SCIENCE

NEW YORK, JUNE 24, 1892.

AIMS OF LABORATORY TRAINING.[1]

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It is only within a comparatively recent period that the chemical laboratory has attained the prominent position it now occupies in colleges and schools of science. Indeed, in its present development, with facilities for practical study in inorganic and organic chemistry, both elementary and advanced, thirty years ago there was not a single laboratory in this country, and few elsewhere. Probably the earliest attempt in this country to give systematic laboratory instruction, to classes of any magnitude, was made in 1865 at the Massachusetts Institute of Technology. Analytical chemistry had previously been taught to a limited extent in a few institutions for the training of analytical chemists. In organic chemistry, or chemistry of the carbon compounds, instruction was first given by lectures and laboratory work in 1872 at Harvard College. On account, it may be, of the slight attention that technological and applied chemistry has received in this country as compared with Europe, few courses of study at the present date, even in the most prominent schools of science, include practical training in this subject.

In speaking of the functions of the modern chemical laboratory, it should be considered as an important factor in liberal education as well as a means of preparation for scientific pursuits; and we shall doubtless find our attention fully occupied in describing the principal aims of a laboratory devoted to pure and applied chemistry, without including the no less important work of laboratories in the special fields of agricultural, medical, biological, and sanitary chemistry. That a thorough training in general and descriptive chemistry should now form an essential feature in a liberal course of study, probably no one will venture to doubt. To the man of business, a knowledge of the composition and properties of materials is important as stock in trade. In the practice of law, decisions often involve a consideration of chemical changes as well as the composition of various substances. To men engaged in literary pursuits, in political life, or in the ministry, questions are frequently presented that require for their intelligent consideration a certain knowledge of chemistry. But especially to men engaged in any scientific pursuit, a good knowledge of substances, their occurrence, properties, and relations is indispensable. A chemical laboratory is therefore called upon to provide for each student broad and thorough training in the elementary principles of chemical science, including the composition and properties of matter. As to the best method for such instruction there may have been certain differences of opinion, but I think it is now universally conceded, that, while it is essential that the student should commit to memory important facts and principles as they are presented to him at the lecture table, it is in the laboratory that he recives the discipline of the hand and eye, and in methods of reasoning, that enables him to acquire the true spirit of scientific thought, and to retain a remembrance of facts that otherwise he would soon forget.

[1] An address delivered at the opening of the new chemical laboratory of the Case School of Applied Science, May 12, 1892.

As a foundation for more advanced study in science, especially in the various branches of chemistry, the analytical laboratory is an important adjunct. It is here that the student should not only receive most careful training in the methods of correct manipulation and close attention to the details of analytical processes, but he must acquire familiar acquaintance with the many analytical operations that he will be called upon to perform in the practice of his profession. It is unfortunately true that students are often content with the acquisition of sufficient knowledge to enable them to obtain positions as analytical chemists. Such training, however, is inadequate for the demands of the present day, since chemists are frequently called upon to undertake problems in technical chemistry that require broader qualifications. A very considerable part of manufacturing operations in industrial chemistry are based upon the properties and reactions of the carbon compounds, and any course of instruction in applied chemistry must be regarded as seriously deficient if it does not include thorough discipline in organic chemistry.

In a preparatory course of four years in chemistry, then, if thorough drill in the elementary chemistry of the first year is followed by instruction in analytic and theoretical chemistry, extending through two years, with an equally extended course on the carbon compounds, the student will be prepared in the fourth year to appreciate a comprehensive, practical course in industrial and applied chemistry. Incidentally, in the more advanced subjects, he should form at least some slight acquaintance with methods of study and investigation outside of the ordinary routine. Indeed, ability to undertake original problems such as are constantly presented for solution in industrial operations has a pecuniary value that is well recognized. It is in fact the basis of many commercial enterprises.

