Dr. Craigie from the Author

LETTER,

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LETTER

TO THE RIGHT HONOURABLE

GEORGE, EARL OF ABERDEEN, K.T.,

&c. &c.,

PRINCIPAL SECRETARY OF STATE FOR FOREIGN AFFAIRS,

CHANCELLOR OF THE UNIVERSITY AND KING'S COLLEGE, ABERDEEN,

ON THE STATE OF

THE SCHOOLS OF CHEMISTRY

IN THE UNITED KINGDOM.

BY WILLIAM GREGORY, M.D.,

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LETTER,

&c.

My Lord,

I have been induced to take the liberty of addressing your Lordship on a very important subject, namely, the state of the Schools of Chemistry in the United Kingdom, by the circumstance, that your Lordship is the head of the venerable Institution in which I have the honour to occupy a chair. But, independently of this, the high reputation acquired by your Lordship as an accomplished scholar and a munificent encourager of the arts, added to the powerful influence which your Lordship's high official station and personal character must give you in her Majesty's councils, would justify the call I am about to make on your Lordship's attention and indulgence.

Convinced that no one has the interests of science and the true welfare of his country more sincerely at heart than your Lordship, I shall make no apology for beseeching your Lordship's attention to a subject which has the most direct and powerful influence on both, but proceed at once to lay before your Lordship certain statements of fact, in reference to the great importance of chemistry to the British nation, and to the means of instruction in the practice of chemistry which are accessible to her Majesty's subjects.

In no country will the vast importance of chemistry to mankind be more readily acknowledged than in Britain. We have constantly before our eyes, in a greater degree than any other people, the innumerable applications of this science to useful purposes in our manufactures; and every one knows, that the steam engine, the safety lamp, gas light, and a hundred other inventions, are so many benefits conferred by science on mankind within the last half century.

But, even among us, few are aware of the extent to which chemical manufactures are essential to our national prosperity, and inextricably interwoven in the whole fabric of those useful arts on which our physical comfort and happiness, as well as our trade and commerce, are entirely dependent.

Your Lordship will, therefore, I trust, forgive me, if I venture here briefly to trace the history of one branch of chemical manufacture, with its applications to other departments of industry. The example I shall select is the manufacture of sulphuric acid, which has in this country reached so high a state of perfection. I shall endeavour to explain the cause of that increased demand which led to the great improvements in the manufacture of this acid, the very remarkable results which gradually flowed from its increased supply at a low price, and the important bearings of this branch of industry on the national interests.

It is particularly worthy of remark, that these results have followed in very rapid succession, and that, without exception, they have arisen from the application of purely scientific principles to the solution of practical problems;

a striking proof of the truth that the cultivation of natural science for its own sake is the only true source of useful discoveries. The problems I have alluded to could only have been solved by men who had devoted their lives to purely scientific research, and had thus established those principles of universal application which enabled them to attain the objects at which they aimed. The past success ought also to teach us, that the diligent research after new truths, however they may at first appear remote from any practical application, will yield, in course of time, practical results of equal or greater importance; that no well ascertained fact in natural science is ever barren: and that the best method of promoting practical improvements is to encourage scientific research.

In describing briefly the multiplied relations of this important manufacture, I shall avail myself of a very able anonymous article on the subject, which lately appeared in the "Allgemeine Zeitung," and has obviously been written with a view to direct the attention of the German public to the importance of the subject. Without professing to give a mere translation, I will give the substance of this paper, requesting your Lordship to bear in mind, that the whole account is given as a specimen of the effects produced by one chemical manufacture only, although that is probably the most important of all, if we except the iron manufacture.

The first great stimulus to the improvement of the manufacture of sulphuric acid was given by the announcement of a prize of 1,000,000 francs (£40,000), offered by the Emperor Napoleon for the discovery of a simple and cheap process for extracting soda from sea salt. Soda, as is well known, has been used, from time immemorial, for the manufacture of soap and glass, two products of the highest value to mankind. Indeed, the use of soap is so essential to comfort, that the quantity of soap consumed by any people may be viewed as a direct measure of the degree of civilization and happiness they enjoy. Its use depends on the feelings of comfort, nay, on the sense of the beautiful, which are inseparable from cleanliness. Where these feelings prevail, there, we may be sure, civilization and happiness are to be found. The princes, counts, and barons, the rich and powerful in the middle ages, who concealed with costly spices and odours the offensive exhalations of their skin and of their clothes, which rarely came into contact with soap, indulged, it is true, in greater luxury in their sumptuous feasts and splendid dresses than their descendants in modern times. But how vast is the difference between their days and ours, in which personal filth has come to be synonymous with absolute misery!

It is to glass, again, that the poor man owes the inestimable blessing of the free admission of light to his dwelling, even in the coldest climate. It is not easy to exaggerate the value of these two products, soap and glass, to mankind. During the war, France was deprived of her accustomed supply of barilla (the usual source of soda) and of soap from Spain, the ports of both countries being watched by the British fleet. The high price of soda, soap, and glass, consequent on this state of matters, led to the offer of the prize above mentioned; and the problem was solved by the French chemist, LEBLANC, who furnished a cheap and simple process for extracting soda from sea salt. France soon supplied herself at a cheaper rate than before; manufactories of soda, soap, and glass, arose and flourished; and the bitter feelings excited among the Spaniards by the permanent loss of a lucrative trade were not without their influence in bringing the Peninsular war to a fortunate conclusion, and in hurling Napoleon from the imperial throne.

Such were the immediate results of Leblanc's discovery; but it is painful to add, that he never received the reward he had so well deserved. The restoration occurred in the interval; the new government had more pressing debts to discharge; and it is understood that the claim has now been shut out by prescription. Let us now consider the nature of Leblanc's process.

