(1621 mm.), but the Kammalans are shorter (1597 mm.). The Brahmans are better nourished, and have broader heads (142 mm.), the other three castes averaging 137 mm.; they also have the largest hands. Taking them all round, there is not that difference between the Brahmans and Pariahs that one might expect to find; but this can be explained by racial mixture. A. C. H.

## *SCIENTIFIC EDUCATION IN GERMANY AND ENGLAND.*[1]

IN our frequent discussions on scientific education, we have both often been struck with some points of very great difference between the English and the German way of dealing with it. As it may be asserted without national arrogance that University education is in Germany in a more satisfactory condition than in your country, you are, of course, anxious to know which of the German customs I consider most effective in bringing about this better state of things; and I will, therefore, try to point them out. Of course, I shall confine myself to the subject of natural science, and especially chemistry and physics, feeling myself unable to deal with sciences beyond my knowledge. The main point of our system may be expressed in one word—freedom—freedom of teaching and freedom of learning. The first involves for the teacher the necessity of forming in his mind a clear conception of the scope of his science, for, as he is free to choose any possible method of view, he feels himself answerable for the particular one he has chosen. And in the same way the student feels himself responsible for the method and the subjects of his studies, inasmuch as he is free to choose any teacher and any subject. One who has not seen this system in action may be inclined to think that such a system must lead to arbitrary and irresponsible methods on the side of the teacher, and to confusion on the part of the student. But the former is avoided, because at the beginning of his career the teacher is dependent for his advancement on the results of his scientific views, and is naturally anxious to improve his position in the educational world. And as for the students, they themselves impose certain restrictions on their own freedom. Most of them feel that they require some advice and guidance, and they therefore follow the usual and approved order in conducting their studies. As to the inventive man of original ideas, it has often been proved that for him any way is almost as good as any other, for he is sure to do his best anywhere. Moreover, such a man very soon excites the interest of one of his teachers, and is personally led by him, generally to the great advantage of both.

Let me illustrate these general remarks by considering the course followed by an average chemist. In his first half-year he hears lectures on inorganic chemistry, physics, mineralogy, sometimes botany, and of late often differential calculus. Moreover, the German student is accustomed to take a more or less strong interest in general philosophy or history, and to add in his *Belegbuch* (list of lectures) to the above-named *Fachcollegien* (specialised studies) one or two lectures on philosophy, general or German history, or the like. Very often there are in the University one or more popular professors whose lectures are heard by students of all faculties without reference to their special studies. The student who has heard during his stay at the University only lectures belonging strictly to his *Fach*, is not well thought of, and is to some extent looked down on as a narrow specialist. But I must add that such views are not prevalent in all faculties, and there are some—*e.g.*, the faculty of law—whose students confine themselves, with few exceptions, to attending exclusively lectures in that faculty.

In the second half-year the chemical student begins with practical laboratory work. Notwithstanding the perfect freedom of the teachers, the system first introduced by Liebig into his laboratory at Giessen is still universally adopted in German universities and technical high schools—viz. qualitative and quantitative chemical analysis, the former conjoined with simple spectroscopic work, the latter amplified by volumetric analysis. This is followed by a course of chemical preparations, formerly chiefly inorganic, now chiefly organic. Even here, a regular system is being widely developed owing to the use of some well-known text-books. Of late years this course is followed in some laboratories by a series of exercises in physical chemistry and electro-chemistry.

While these practical exercises, which last for three or four half-years, are being carried out, the student completes his knowledge of physics, mathematics, and the other allied sciences by hearing lectures and working practically in the physical and often also in some other laboratory. The exercises done, he goes to the professor and asks him for a "theme" to begin his "work"—viz., his dissertation for the degree of Doctor of Philosophy. This is the most important moment in his life as a student, for it generally determines the special line of his future career. The "theme" is usually taken from the particular branch of the subject at which the professor himself is working; but, as the scientific name and position of the professor depends, not only on his own work, but to a large extent on the work issuing from his laboratory, he is careful not to limit himself to too narrow a range of his science.

Of course it is best of all if the student selects for himself a suitable "theme," suggested to him by his lectures or practical work, or from private study of the literature of the science. But this seldom happens, for the young student is not yet able to discern the bearing of special questions, and lacks knowledge how to work them out. Sometimes (but not very often, indeed) he points out to his professor in a general way the kind of problems he would like to work at, and the professor suggests to him a special problem out of this range of subjects. During the working out of his chosen subject the student learns generally much more than he has heard at lectures. Every part of the investigation forces him to revise the scientific foundations of the operations he performs. During this time the incidental short lectures given by the professor on his daily round from one to another of the advanced students are most effective in deepening and strengthening the student's knowledge. As these explanatory remarks are generally heard not only by the student whose work has caused them, but also by a number of fellow-students working near, a fairly wide range of scientific questions are dealt with in their hearing. Often these small lectures develop themselves into discussions, and, as for myself, I judge from the frequency of such discussions between the students whether the session will turn out a good one or not. If the professor thinks the work sufficiently complete to be used as a dissertation, the student proceeds to the close of his studies. He prepares himself for the examination, which is conducted by the very professors whose lectures he has heard and in whose laboratories he has worked. This examination varies somewhat in different universities, but in no case is it either very long or extensive; indeed, it is not considered as very important. For we are all aware what an uncertain means of determining a man's knowledge and capabilities an examination is, and how much its issue depends upon accidental circumstances. Part of this uncertainty is removed by the fact that the professor and the pupil know each other, are acquainted with one another's modes of expression and scientific views. The main purpose of the examination is to induce the student to widen his knowledge to a greater extent than is covered by the subject of his dissertation; but, indeed, it happens very seldom that a student whose work is considered sufficient does not pass the examination.