With this brief outline of what may be regarded as the principal aims to be kept in view in the management of a laboratory, perhaps it will be of interest to examine into the causes that have led to the recent development of laboratory methods. Although, as already explained, these methods have been largely developed within thirty years, it should not be understood that the foundation for them has been laid within this period. On the contrary, a knowledge of certain processes involving chemical principles conducive to the comfort and convenience of mankind is older than history itself. Metallic implements and coins of the bronze age indicate that the prehistoric races were acquainted with methods for the reduction and alloying of metals. That the ancient Egyptians understood the preparation of indigo and its application to dyeing is shown by the presence of tissues dyed with this substance on mummies taken from their oldest tombs. The extraction of turkey-red from madder was early known to the Egyptians, Persians, and Indians, and later to the Greeks and Romans. It would be impossible in a limited space to describe the numerous discoveries of the early ages, or the multitude of facts collected by the alchemists in their endeavors to discover the philosopher's stone which would enable them to transform the baser metals into the nobler, and in their search for the *elixir vitæ*, a panacea for all the ills of man. Notwithstanding this vast accumulation of facts, no efforts were made toward a systematic arrangement for the basis of a science, until late in the last century the foundation of chemistry as an exact science was established mainly through the labors of such men as Priestley, Scheele, Cavendish, and Lavoisier. To the latter especially is honor due for introducing the balance as a means of conducting chemical operations on a quantitative basis. The first great event of this period was the discovery of oxygen gas as a constituent of the atmosphere by Priestley, and it was soon followed by a determination of the composition of water, for which Cavendish receives credit. The classic experiment of Lavoisier, in which he ascertained the quantitative proportion of oxygen in the atmosphere, was the beginning of definite ideas concerning the composition of matter. The earlier part of the present century was honored by the brilliant researches of Sir H. Davy, Gay Lussac, Dalton, Berselius, and other investigators, which contributed so largely toward the foundations of modern chemistry, and which resulted in the law of gaseous combination of Gay Lussac, the laws of definite and multiple proportions of Dalton, and the law of Avogardro relating to the molecular composition of matter. These deductions were followed by many theories, which were later modified or replaced by others as new facts were discovered, until there has resulted a substantial system of nomenclature and theoretical principles, sufficient at least for working hypotheses, and sufficient to explain the greater portion of well-authenticated facts. Of recent contributions to chemical theories probably there are none of greater service in classification and arrangement, or that afford better opportunities for speculative research, than the periodic law which we owe to Newlands, Lothar Meyer, and Mendelejeff.

The application of chemical principles seldom precedes a good understanding of the principles themselves. Operations may indeed be carried on in a haphazard fashion according to empirical rules, but the results are apt to be unsatisfactory. We should therefore expect to see the development of technological chemistry following in certain lines the general advancement in scientific knowledge, and it is not difficult to understand the marvellous growth in applied chemistry during the last fifty years. Probably the most important branch of chemical industry that has ever been created is the manufacture of sulphuric acid. There is scarcely a commercial process involving chemical changes that is not dependent directly or indirectly upon the use of this acid; and, while at present the yearly production amounts to several million tons, it is only one hundred and fifty years since the lead-chamber process was first devised, and only one hundred years since Chaptal introduced the improvements for the continuous process now in use. A scarcely less important branch of industrial chemistry is that of bleaching, which resulted from the application by Berthollet, in 1788, of the properties of chlorine, already discovered by Scheele, in 1777, to destroy certain coloring principles without injury to the vegetable fibres. The manufacture of illuminating gas, which is such an important factor in modern life, was first attempted in 1798, and outside lighting with gas in 1812.

Many other illustrations might be presented to show how recent is the growth of technological chemistry, but it is in the domain of organic chemistry that the development has been most wonderful. Here is a quantity of urea, which, as everyone knows, is a constituent of various fluids in the circulation of animals. In 1828 the illustrious chemist Woehler obtained this substance simply by heating ammonium cyanate, and it was the first instance of the artificial preparation of a substance of organic origin. This was the beginning of synthetic organic chemistry. In attempting to illustrate what has since been accomplished in this field, we will select as a single example the multitude of substances that have been obtained from coal-tar, a bye-product in the distillation of coal for illuminating gas, and we will ask your attention to this chart, which shows a graphical arrangement of many of these compounds in their genealogical descent from coal.