To convert salt into soda, the first step, according to this process, which is now, with some modifications, uniformly followed, is to convert the salt into sulphate of soda. This can only be done by means of sulphuric acid, of which 80lbs. are required for 100lbs. of salt. Hence, one of the first effects of Leblanc's discovery was, to create a very large demand for sulphuric acid. It is obvious, that as soon as the government, by reducing the duty on salt, reduced its price to a minimum, the price of soda became dependent on that of sulphuric acid. This circumstance, together with the extensive demand, and the large profits realized by the makers of sulphuric acid, turned the attention of men of science to the improvement of this latter manufacture; and every year produced some new amelioration, while the price of the acid steadily fell, and the demand for it as steadily increased. Its formation was studied by the most accomplished chemists, and brought by degrees to its present nearly perfect state.

Sulphuric acid is made in vessels, or rather chambers, of lead, and so large is the scale of operations in some manufactories, that one of these chambers would contain with ease a middle-sized house of two stories. So nearly does practice in these great manufactories approach to theory, that 100 lbs. of sulphur, which, by theory, should yield 306 lbs. of sulphuric acid, do actually yield 300 lbs.

In this manufacture, the price of the product depends partly on the apparatus, partly on the price of the materials, sulphur and saltpetre; and in both, a great reduction has been effected. Till lately, the plates of lead, of which the chambers are formed, were soldered together with difficulty, by means of lead, no other solder being able to withstand the action of the acid. The operation of soldering cost nearly as much as the plates themselves; but now that the oxy-hydrogen blowpipe is used for the purpose, the expense is a mere trifle, while the operation is so easy, that a child may perform it. Again, the acid was formerly concentrated in enormous glass retorts; these were exposed to breakage, occasioning heavy loss, and destroying the furnaces; vessels of platinum are now used for concentrating the acid, and although these sometimes cost from £1,000 to £1,500 apiece, they are found, from their durability, to be a source of economy, and have materially contributed to bring about the very low price of the acid: moreover, it is the demand for platinum for such vessels that alone renders profitable the working of the Russian mines of that metal. We may see by this, how every discovery acts in many different ways, and always advantageously.

When economy had been pushed thus far in the apparatus, the price of the materials became a point of more importance than previously; that of nitre was so high, as to stimulate the manufacturer to search for some substitute, which was speedily found in the nitrate of soda, enormous beds of which cover whole plains in South America. This salt is much cheaper than saltpetre, and preferable to it for the manufacture both of nitric acid and of sulphuric acid; but besides the direct effect of cheapening these acids, the introduction of nitrate of soda, by limiting the use of saltpetre to the making of gunpowder, for which nitrate of soda does not answer, has produced the indirect effect of cheapening gunpowder, the price of saltpetre necessarily falling as the demand for it diminished. This must be, in time, a material source of saving to governments.

Finally, with regard to the chief material, sulphur, on which the price of sulphuric acid now principally depends, it is well known that our manufacturers derive nearly their whole supply from Sicily, so that Naples may be said to possess a monopoly of that article. That the trade in sulphur is highly important to both nations is obvious, when we reflect on the enormous quantities of sulphuric acid now manufactured in Britain alone. A small manufactory will produce from 250 to 300 tons annually; a large one 3,000 tons, or more: it is no wonder, then, that the late interruption to the trade in sulphur caused great uneasiness among our manufacturers; but it had another effect: the attention of chemists was keenly directed to other means of procuring sulphur, and, during the period of obstruction to the sulphur trade, it is said that no less than fifteen patents were taken out in England for recovering the sulphur from the sulphuric acid used in the soda manufacture. The restoration of the trade to its accustomed channel has postponed the accomplishment of this object; but the impulse has been given, and

Naples may ere long find good cause to regret that she ever allowed any obstruction to the trade in sulphur. We have whole mountains of gypsum and heavy spar, and abundance of pyrites and galena, all of them minerals containing sulphur, which we shall one day find the means of extracting economically; indeed, during the period above alluded to, many tons of sulphuric acid were actually made from iron pyrites. When we consider the resources of modern chemistry, it will not appear improbable, that if the sulphur trade had been obstructed for a year longer, it might by this time have been lost to Naples for ever.

These considerations are of themselves sufficient to shew that the manufacture of sulphuric acid has become a matter of national importance, were it only on account of its use in making soda; that alkali is now sold in a state of perfect purity, and at a wonderfully low price, so low, indeed, as almost to have put an end to the use of potash. The quality of glass and soap has been very much improved, and their price greatly diminished; the consumption of both articles has naturally increased in a corresponding ratio. Wood ashes, no longer in demand to nearly the same extent as formerly for manufactures, must also fall in price, and will soon be employed as one of the most powerful manures for our wheat fields.

Such are a few of the bearings of the manufacture of sulphuric acid, called into existence, or at least vitally improved, by the demand for cheap soda: but this is not all; and although it is impossible here to follow out all the ramifications of this remarkable branch of industry, I cannot refrain from pointing out one or two of its immediate results, which have not yet been adverted to.

