aim to strive for, in healthy competition with his fellow students. The German polytechnics are in this respect less fortunate than our Swiss institute; in the former only a small minority of the students go in for the diploma, whereas with us most of the students enter with the purpose of ultimately obtaining the diploma. Many of them drop off on the way; some others, in spite of all exertions, do not reach the goal, but about half of the total number of students leave the school, not merely in possession of a piece of stamped paper, but in that of all the additional knowledge they have acquired in quest of that paper, and which they would not have got without such an inducement. It is a great satisfaction to our institution that its diploma is eagerly sought, and hard work bestowed upon it, by nearly all the sons of wealthy manufacturers, who have been born with a silver spoon in their mouth, and whose future places are absolutely secure to them without a diploma;

but these young men are well under the sway of that healthy spirit of doing work which prevails at our institution, in consequence of the great value attributed to the diploma. Most of these wealthy young men are ashamed of standing lazily by, while their fellow students strain every nerve for the diploma; they want to show what mettle they are made of, and they therefore go in for the diploma as well, to their lasting benefit in more ways than one.

The diploma examination in our case comprises a full knowledge of general inorganic and organic chemistry, to the same extent as the universities require for the degree of Ph.D., further, of mechanics, physics, and mathematics, including the elements of the calculus, and at least some of the departments of natural history. In the field of chemical technology the general chapters are compulsory, but the candidate has the option of being examined in a number of special chapters according to his choice; further in the elements of engineering and building construction. Moreover, each student must do a considerable amount of special laboratory work extending over a whole semester, by which he proves his skill in all departments of chemical analysis and in preparing any chemical substances described in chemical literature or in patents. For the diploma itself we do not require any difficult research work; but most of our graduates aspire to the title of Ph.D., and for this they are obliged to do substantial research work which generally keeps them in the laboratory about a twelvemonth over and above their proper college time. When they have accomplished this they have not merely got an ornamental title, but they have, what is certainly of greater importance, acquired such a mastery of our science that we can confidently dismiss them into practical life. Even then, it is hardly necessary to say, great differences exist among them. Some remain in modest situations all their lives, but others rise quickly to higher places, every one according to his abilities and to his deserts. The successful men, without a single exception that I know of, look with warm gratitude on the institution where they have received their scientific training and which has raised them above the hap-hazard luck of rule-of-thumb experience as

well as above the one-sidedness of autodidactic studies—both of which are excellent as far as they go and not to be despised by any means in themselves, but neither of which can cope with a carefully devised and conscientiously carried out scheme of training the mind for the profession of a technical chemist such as I have had the honor of laying before you. Nobody is more conscious than I that at no existing institution has the beau ideal of such a scheme as yet been attained, but at Zurich we believe that we are, on the whole, on the right way, and that we shall do well not to exchange our plan for a totally different one, but rather try to improve it on the lines on which we are now working.

THE NEED OF STANDARD METHODS FOR THE ANALYSIS OF IRON AND STEEL, WITH SOME PROPOSED STANDARD METHODS.[1]

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MUCH might be said upon the desirability, nay even necessity of different chemists being able to get concordant or agreeing results, when working in the same field, or upon the same sample. If two chemists happen to be engaged in an investigation, or research in the same field, it is obvious that the value of any conclusions, which they may reach, is very small, if the analyses obtained by each, do not agree within reasonable limits of error. Or again if chemical analyses are to be used as the basis of commercial transactions, and the chemist in the interest of the buyer, does not get the same results as the chemist in the interest of the seller, it is clear that the transaction can only be brought to a conclusion by arbitration, or mutual concession. Of course what is desired in every case is the truth; but if two chemists working in the same field, or on the same sample, do not agree, where is the truth? That there is a difficulty of this kind in the chemical analysis of iron and steel at the present time, we are confident few who are well informed on the state of affairs will be bold enough to deny. And it is not difficult to see why there should be discrepancy between chem-

[1] Read before the World's Congress of Chemists, August 21, 1893.