With this brief review of the development of the chemical laboratory and the purposes of laboratory instruction, a question will doubtless arise as to its future efficiency in scientific education, and especially as to the part it will be expected to perform in promoting the material interests of society. While the utilitarian principle of the latter aim would naturally become the more important feature of laboratory training, in the school of science it should never be forgotten that whatever of mental culture or discipline the student receives must be derived from the courses of study that are intended as a preparation for his special vocation. Constant vigilance is therefore necessary to restrain the natural disposition of the average student, which leads him to avoid all possible mental exertion and to concentrate his energy upon the mechanical side of routine laboratory practice.

The elementary courses of the freshman year constitute the formative period, and if correct habits are early established, the more advanced work of later years will be undertaken in the true spirit of scientific study. But if, on the other hand, the student falls into careless or indifferent methods, it is rarely that he recovers from them. Concerning the preparation that must be provided to meet the demands of the future in applied chemistry, the foundation will be chemical analysis. No process involving chemical changes can be conducted intelligently and economically unless it is carefully controlled by a complete knowledge, not only of materials employed and valuable products obtained, but also of slags, gases, and all waste products. In the great smelting works in Europe ores are purchased for everything of value they contain. If a gold or silver ore contains, for example, arsenic, antimony, nickel, zinc, and bismuth, in appreciable quantities, the process of smelting will have due reference to the separation of every one of these constituents. In America, with enormous stores of the richest ores and supplies ready at hand, miners and manufacturers have found the principal constituents too profitable to waste time in the recovery of bye-products. Many a western ore-dump will richly repay for reworking to recover what at first was thrown aside as unprofitable material, and in several directions this fact is even now receiving attention. If the price of coal in Cleveland was twelve dollars per ton, as it is in Switzerland, instead of two dollars per ton, the price now paid here, instead of an atmosphere laden with valuable fuel, the process of combustion would be controlled so that nothing but legitimate constituents of smoke could escape. Important changes in this respect, however, are in progress, and manufacturers are appreciating more fully the importance of accurate scientific knowledge and the services of skilled analysts.

Allusion has been made to a higher field for the employment of educated chemists than that of analytical chemistry, and it is one in which we may expect extensive developments. It is a familiar fact that many materials in daily use can only be obtained by importation from other countries; but the immense quantities of certain manufactured products annually imported may not be generally appreciated. Notwithstanding our abundant supplies of crude materials, with cheap fuel in unlimited quantities and a ready market with an increasing demand, we continue to pay enormous sums for imported products that should be produced at home. The causes of this condition of affairs should not be far to seek. That it is not from lack of enterprise is evident from the readiness with which novel schemes are able to secure financial support. It is generally understood that the principal hindrance to home production is the high cost of labor as compared with prices paid in Europe, and it is sometimes hinted that it is in part due to a lack of thoroughly trained scientific specialists. As regards the higher cost of manual labor here, it would seem that the difference must be less than the cost of importation, which includes the tariff. If this state of affairs is in any degree due to a dearth of scientific men capable of conducting manufacturing operations, and the scientific schools cannot produce such men, truly the schools are not taking advantage of their opportunities. That such a feeling exists with some manufacturers is evident from the fact that they send abroad for their chemists. Whether better talent is secured than can be obtained at home may well be regarded as an open question. Perhaps a still broader view of the situation is necessary; it may be that our invested capital is too busy in securing lucrative returns from business enterprises connected with the development of our natural resources to undertake operations that require skilful management to yield even a fair profit, and that we are therefore better content at present to pay importers' prices than to manufacture ourselves. If this be true, we must wait with patience for a change that will surely come.