It has already been mentioned, that sea salt, in order to yield soda, must first be converted into sulphate of soda; now, in acting on the salt for this purpose with sulphuric acid, an enormous quantity of muriatic acid is produced, which, in the earlier periods of the manufacture of soda from salt, was thrown away as worthless, so great were the profits realized on the soda; but muriatic acid contains chlorine, and no other compound of chlorine yields that body more easily or more cheaply than muriatic acid. The bleaching properties of chlorine were known, but had not yet been applied on the great scale. At first the chlorine was disengaged directly from the muriatic acid, and brought in contact with the cloth to be bleached, in the form of gas; but it was soon found that, by combining the chlorine with lime, it might be obtained in a solid form (bleaching powder), capable of transportation to any distance; hence arose a new and lucrative manufacture, of such importance, that it may safely be asserted, that, but for the discovery of the bleaching powder, the cotton manufactures of Britain would never have attained their present development: nay more, had the British manufacturers been tied down to the old method of bleaching, they could not long have competed, in the price of cottons, with France or Germany.

To bleach in the old style, the first requisite is land, and that good and well exposed meadow land. The cloth must be exposed for several weeks, and that only *during summer*, to sun and air, and must besides be constantly watered by hand. Now, a single manufactory, of moderate size, near Glasgow, bleaches, on the new system, on an average, 1,400 pieces of cloth *daily throughout the year*. Let us only consider what an amount of capital would be required merely to rent the land necessary for bleaching in the old manner this enormous quantity of cloth, in the vicinity of a large city. Let us reflect on the time and labour that would be indispensable, and we shall soon perceive that, with such burdens, the British manufacturer could not compete with his rivals on the continent, where vast tracts of fine meadow land might be had, distant from any great city, at a far cheaper rate, and in a more sunny climate. The superiority of our machinery would thus be in a great measure neutralised, were it not for the manufacture of bleaching powder, which in its turn depends on those of sulphuric acid and of soda. I need not do more than allude to the use of the bleaching powder in paper-making, which is one great cause of the superior quality and low price of paper in Britain.

Another important use to which the muriatic acid produced in the soda manufacture, and formerly thrown away, is now applied, is that of preparing cheap and superior glue from bones. Bones consist of bone earth and glue; the former is readily dissolved by diluted muriatic acid, while the latter is left, and has only to be dissolved in warm water to be ready for use. The acid solution of the bone earth, on the other hand, promises to be an admirable form of using that earth as manure. Professor Liebig, in his late valuable work on Agricultural Chemistry, has recommended this application. At present, the solution in question is thrown away as useless in the glue manufactories.

The last application of sulphuric acid which I shall here mention is a very recent one, and owes its origin to one of the most scientific chemists of the day, M. Gay-

Lussac. It consists in its employment in the refining or purification of silver.

Silver, as it comes from the mines, is alloyed with one-half, or rather more, of copper. It also contains a small quantity of gold. It must be refined—that is, purified; and the pure or fine silver is then alloyed with the due amount of copper to form the standard silver.

Raw silver was formerly refined by cupellation, a process which cost about 35*s.* for 50 lbs. of silver. The gold contained in the silver would not repay the expense of extracting it, and was therefore allowed to remain, and to circulate in the silver, absolutely worthless. But by means of sulphuric acid, cupellation is avoided; the silver is refined at a most trifling cost, and the gold is obtained by the same operation: nay, even the copper which was formerly lost, is now preserved; and although the gold only amounts to from $\frac{1}{2000}$th to $\frac{1}{1200}$th of the weight of the silver, yet as its value is about $1\frac{1}{2}$ per cent. of that of the silver, it not only repays the whole expense of refining, but leaves a clear profit to the refiners. This beautiful application of chemistry has given rise to the singular and apparently anomalous result, that the seller of raw silver receives from the mint the exact quantity of pure silver which his alloy, on being tested, is found to contain, and likewise the whole amount of the copper present in the alloy, thus apparently paying nothing for the process of refining. The refiner is paid by the gold which he retains, and which was formerly lost to every one. The saving effected by this improvement to the French mint is stated to have been enormous.

I must not dwell longer on details of this kind; but I would mention, in passing, that but for the wonderfully low price of sulphuric acid, it would have been impossible to produce a number of useful articles not yet mentioned; such as the beautiful stearine candles, phosphorus, phosphorus matches, lucifer matches, and many other products equally remarkable for their superior quality and for their astonishing cheapness. The present prices of sulphuric, nitric, and muriatic acids, of soda, soap, glass, phosphorus, &c. &c. would have been considered, a quarter of a century ago, as fabulous and impossible. Who can foresee what new discoveries, or what improvements on old ones, may arise during the next twenty-five years?

I trust that the foregoing considerations will render it obvious that our chemical manufactures possess a higher degree of national importance than people are generally aware of. Let us only reflect in how many ways a rise in the price of sulphuric acid would be disadvantageously felt; that it would affect the price of soda, soap, glass, bleaching powder, cotton, and all the products I have mentioned, besides many more; and it will then appear quite natural that the late obstruction to the sulphur trade should have threatened to excite war. It is clear that these manufactures are now inseparably connected with almost every branch of our trade and commerce, and that they cannot suffer without causing severe national loss.

It is obvious, from these facts, that if any nation is bound to encourage and promote the study of practical chemistry, it is the British nation, which has derived, and continues to derive, such vast advantages from the application of its principles to the useful arts. Yet, if we investigate the subject, we shall find that the opportunities afforded in this country for the study of practical chemistry are exceedingly limited; and that, in point of fact, we possess no institution where the student can acquire, at a reasonable rate, the art of scientific research, in the only way in which it can really be acquired, that is, by constant practice in the laboratory.

The elements of chemistry must always be taught by lectures, and for these there may be said to be sufficient provision in this country. But lectures are not sufficient; they cannot carry the student beyond the elements, and the idea of teaching the art of research in lectures is quite absurd. That art consists in the making of experiments, with a view to ascertain some new truth, or to correct some error.