We have no great fear that this system may induce a professor to treat his own pupils in too lenient a way, and so lower the standard of the Doctor's degree. There was a time when such abuses used to occur, but there very soon arose such public indignation that the abuses ceased to occur. Even at the present day similar instances occasionally occur, but, as before remarked, the position of a professor depends in such a degree upon the value of the dissertations worked out under his supervision, that such deviations from the right way correct themselves in the course of time. The most effective instrument for that purpose is the publication of all dissertations and the consequent public control over them; for this reason publication is, I believe, compulsorily prescribed in all German universities.

When the student has finished his course he is still entirely free to choose between a scientific and a technical career. This is a very important point in our educational system; it is made possible by the circumstance that the occupation of a technical chemist in works is very often almost as scientific in its character as in a university laboratory. This is connected with a remarkable feature in the development of technical chemistry in Germany—the very point upon which the important position of chemical manufacture in this country depends. The organisation of the power of invention in manufactures and on a large

[1] A letter from Prof. W. Ostwald, communicated by Prof. W. Ramsay to the *Times*, August 25.

scale is, as far as I know, unique in the world's history, and it is the very marrow of our splendid development. Each large work has the greater part of its scientific staff—and there are often more than 100 *doctores phil.* in a single manufactory—occupied, not in the management of the manfacture, but in making inventions. The research laboratory in such a work is only different from one in a university by its being more splendidly and sumptuously fitted than the latter. I have heard from the business managers of such works that they have not unfrequently men who have worked for four years without practical success; but if they know them to possess ability they keep them notwithstanding, and in most cases with ultimate success sufficient to pay the expenses of the former resultless years.

It seems to me a point of the greatest importance that the conviction of the practical usefulness of a theoretical or purely scientific training is fully understood in Germany by the leaders of great manufactories. When, some years ago, I had occasion to preside at a meeting, consisting of about two-thirds practical men and one-third teachers, I was much surprised to observe the unhesitating belief of the former in the usefulness of entirely theoretical investigations. And I know a case where, quite recently, an "extraordinary" professor of a university has been offered a very large salary to induce him to enter a works, only for the purpose of undertaking researches regarding the practical use of some scientific methods which he had been working at with considerable success. No special instructions are given to him, for it is taken for granted that he himself will find the most promising methods; only, in order to increase his interest in the business, part of his remuneration has been made proportional to the commercial success of his future inventions. From this clear understanding of the commercial importance of science by the directors of industrial establishments there science itself gains another advantage. A scientific man can be almost sure, if he wants in his investigations the help of such technical means as only great works can afford, that he will get such assistance at once on application to any work; and the scientific papers of German chemists very often contain acknowledgments, with due thanks, of considerable help they have thus obtained.

Besides these advantages for the development of scientific and technical chemistry in Germany there exists another very important factor—practical assistance from the Government. Universities are in Germany affairs of the State, not of the Empire, and in no other point has the division of the Fatherland into many smaller countries proved itself to such a degree a boon and a blessing. The essential character of the German universities, the freedom conferred by the independence of the numerous universities, is never lost. There have been hard times occasionally for the universities of one country or another; but some universities were always to be found where even in times of hard oppression liberty of teaching and learning remained complete and unaffected, and the spirit of pure unalloyed scientific research was preserved and encouraged. So this palladium of intellectual freedom has never been lost; and it regained the former influence as soon as the casual oppression ceased. In our days there is among all the separate State Governments in Germany a clear conviction of the importance of practical support being given to pure scientific research. To take one instance, in order to facilitate teaching and research in electro-chemistry (a recently developed branch of science) a suggestion by some leading practical scientific men to the members of the Government was sufficient. Upon such a suggestion a considerable sum of money was spent first by the Prussian Government for the endowment of electro-chemical chairs and laboratories in the three "polytechnic" colleges of that country. A short time afterwards it was resolved to erect at one of the universities (Göttingen) an institute for physical chemistry, and especially electro-chemistry, in the shape of a building which has just been completed. At the same time, other German countries have begun to grant to their universities and technical colleges considerable sums of money for similar purposes, *e.g.* the Saxon Landtag alone has unanimously voted half a million marks (= £25,000) for the erection of a splendid laboratory for physical chemistry at Leipzig.