Altogether the outlook for the immediate future is encouraging. In several directions the manufacture of chemical products has begun, and others will follow. There are certain lines along which rapid development may evidently soon be expected, and one of the most promising is sal-soda. Until quite recently the Le Blanc process, which was invented in France to manufacture soda-ash when the supply from natural sources was largely cut off during the French Revolution, has supplied the world since early in the present century. In utilizing all bye-products the great Le Blanc works of Europe have been able to produce soda-ash at a trifling cost. A Le Blanc plant has never been established here, and probably one never will be. Such a plant requires an immense capital, and, besides, a combination of coal, salt, and limestone, that can be found close at hand in but few localities. Within a few years another method, known as the ammonia-soda process, has been put into operation in Europe. The first-cost of a plant for this process is not large, and since it furnishes a purer product than the Le Blanc method, it will probably supply a considerable portion of the sal-soda of the future, especially in this country. The newer method has the especial advantage that it forms bicarbonate of soda direct and very pure. Two plants for this process have been erected here, one of which has been in operation at Syracuse, N.Y., for several years, and the other has recently been erected in Cleveland.

As another illustration of the possibilities in store for us, I will ask your attention to this lump of porcelain clay that came from a large deposit in Maryland, and there are large deposits in other localities. This clay is quite as pure and quite as well adapted for the manufacture of the finest porcelain as any in use in France or Germany. Of the other materials necessary in this industry, this quartz and this feldspar are just as pure, and we have extensive deposits of both. We have also cheap fuel, and yet we pay a tariff of forty-five per cent *ad valorem* for English, French, and German porcelain, besides paying the potter a fair price for his labor. All such porcelain as we have before us is made at the Royal Berlin Porcelain Factory, where it has been shaped, baked, and decorated by father and son for one hundred and thirty years. Who will venture to predict the possible developments in our own country during an equal period in the future? At present we make certain kinds of ware, but no one needs to be told the difference between it and the elegant Dresden, Sevres, or Royal Worcester.

A single additional example will doubtless suffice to show what we may reasonably expect in the future. The production of artificial dyes and colors from coal-tar has assumed enormous proportions since it was begun thirty years ago. Graebe and Liebermann invented the process for the preparation of artificial alizarine in 1869, and in 1880 it was estimated that this invention had saved $20,000,000, the additional cost if the same quantity of this dye-stuff had been obtained from natural madder. At present there are twelve large alizarine factories in Germany and England, but not one in the United States. The annual production of anthracene paste, the source of alizarine, is three thousand tons; but not a single pound is manufactured here. Of the total output of alizarine, 2,154,930 pounds, valued at $358,882, are consumed in this country. The estimated daily production of aniline and similar dyes, in England, France, and Germany, is estimated at 35,000 pounds, and in 1890 importations into the United States were valued at $1,787,558. Naphthalene, another constituent of coal-tar, until quite recently was practically a waste product; but thorough study of the naphtols, their sulphonic acids and other derivatives, has revealed the beauty and permanency of the numerous colors that may be derived from them, and they are now produced in considerable quantities. One factory in this country holds patents for the preparation of colors from naphtol-sulphonic acids. Yet with this condition of our manufactures we have the largest deposits of coal in the world, and the products of its distillation are collected in immense quantities. These products have even been sent abroad to be manufactered into colors and returned to us for consumption at a very high cost.

A clearer insight into the extent of our importations of products that might be produced at home may be given by a review of quantities and values selected from the Annual Report of the Bureau of Statistics on Foreign Commerce and Navigation for the year ending June 20, 1890: —

	Pounds.		Values.
Potassic chlorate	2,442,775		
" dichromate	1,166,00)		
" ferrocyanide	849,070		
Total soda, including ash, salt-cake, bicarbonate	334,531,050	Duty	$5,099,327 $1,688,071
Sodic hydrate	79,481,923		
Kaolin (tons)	27,136		
Total clays (tons)	336,488		
China and Pottery			$4,791,474
Glassware			$7,351,570
Glucose	911,573		
Iron, steel, and manufactures of the same		Duty	$43,493,074 $18,384.175
Carbolic acid	522,237		
Oxalic acid	1,973,050		
Alizarine, artificial and natural	2,155,020		
Manganese binoxide	22,587,848		
Milk-sugar	339,684		
Alum	6,822,035		
Ammonium salts	6,911,323		
Coal-tar colors not enumerated			$1,813,771
Dextrine	9,183,566		
Glycerine (Crude)	11,811,308		
" (Refined)	210,545		
Lead acetate	19,000		