Every experiment may be regarded as a question addressed to Nature: the phenomena observed are the words of the language in which Nature answers the question; and it is only when the inquirer is familiar with the language, and when the question is distinctly put, than an answer can be expected. If these conditions be fulfilled, the answer is obtained without fail, and the observer is capable of interpreting it.

Now in the lecture-room we can only learn the alphabet, as it were, of this language, the elements of the new speech; such are, for example, the properties of matter, the laws of combination, and the characters by which one body is to be distinguished from another. It is in the laboratory alone that we can learn the use of this alphabet; that we can become familiar with the words it yields; that we can learn to shape our questions aright and to read the answers. When we know thus much, we can enter on research with some prospect of success; and it is not too much to say, that no question has ever been distinctly addressed to Nature in the language of experiment, which has not received an answer; that no problem in natural science has ever been clearly given, which has not been experimentally resolved. Hence the vast, the paramount importance to the chemist of a proper education in the art of research, or, in other words, of practical chemistry.

But practical chemistry, or the art of research, is, from its very nature, an expensive study; probably much more expensive than any other branch of education. There are required, first, a convenient and spacious laboratory, expressly fitted up for the purpose; secondly, a complete apparatus; thirdly, a large supply of fuel; fourthly, the substances or materials without which chemistry cannot be practised; and lastly, a qualified assistant, capable of taking charge of the laboratory, and of superintending, under the professor, the working pupils; besides preparing the experiments for the lectures, which, for the benefit of beginners, should always be given in a practical school.

The laboratory must include several rooms, of which one, the largest, should be devoted to the practical operations of the students. This room must be well supplied with water, airy, well lighted and ventilated; it must contain several furnaces and hearths, so arranged as to allow the products of combustion to be carried off: one large sand-bath at least, with a hot air chamber below it; a still, for providing a constant supply of distilled water; and, finally, it must be well furnished with tables, drawers, presses, and shelving.

With regard to apparatus, besides the common and indispensable articles of glass, porcelain, and metal, including portable furnaces for charcoal and gas, and spirit lamps, every laboratory of research should possess one or more delicate but strong balances, with accurately divided weights; one or more air pumps, with numerous plates of ground metal, capable of being detached from the pump when exhausted, and kept in that state.

A store of glass and other ordinary apparatus should be kept in a distinct room, which should be sold at prime cost to the students, that each may have his own, as far at least as the smaller articles are concerned. A blow-pipe table for working glass should be attached to this store-room, or to another in which the stock of materials is kept. A small room, clear of the laboratory, is also required for the balances, air-pumps, and other delicate apparatus, which would be injured by corrosive vapours. In this room, a select library of chemistry, for the use of students while in the laboratory, ought to be kept; and either here or elsewhere, a cabinet of chemical specimens, carefully arranged and labelled, should be preserved, for the purpose of illustration. If possible, there ought to be an inferior laboratory or small kitchen, for operations on the large scale, such as the distillation of acids, and the preparation of other products consumed in a laboratory of research; and a sheltered table in the open air ought to be provided, for offensive and unwholesome processes, which often occur. Of course, there must be a cellar for fuel. Finally, the lecture-room ought to adjoin the laboratory, if possible, that all the apparatus, materials, and specimens, required in the lectures, may be close at hand.

Such is a brief and imperfect sketch of what is absolutely essential in a laboratory where the art of research is to be taught. I regret to say, that hardly any university in this country, and but few on the continent, can be said to possess one-half of this necessary accommodation.

In the laboratory of the university of Giessen, built and furnished under the superintendence of Professor Liebig, all the conveniences above mentioned, and a good many more, have been liberally supplied. I have carefully examined the whole of Professor Liebig's arrangements, and shall have occasion presently to allude to the good effects produced by them. At present, I would direct attention to the fact, that although such arrangements cannot be carried into effect without expense, yet the sum required, if the plans be judicious, is far smaller than could possibly have been expected. It is certain that, in many cases, more money has been expended on the most imperfect laboratory than would have sufficed to produce one even superior to that of Giessen.

The necessity of a qualified assistant will appear, when we consider the continual superintendence required by beginners in practical chemistry, and the vital necessity of order and method in a laboratory. It is true that the professor may often obtain the temporary assistance of some advanced pupil, who exchanges his labour for the additional knowledge to be thus acquired; but this can never supersede the necessity of a permanent assistant, who knows by experience the wants of the students, and learns to keep up a regular supply of those materials which must be made in the laboratory, because they either cannot be purchased at all, or cannot be purchased cheap. Indeed, with all the gratuitous aid that students can give, the place of assistant is one of severe labour. The assistant must therefore have a salary, the amount of which will vary in different localities and under different circumstances. Besides such an assistant, however, qualified by his chemical knowledge, there must be a servant for the coarser and menial work, who may soon learn to perform certain useful operations, and who may also be store-keeper. He must also be paid, in one form or another.

The absolutely necessary expenses of a laboratory may therefore be classed under three heads:

1. The original outlay in building and furnishing the laboratory.

2. The annual outlay for materials, for the wear and tear of apparatus, and for fuel.

3. The salaries of an assistant and a servant.

It is clear that this expense must be borne, either by the institution itself to which the laboratory belongs, by the public, by the professor, or, finally, by the students.

In this country, the existing laboratories have generally, indeed I may say always, been provided by the universities to which they belong; while the burden of the annual expenditure is thrown on the professor or on the students. In most cases, the apparatus, or a great part of it, has been purchased by the professor, and consequently belongs to him, an arrangement fraught with inconvenience in the case of the death or removal of the professor, and the appointment of his successor.