You will excuse my boasting about our German management of this most important question of scientific education. It is no blind admiration without criticism, for I know by practical experience the management in other countries, and I can compare them. And it is only for the sake of science itself that I write these lines. If they should help the spread of the conviction of the incomparable practical usefulness of every support given to pure science, together with the recognition of the fact that the latter can only grow in an atmosphere of liberty and confidence, I should regard it as tending towards the progress of science itself, and destined to exercise such an influence on scientific progress as may be compared with the discovery of the most remarkable scientific fact.

## *THE HOMOGENEITY OF ARGON AND OF HELIUM.*[1]

THE question of the homogeneity of argon has been discussed by Lord Rayleigh and one of us in their memoir on Argon (*Phil. Trans.*, A, p. 236, 1895). But at that epoch the data were not sufficiently numerous to enable us to arrive at very definite conclusions. The discovery of helium and the analysis of its spectrum by Runge and Paschen (*Sitzungsberichte d. Akad. d. Wissenschaften*, pp. 639 and 759, Berlin, 1895) lead to the thought that this body may be a mixture of two gases.

To elucidate this question we submitted these two gases to a methodical diffusion, causing them to traverse a duct of porous pipe-clay submitted on one of its surfaces to the action of a vacuum. We satisfied ourselves that we might thus effect the separation of hydrogen and helium and that of oxygen and carbonic acid, and that, by measuring the rapidity of the descent of a column of mercury introduced in the circuit of the apparatus, it is possible to arrive at a good determination of the molecular weight of various gases. We have then tried to separate argon into two parts by a method analogous to the separation of liquids by fractionated distillation.

The quantity of argon was close upon 400 c.c. The gas was then treated in the manner shown in the following scheme:—

| | More diffusible. | | I. | | | Less diffusible. |
|---|---|---|---|---|---|---|
| | $\frac{1}{2}$ | . . . . | | | . . . . | $\frac{1}{2}$ |
| II. | $\frac{2}{3}$ | . . . . | $\frac{1}{3}$ | $\frac{1}{3}$ | . . . . | $\frac{2}{3}$ |
| | $\frac{1}{2}$ | . . . . | | | . . . . | $\frac{1}{2}$ |
| III. | $\frac{2}{3}$ | . . . . | $\frac{1}{3}$ | $\frac{1}{3}$ | . . . . | $\frac{2}{3}$ |
| | $\frac{1}{2}$ | . . . . | | | . . . . | $\frac{1}{2}$ |
| IV. | $\frac{2}{3}$ | . . . . | $\frac{1}{3}$ | $\frac{1}{3}$ | . . . . | $\frac{2}{3}$ |
| | $\frac{1}{2}$ | . . . . | | | . . . . | $\frac{1}{2}$ |

We determined the density of the two extreme portions, and found that the one which ought to be the lightest had the density (O = 10) of 19·93, and the heaviest of 20·01. The separation, if it takes place, is therefore minimal.

The same experiment executed with helium yielded other results. The density of the specimen which passed first was 1·874, and that of the gas remaining in the apparatus 2·133. A great number of fractionations did not change these figures; even the spectra of the two specimens were absolutely identical. Even the first bubbles of the lighter gas showed the same lines, with the same intensity, as the last bubbles which remained in the apparatus. There was no difference in fifty fractions.

Lord Rayleigh has had the kindness to measure the refraction of the two specimens of gas. Whilst the lighter gives the figure 0·1350 (atmospheric air = 1), the heavier had a refraction expressed by the figure 0·1524. Now these two numbers have a relation almost identical with the relation of the densities, for—

$$\frac{0{\cdot}1350}{0{\cdot}1524} = \frac{1{\cdot}874}{2{\cdot}110} \text{ in place of } \frac{1{\cdot}874}{2{\cdot}133}$$

Let us now consider what happens when we submit a mixture of the two gases to diffusion. Let us take, *e.g.*, a mixture of hydrogen with an excess of oxygen. After a sufficient number of operations we obtain pure oxygen on the one hand, and on the other a mixture of 1 part of hydrogen with 4 parts of oxygen. It will not be possible to separate this mixture into its constituents, on account of the equal diffusion of oxygen and hydrogen when thus mixed. The identity of the spectra of helium prevent us from deciding which is the pure gas and which is the mixture. Calculation establishes that if we suppose the heavier gas is a mixture, the density of the lighter, supposed pure, ought to be 1·58. Helium, lastly, if it consists of a mixture of two gases, is formed either of two gases of the densities

[1] A paper presented to the Paris Academy of Sciences on July 27, by Prof. W. Ramsay and Dr. J. Norman Collie. (Reprinted from the *Chemical News.*)