These illustrations are doubtless sufficient to indicate the extensive field that is open for the development of technological chemistry; and, with all deference to the aid that should be expected from the study of chemistry in the various systems of liberal education, they seem to afford convincing evidence that, in its highest efficiency, the chemical laboratory of the future should include the promotion of industries that depend upon the application of chemical principles.

NOTES AND NEWS.

THE railway which is at some time or other to traverse the African continent has been opened as far as a point near Cazengo, 140 miles from the starting-point, St. Paul de Loanda.

— A South African and International Exhibition will be opened at Kimberley in September. The processes of winning diamonds and gold will be shown; the machinery department will contain a large variety of machinery employed for mining and agricultural purposes; and the agricultural interests of the colonies and neighboring states will receive special attention.

— The British Medical Association, says *Nature*, will hold its sixtieth annual meeting at Nottingham on July 26, and the three following days. Mr. Joseph White, consulting surgeon of the Nottingham General Hospital, will preside. Addresses will be given in medicine by Professor James Cumming of Queen's College, Belfast; in surgery by Professor W. H. Hingston of Montreal; and in bacteriology by Dr. G. Sims Woodhead of the Research Laboratory of the Colleges of Physicians and Surgeons, England. The scientific work of the meeting will be done in ten sections.

— Through the courtesy of his friends, the editors of *The Scottish Geographical Magazine* have had an opportunity of perusing a diary by Mr. F. J. Matthew of a ride of 1,000 miles through a little-known part of the territory of the Argentine Republic. On Oct. 5 he started from Buenos Ayres by train, and reached Mendoza on the 7th. Thence he travelled, partly by coach, partly on horseback, to San Rafael, a distance of 210 miles. Having collected a store of provisions, the traveller set out on Nov. 16, with six mules and a man, and, crossing the river Diamante, took a westerly direction towards the Cordilleras, the route being through very beautiful scenery, for the Andes were not far distant, and the second night was passed at an elevation of 4,450 feet above sea-level. On the third day the river Atuel was reached, and two or three days later Mr. Matthew rested at the *estancia* of an English doctor living in Mendoza, where 15,000 sheep and 6,000 or 7,000 head of cattle are fed. Thirty miles from this *estancia* lies the lake Llancanelo, a narrow sheet of water several leagues in length. Two years ago part of it dried up, leaving a flat expanse of smooth sand nine miles across. Seen from the middle, this sandy plain has a bright-blue, glassy appearance, and counterfeits water wonderfully. The lake is fed by two streams, but has no visible outlet. It is said to be drained by a subterranean stream. At any rate, in the dried bed are to be seen several of those funnel-shaped depressions common in the Karst formation; their sides are encrusted with salt. The country around is wild, and the climate cool, the altitudes at which the camp was pitched being 5,600 to 5,800 feet. Game is plentiful. Herds of guanacos were often met with, and pumas are so numerous that horse-breeding is impossible, as they kill all the foals. Near Chacaico, where Mr. Matthew stayed a month, he observed eagles, condors — which are very destructive among the calves and sheep — rattlesnakes, otters, and a variety of chinchilla (probably the Alpine viscacha, *Lagidium Peruanum*). At Agua Nueva, twenty-one miles east of Chacaico, a large quantity of stock — horses, cattle, sheep, and goats — is fed by squatters, who pay a small rent for the use of the *camp* or run (*campo*). The pasture is excellent, but last year locusts played great havoc among the more tender grasses. The return journey was made across the Atuel and Salado rivers, and over the Central Pampa to Trenque Lauquen. The country, at first rocky, changed to level pampa of poor soil covered with prickly shrubs. Rain came down in torrents and swelled the rivers, so that they were difficult to cross. Water, which is scarce even among the mountains, is often not to be procured during a ride of fifty miles. Mosquitoes were troublesome, and at one camp a swarm of locusts obliged the traveller to pack up and move on. In the province of San Luis woods began to appear, and improved the landscape. Near Cochico is a series of shallow lakes of brackish water, studded all over with dry, barkless trees. For two or three days Mr. Matthew rode through dense woods, and then entered the grassy pampa, where *estancias* were more numerous, and the track well worn. Nothing but grass, reaching up to the knee of a man on horseback, can be seen the whole day long. Most of it is *pasto amargo* (bitter grass), and the sheep do not seem to thrive on it. The sheep are of different breeds — Lincoln, Merino, Rambouillet — and the cattle mostly crossed shorthorns. Trenque Lauquen is on a railway, by which Buenos Ayres can be reached in twelve hours.