It has already been stated that our laboratories are generally very far from being complete, and the same may be said of the apparatus. This is only the natural result of the system, by which so large a share of the expense is thrown on the professors or on the students. Even where a tolerable laboratory and apparatus have been provided, it cannot reasonably be expected that the teacher should bear the annual expense. There is but one way in which he can avoid a heavy loss, and that is, by charging a high fee for laboratory practice. In Paris, the usual fee for an eight months' course is 1,500 francs, or £60. In London, for a six months' course, it is generally about £50.

Nothing can be more certain than that these charges, although far from exorbitant, are quite beyond the means of students in general. Nor is it among those who can readily afford such fees that the most diligent students are to be found. The natural consequence is, that but few students study practical chemistry on these terms. In short, the attempt to throw the burden on the students effectually prevents the formation of an efficient school of research.

In those instances in which such a school has been formed, and has existed for a time, the burden has invariably been borne by the teachers, who have exacted only such fees as were within the power of the students to pay; but as this plan involved a serious loss to the teachers, it has also failed in creating an efficient school. Those teachers who, much to their credit, have made the attempt, have found it absolutely necessary to relinquish it, after sustaining considerable loss.

At present several laboratories are nominally open to advanced students, for the purposes of research, at the high fee above mentioned, or even at a charge considerably lower, but it may be stated as certain, that such a school as I am anxious to see established nowhere exists in the United Kingdom.

That such a school, however, may be formed, and may flourish without any peculiar advantages of situation, we have positive proof in the case of Giessen, already alluded to, where, at this moment, fifty practical students are employed in the laboratory; the number having steadily increased up to this point during the last fifteen years, and more especially since the completion of the laboratory in 1835.

In this country, for the reasons above stated, hardly any students have the advantage of a tolerably complete education in chemistry, except the few who act as assistants to our professors ; but even they have not the same advantages as the students at Giessen, because the languishing condition of our schools affords no inducement to multiply the facilities of practical study. As a proof of the truth of this statement, it may be mentioned that any one who wishes to become practically familiar with the processes employed in organic analysis cannot do so at home ; but must go either to Paris, to Berlin, to Göttingen, or to Giessen, where he will see all these important operations hourly practised.

Many of our rising chemists, indeed all such as have distinguished themselves by researches in organic chemistry, have studied this branch of science on the continent; and I could name several of our professors who have done the same. These facts can only be accounted for by the want of proper schools at home; and that this is no temporary deficiency is obvious from the fact that the number of young British chemists who study abroad is annually increasing; while a reference to the scientific journals will shew, that till our students adopted the system of studying in the continental schools, organic chemistry, which has made such amazing progress of late years, was cultivated almost exclusively on the continent, and lamentably neglected here.

It may safely be affirmed, that if proper schools of research had existed in the United Kingdom, British chemists would have taken a far more active part in the cultivation of organic chemistry. Our general neglect of this fertile and inexhaustible field of discovery, the importance of which cannot be overrated, is in itself a sufficient proof that our system of instruction must have been very deficient.

On the other hand, nothing can prove more clearly the superiority of the system established at Giessen than the acknowledged fact, that to this school alone we are indebted for a very large proportion of those researches which have advanced organic chemistry to its present very flourishing condition. It would hardly be exaggeration to say that all the other schools of Europe together have not done more for organic chemistry than the school of Giessen. The resort to it of students from all parts of the world is another proof of the very high character it has acquired as a school of research.

Let us inquire, therefore, what there is, in the system adopted at Giessen, to account for results so different from those which have flowed from the system followed in this and some other countries. We shall find the cause of the difference to be very simple.

The principle on which the School of Practical Chemistry at Giessen is founded is that of enabling the professor to open his laboratory, provided as it is with every thing necessary for research, on terms which allow almost every student with ease to avail himself of the opportunity.

At an early period, I expect, through the kindness of Professor Liebig, to be enabled to lay before your Lordship the plans of the laboratory at Giessen, with a statement of its actual expense, and other important details of its management: at present I can do no more than give a very brief and general account of the expenses connected with it, and the terms on which it is opened to students. I beg leave to state, that in this matter I speak from intimate personal knowledge of the laboratory, and of the working of the system there adopted.

The professor has a handsome salary and a free house. The laboratory has been built, on plans approved by him, at the expense of his government; and the entire cost, including all furnaces, sand-baths, water-pipes, and the numerous indispensable fixtures of a laboratory, amounted to 13,000 florins, or about £1,120 sterling. Considering its extent and completeness, and the large number of students it can accommodate, this sum must be regarded as very small; and it is certain that more has often been expended in the construction of far inferior laboratories. In many of our universities, I have no doubt that a much smaller sum, judiciously expended in altering, enlarging, or improving the existing laboratories, would suffice to furnish ample accommodation for such a number of students as might be expected to enter them. On an average, £1,000 might be assumed as sufficient, making allowance for the higher price in this country, both of labour and of building materials. I do not know whether the above sum of £1,120 at Giessen includes any part of the moveable apparatus, or, if it does so, how much. But of this kind of apparatus our universities have generally a tolerable supply, although it is often, in great part, the property of the professor. At all events, a moderate sum would secure a sufficient apparatus, to belong to the laboratory, and to be used by all the students, under certain regulations; while each student, according to the plan followed at Giessen, which I will presently describe, should purchase certain cheap articles of apparatus, to belong to himself, and to be used by himself alone.

The next point in the system adopted at Giessen is the annual allowance for laboratory expenses, that is—for wear and tear of apparatus, for chemical materials, and for fuel. At Giessen, the annual allowance, under this head, is about £130, which is found sufficient to defray the cost of the lecturers and laboratory, when the working students do not exceed fifteen. It is paid by the government.

The government also pays the salaries of an assistant and a servant. Two or more assistants are necessary when the working pupils are numerous; but at present I cannot say whether the second assistant is paid by the government or by the professor. I know that a third, when required, is paid for by the professor.

The fees paid by working pupils are calculated according to the number of days per week, during the course, that they employ in the laboratory; it being found far more advantageous to devote one whole day to practical chemistry than two half ones, owing to the tedious nature of many processes, which, besides, cannot be interrupted. So much is this the case, that no student is received, except on condition of devoting the entire day to practical chemistry. Those who work one day during the week pay 13 florins for the course, or about £1. 2*s*. For every additional day, the charge is the same; and those, the great majority, who work six days per week, pay 78 florins, or about £6. 14*s*. for the course. The length of the course is from eight to nine months.

Each student provides himself, from a stock kept by the servant, and sold at prime cost, with a certain quantity of apparatus, such as a spirit lamp, test tubes, combustion tubes for analysis, precipitating jars, evaporating basins, funnels, &c. These articles belong to himself exclusively, and remain at that part of the table which is marked off for him. The tables are furnished, at frequent intervals, with complete sets of bottles, labelled in enamel, containing all the necessary re-agents: these belong to the laboratory. When a student's course is finished, he either takes with him the apparatus he has purchased, or disposes of it to a new-comer. Many of the students take home with them complete sets of portable apparatus, of which they have learned the use.

The fee above mentioned, and the small apparatus, constitute the whole of the necessary charge to the student, and the latter is a very trifling item in Germany. In this country, glass and porcelain, for chemical purposes, are considerably dearer, besides being of very inferior quality; but if the excise laws, in regard to glass, were so modified as to allow good glass, for chemical purposes, to be made at home, or if the duty on foreign glass and porcelain, *imported for scientific purposes,* were remitted, as it ought to be, such apparatus might be as cheap in this country as it has long, to the great benefit of science, been on the continent. The heavy duty (or rather duties, for there are two, amounting to about 50 or 60 per cent.) on foreign glass is a most serious obstacle to the cultivation of chemistry in this country.

The student, having previously attended lectures on chemistry, is first carried through a course of qualitative analysis, till he is thoroughly acquainted with the characters of chemical substances. He then proceeds to enter on some original investigation, either selected by himself, or suggested by the professor. He thus rapidly acquires a full command over the resources of chemistry, and is very generally enabled to obtain results worthy of publication. By this means he becomes known, and in a short time obtains some situation, either as professor in a university or gymnasium, assistant to a professor, or superintendent of some chemical manufacture.

It is worthy of notice, that whether the object of the student be to qualify himself as a teacher of chemistry, to learn the bearing of that science on medicine and physiology, or to become a manufacturer, the same purely scientific education in the art of research is recommended to all. It would be impossible, for example, to teach specially all the different chemical manufactures, so that the future iron-smelter should learn only iron-smelting, the soap-boiler only soap-boiling, &c.; and, if possible, it would be the reverse of beneficial. It is found by experience, that when all learn the general principles of chemistry, they acquire the special details of any manufacture in the manufactory in a far shorter time than they could have done in the laboratory. No attempt is made, therefore, to teach on the small scale processes that must be practised on the large scale. The student learns practically those principles by which all chemical manufactures must be regulated, and the result may be best stated in the words of Professor Liebig himself.

" It is generally in fear and trembling that they follow
" my advice, which is, to devote their whole attention, not
" to imitating manufacturing processes in the laboratory,
" but to learning how purely scientific problems are to be

" resolved. Their intellect soon and easily learns how to " find the best means : it is they themselves who modify " and shape their means according to circumstances. " Every operation, every analysis, which serves to clear " up a given question, or which must be performed in " order to discover the conditions essential to the resolu- " tion of the problem, has a specific object. Each process " thus acquires a certain charm that effectually wards off " fatigue; and when the problem is once resolved, the " student has learned the means of solving all similar " problems. I am acquainted with many of my former " pupils who are now at the head of every variety of " chemical manufacture. Without having ever practised " these in the laboratory, they became in the first half- " hour perfectly familiar with the whole process; and the " next half-hour commonly produced a number of well- " devised improvements in the manufacture. They had " acquired in the laboratory the most exact knowledge of " the properties of the materials which they had to em- " ploy, and were accustomed, as the only way of avoiding " errors, to subject the products of chemical reactions to " a searching investigation in regard to their composition; " and they thus at once discovered the sources of error, " the means of avoiding loss, and the best methods of " improving the apparatus, or perfecting the process. All " this is not learned, when the student enters a laboratory " for the purpose of practising a given process by recipe."*

I have been thus minute on this point, because I wish it to be generally known, that, even for directly practical purposes, the most purely scientific education is really the

* Ueber den Zustand des Chemie in Preussen, by Dr. Justus Liebig, Professor of Chemistry at Giessen, 1840.

best, and is more certain to lead to improvements in practice than the most laborious experience in any one manufacture, gained, as it generally is, at the expense of general principles.

Such is a sketch of the system pursued at Giessen. For its results, we have only to look at the very numerous and valuable researches which have issued from that school; to the large number of its pupils now distinguishing themselves as teachers of chemistry, as writers and experimenters, and as chemical manufacturers; and finally to its flourishing condition at the present time, so different from that of any British school of practical chemistry.