— A new application of the stems of the larger-growing species of bamboo has recently been adopted in China for the manufacture of small trays and ornamental articles for export to Europe. It is known in China as bamboo sheeting, and it is said to be carried on at present only to a limited extent at Wenchow, where, notwithstanding that it is quite a new trade, about ten firms are now engaged in it. The process adopted is as follows: A length of bamboo is cut off, and then pared with an axe till it is of the thickness required. It is next planed with a spokeshave, and the thin cylinder so obtained is slit up, so that, on being opened out, it forms a sheet. A number of these cylinders, placed one inside the other, are immersed in boiling water for a few minutes, to render them flexible, and they are then unrolled and flattened out, by being subjected to pressure under heavy stones. These sheets are sometimes used for making fretwork and carved screens, fans, etc.; and the small, pale straw-colored pin-trays, for toilet tables, which appeared in the London shops last season, are apparently made from this specially prepared bamboo. It seems to adapt itself extremely well for moulding into many forms, and might be made available in this country for various kinds of veneering. The bamboo now appears to be the *Dendrocalamus latiflorus*, and specimens of the sheeting, and articles made from it, may be seen in Museum No. 2 of the Royal Gardens, Kew, says *The Journal of the Society of Arts*.

— The first sunshine recorder was the invention of Mr. John C. Campbell of Islay, and consisted of a hemispherical bowl, in which a spherical glass ball stood on a low pedastal. As the sun passed across the sky, its rays, concentrated by the ball, burned a groove in the side of the bowl. With this instrument the amount of sunshine during six months was roughly recorded, and the character of individual months was fairly shown, but the grooves of two successive days could not be distinguished from each other, the change in the sun's declination being very slight. Slips of cardboard were afterwards substituted for the wooden bowl; and in the present form of apparatus, devised by Sir G. G. Stokes, according to *The Scottish Geographical Magazine*, three brass grooves, concentric with the spherical lens and adjusted for the latitude, hold the cards for summer, winter, and the equinoxes, respectively. The cards are changed daily at sunset. This instrument is not without defects. When the sun is low it ceases to act, and at all times the slightest film of cloud, hardly visible to the eye, is sufficient to check the burning power of the sun's rays. Photographic processes have been devised by Mr. Jordan, Professor M'Leod, and others, but they are less easily managed. The Stokes-Campbell instruments have been in use since 1880, and the Meteorological Office has issued a report on the sunshine recorded during the years 1881–90. The sunniest spots in the Kingdom are the Channel Islands, which enjoy sunshine during 39.9 per cent of the time the sun is above the horizon in the course of the year. Falmouth shows the next highest record, 35.7 per cent, and along the whole coast of England from Milford Haven to Yarmouth there is no great variation. The coast naturally receives more sun than inland districts, where clouds are formed by the hills, and in towns the percentage is low owing to the smoke. As regards the monthly means, it is found that in Jersey alone does the sunshine ever attain to half the amount