As courses of practical chemistry are given in our medical schools, it may be necessary to state, that these have hardly any thing in common with such a course of instruction as I have described. They are confined to medical students, who are required to attend them; but as they are limited to one hour daily for three months, it is obvious that they afford no means of acquiring the art of research. As far as they go, they are doubtless useful; but they are in a great measure devoted to impressing more firmly on the minds of the students the elements of the science as taught in lectures, to pharmacy, and to the detection of poisons. The schools of practical chemistry which I have endeavoured to describe and recommend are not for medical students, but for training those who wish to devote themselves to chemistry as a profession; and such schools we have not.

It will now, I trust, appear clearly, that the cause of this deficiency is the circumstance, that the necessary expenditure, not being otherwise provided for, falls on the teacher or the pupil, neither of whom is able to bear it.

It is the liberality of the government of Hesse Darmstadt, in enabling Professor Liebig to open his laboratory on reasonable terms, that alone has made the establishment of a school of research possible at Giessen; and it may safely be stated, that till our professors are enabled to do the same, they will never succeed in forming such a school.

I have endeavoured to shew that the necessary expense is not very heavy, although beyond the means of our professors or of our students. I would fain hope, that where a university possesses funds applicable to such an object, the authorities, when convinced of its importance, will not hesitate to provide what may be required. But your Lordship is well aware, that in the Scottish universities there are no funds out of which this expense could be defrayed. I believe that every one of them, without exception, has made considerable sacrifices with a view of promoting the study of chemistry; but more is required, and I trust your Lordship will agree with me in thinking that the importance of the object justifies an application to government.

I would not be understood to object to the system, which has produced such good effects in the Scottish universities, of making the income of a professor dependent, in a great measure, on his diligence and success as a lecturer. But before this principle can be applied, the expenses necessary to carry on the course must, when they are considerable, be otherwise provided for. No professor, out of the income derived from students' fees alone, could support the expenses of a practical school, including laboratory, apparatus, materials and assistants; and if the fee be raised, the school will fail for want of students.

Even where lectures alone are given, the expense is such, that the necessity and justice of relieving the professor, of the whole or of the greater part of it, has always been admitted. Hence a laboratory and apparatus, however imperfect, is generally supplied; and there is, I believe, occasionally an allowance for an assistant, or for laboratory expenses. But in no case that I am acquainted with are the allowances such, that the expenses do not materially encroach on the income derived from fees, even in the case of the mere lecturer; while in most cases, not only is the accommodation quite insufficient, but the whole expenditure is borne by the professor; a burden from which, in almost every other branch of education, the teacher is necessarily free. The expense is naturally increased where practical chemistry is taught.

It may be said, that British chemists have hitherto, under the present system, borne their full share in the discoveries of modern science: and the remark is true, down to a certain period. When, towards the end of the last century, the researches of Lavoisier, Black, Cavendish, Priestley and Scheele, created the modern science of chemistry, it was for some time cultivated, with zeal and success, by a few distinguished men in all countries; and if the continent produced Berzelius and Gay-Lussac, we could boast of Davy and Wollaston. But a new era has begun, and while the continental chemists, just named, have formed flourishing schools, England cannot be said to possess a school at all. We can still boast of individual chemists standing on a level with the most illustrious names of the continent; but where are we to look for their successors? Not certainly among home educated chemists, for the great majority of our rising chemists have studied abroad, as already mentioned: moreover, the boast that we have borne our full share in modern discoveries has for a good many years ceased to be true. The history of the rapid development of organic chemistry, for example, is not one in which we have any reason to be proud of the place we hold, or the share we have taken up to the present time; and yet it is this very branch of chemistry that forms the distinctive character of the science during the last quarter of a century. The wonderful discoveries in electricity, galvanism, magnetism, light and heat, made during the same period, although in many cases the work of chemists, belong to physics rather than to chemistry. It is in pure chemistry that we have fallen behind, and no longer occupy the position of our fathers, and this, as I trust I have shewn, from the want of schools of research. Science is no longer confined, as it was fifty years ago, to a few individuals; and while our continental neighbours place it within the reach of all, we must do so likewise, or be content to fall still further behind, and to see our young men, such of them at least as can afford it, go abroad to learn what they cannot learn at home.

There never was a time at which the study of chemistry promised more splendid results than it now does. The scientific world is occupied, among other subjects, with the applications of the newly created science of organic chemistry to agriculture and physiology, as developed in a recent work by Professor Liebig. That most interesting volume shews that we are only at the commencement of an epoch, in which the labours of those who have established the principles of organic chemistry will be applied to practice, leading to results, the value of which to mankind cannot be estimated. Now, for the means which have enabled Professor Liebig to carry on the science of agriculture so far beyond the point at which the illustrious Davy left it—in a word, for the existing science of organic chemistry—he has been indebted, almost exclusively, to the labours of continental chemists; and if British chemists, as a body, have had so small a share in laying the foundation, we cannot hope that they shall take the lead in erecting the superstructure.

I have cited the school of Giessen as the model of a school of research, and I have done this for two reasons: first, because I could speak of it from accurate personal knowledge, and because its success is too obvious and universally known to be for a moment placed in doubt: secondly, because, even on the continent, it is generally admitted to be superior to any other; in fact, in most continental countries, the state of the schools of research approaches pretty nearly to that of our own. In Austria there are none. In Prussia, for want of a system like that of Giessen, the expense is thrown on the student or on the professor; and the consequence is, as with us, that the very distinguished chemists who fill the chairs of chemistry in the Prussian universities are unable to form schools of research, and rarely have more than one or two pupils, generally assistants, engaged in research. In Paris, although the ordinary students must bear the expense, as formerly stated, and consequently there are few on these terms, yet the very numerous professorships in the French metropolis, and the great demand for qualified assistants to these, give a stimulus sufficient to form an important school, although very far short of what a better system might produce.

I have great pleasure in being able to state that the example so liberally set by the government of Hesse Darmstadt, and the results which have followed the system adopted at Giessen, have not been lost on other states. The Austrian government has taken measures for placing its schools of chemistry on a better footing; the Prussian government has applied to the universities for advice and information on the subject. In Saxony much has already been done in the way of improvement; and there is every prospect of the establishment of an effective school in Leipsic under Professor Erdmann. Finally, in Hanover, a school has already arisen, at Göttingen, which began under the celebrated Stromeyer, and is now steadily improving under the auspices of Professor Wöhler. I trust that the British government will not be the last to see the importance of schools of research, or to adopt such measures as will render their permanent existence in this country possible.

What these measures are I have endeavoured generally to explain. Each professor ought to be supplied with a well-appointed laboratory and apparatus; with an assistant and a servant, or an allowance for them; and with an annual sum, for laboratory expenses, sufficient to protect him from loss, on the supposition of a certain limited number of working students.

I beg that your Lordship will particularly observe, that my only object is to enable the professor to teach the art of research without loss. This branch of the profession can never, from its nature, be a source of emolument to him, nor indeed of advantage, except indirectly by increasing his reputation; but he is, I humbly conceive, entitled to the small amount derived from fees such as I have mentioned, which form no adequate compensation for the labour and anxiety to which he is exposed.

In Giessen, when the working pupils amount to fifteen, the annual allowance is just sufficient; and the professor receives the fees paid by these pupils. When the number is greater, the excess of expenditure is paid by the professor, and, of course, with a large number, soon swallows up the fees of the working pupils—if it does not encroach on the fees paid by the students attending the lectures only, or on the professor's salary, his income being made up of the two last items. I have no doubt that the laboratory at Giessen is, with its present numbers, and has been for some years, a source of loss to the professor, whose income would have been larger had he confined himself to lecturing, with his present salary. It will be sufficient, however, for the purposes of science, if the allowance for expenses be such as, with a given number of working pupils, eight, ten, twelve, or fifteen, according to the place, would leave to the teacher the fees of students and his salary, if any. As any increase in the number of working students beyond the prescribed number is quite voluntary on his part, he might be allowed to pay the additional expense, as is done at Giessen. The general result would be, that if the prescribed number of working pupils were taught, the income of the professor would, at first, be increased by the amount of the laboratory fees; while his lectures would most probably, in a short time, be better attended than before, namely, by students, looking forward to the laboratory, and a small addition to his income would arise in this way also. His income, where no salary is attached to the chair, would depend, as at present, entirely on his success as a teacher; but we should possess schools of research, which we never can possess, as long as the attempt to establish them entails loss on the teacher. This, as I have attempted to explain, is the case at present, when the fee is made low enough to meet the means of the student. The plan of protecting the teacher by high fees has been tried, and has entirely failed.

Taking into account the usual rate of fees in this country, and the importance of making practical chemistry as accessible as may be, it appears desirable that the teacher should be enabled to receive working pupils at £1. 1*s*. per day weekly for a course of six months; or, at all events, at not more than £1. 10*s*. per day weekly. A full course of six days weekly for six months would thus cost the student, in the first case £6. 6*s*.; in the second, £9. The latter is nearer to the standard of Giessen, if the difference in the value of money and in general expense be considered. But the former is certainly as much as is likely to be paid in many places; for example, in Aberdeen, whatever students in London might be disposed or enabled to give. In either case, no teacher can be expected to undertake the labour of a school of research, if even this pittance be not secure—that is, if the necessary expense be not otherwise provided for.

If, however, the necessary expense of laboratories of research be provided for, I have no doubt whatever that schools will soon arise in all our universities; that our young men will find the means of becoming accomplished chemists at home, and will no longer be compelled either to go abroad for their education, or to elinquish the study if unable to do so; and that in a very few years British chemists will again assume their proper place among the chemists of Europe. Every one who has had experience in teaching chemistry must have seen, as I have done, many young men, with first-rate abilities and a decided turn for chemical research, who were totally unable to bear the expense of a thorough chemical education at home, or to go abroad in search of it; and who, therefore, turned their attention to some other profession, the education for which was within their means.

I do not know what means the richer universities of Oxford, Cambridge, and Dublin, in none of which does a school of research at present exist, may have of establishing such a school; but the Scottish universities have no funds applicable to this purpose. All of them have some locality set apart as a laboratory, more or less complete in several cases; but in two, namely, King's College, Aberdeen, and St. Andrew's, very deficient. In King's College, the lecture-room, a very good one, is the only laboratory; and it is quite unfit for the accommodation of students engaged in research. A similar arrangement, I believe, exists in St. Andrew's. Notwithstanding this, however, the chief point to be attended to in Scotland would be the annual expense, as, on the average, a small sum would suffice to provide a laboratory. It is not easy to see from what source, save from the public purse, the annual expense could be defrayed. I beg leave, therefore, once more to express a hope that your Lordship may be inclined, in consideration of the very great importance of the object to be attained, to give your countenance to an application to government, for the means of establishing schools of chemical research in such of our universities as do not possess the necessary funds for that object.

In the event of an inquiry being made into the subject, I would beg leave respectfully to suggest that Professor Liebig should be applied to. His experience and success as a teacher of the art of research point him out as the individual whose testimony would be the most valuable.

I hope, before long, to be enabled to lay before your Lordship the plans of the laboratory at Giessen, with details; and in the mean time,

I have the honour to remain,

My Lord,

Your Lordship's most obedient and humble servant,

WILLIAM GREGORY.

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