head-masters who have themselves no knowledge of science. That all head-masters should have such knowledge is a fact which, if science is to be taught at all, trustees and governing bodies must come to recognise before long: meanwhile every school which teaches science thoroughly is training skilled teachers for a not distant generation. Institutions which can give so high a salary as to command a London bachelor of science or a first class Oxford or Cambridge man, will find no more difficulty than attends the choice of all masters: where this is not the case it is sometimes possible by combining mathematics with physical science to tempt a superior man with a sufficient income; and, if only a small salary can be given, the ordinary pass B.A. of the London University will sometimes make a fairly good teacher. But one point has struck me forcibly in my own experience; namely, the unexpected value of general culture in teaching special subjects. The man who knows science admirably, but knows nothing else, prepares boys well for an examination; but his teaching does not stick. The man of wide culture and refinement brings fewer pupils up to a given mark within a given time: but what he has taught remains with them; they never forget or fall back. I am not sure that I understand the phenomenon, but I have noted it repeatedly.

I cannot end this paper without a word as to the educational results which our five years' experience has revealed. The system has brought about this result first of all, that there are no dunces in the school. In a purely classical school, for every promising scholar there are probably two who make indifferent progress, and one who makes no progress at all; and a certain proportion of the school, habitually disheartened, loses the greatest boon which school can give, namely, the habit and the desire of intellectual improvement. By giving importance to abstract and physical science, we at once redress the balance. Every boy progresses in his own subject; some progress in all; no one is depressed, no one thinks learning hateful. Secondly, the teaching of science makes school-work pleasant. The boy's evident enjoyment of the scientific lesson rouses the emulation of other masters. They discover that the teaching of languages may become as interesting as the teaching of science. They realise—a point not often realised—the maxim of Socrates, that no real instruction can be bestowed on learners "παρὰ τοῦ μὴ ἀρέσκοντος, by a teacher who does not give them pleasure." Lastly, the effect on the boy's character is beyond all dispute. It kindles some minds which nothing else could reach at all. It awakes in all minds faculties which would otherwise have continued dormant. It changes, to an extent which we cannot over-estimate, the whole force and character of school-life both to the learner and the teacher. It establishes, as matter of experience, what has long been urged in theory, that the widest culture is the noblest culture; that universality and thoroughness may go together; that the system which confines itself to a single branch of knowledge, does not gain, but loses incomparably, by its exclusiveness: that observation, imagination, and reasoning may all be trained alike; that we may, and so we must, teach many things, and teach them well.

W. TUCKWELL

THE LATE PROFESSOR GRAHAM

AT 9 o'clock in the evening of Thursday, the 16th September, 1869, died at his house, No. 4, Gordon Square, a man whose name will be honoured as long as true greatness is appreciated.

Thomas Graham spent his life in reading the book of Nature, and giving to mankind a knowledge of the truths which he found there. His greatness is to be measured not merely by the amount and importance of the knowledge which he thus gave, but even more by the singleness and strength of purpose with which he devoted his whole life to labours of experimental philosophy.

Some men have made important discoveries by occasionally applying to experimental investigation, powers of mind which they exerted usually in the pursuit of their own worldly advancement.

But from an early age Graham's one great object of life was the discovery of new truths, and he appreciated so fully the value of such work that he resolved to make any personal sacrifices which might be needed for its sake. And nobly he kept his resolution; for at an early stage of his career he endured, for the sake of pursuing chemistry, privations and sufferings so severe, that they are believed to have permanently injured his constitution; and at its very end, long after he had attained a world-wide reputation, when his delicate frame sorely needed the repose which was at his command, he continued to labour even more effectively than before, and to enrich science with new discoveries.

It might be difficult to find in history a character so perfect in its noble simplicity and elevation.

Graham was born at Glasgow, on the 21st December, 1805, the eldest of a family of seven, of whom only one survives.

He went to the English preparatory school at Glasgow, in 1811, and was there under the care of Dr. Angus. In the year 1814 he was removed to the High School, where for four years his studies (which included the Latin language) were directed by Dr. Dymock, and subsequently for one year by the Rector, Dr. Chrystal, under whom he studied Greek. It is said that during these five years he was not once absent at school-time. In 1819 he commenced attendance in the University classes in Glasgow.

Thomas Thomson then occupied the Chair of Chemistry, and young Graham benefited by his instruction, as also by that of Dr. Meikleham, the Professor of Natural Philosophy.

By this time he had already acquired a strong taste for experimental science, and formed a wish to devote himself to chemistry. His father, an able and successful manufacturer, had formed different views for his future career, and wished him to become a minister of the Scotch Church. It is hardly to be wondered at that the father should not have seen in the prosecution of science much scope for an honourable or advantageous career; but young Graham had already seen something of the means afforded by experimental science of getting knowledge from the fountain head—from Nature herself. He felt the need of more such knowledge to mankind, and his scheme of life was formed accordingly.

After taking the degree of M.A. at Glasgow, he continued his studies for two years at Edinburgh, and there studied under Dr. Hope, and enjoyed the friendship of Prof. Leslie. On his return to Glasgow, he taught mathematics for some time at the suggestion and under the patronage of Dr. Meikleham, and subsequently opened a laboratory in Portland Street, Glasgow, where he taught chemistry. It is probable that some of the severest trials of his life occurred at about this period.

While absent from Glasgow he was in the habit of writing regularly and at great length to his mother, and from the tenor of these letters it is easy to see what that mother must have been to him. A writer on the social position of women has described the feelings of boys towards their mothers as scarcely amounting to respect! Young Graham's mother seems to have been his guardian angel, sympathising with his hopes and his sorrows; and certainly his feelings towards her would have been very inadequately described by that frigid word. While studying at Edinburgh he earned, for the first time in his life, some money by literary work, and the whole sum (6*l.*) was expended in presents to his mother and sisters.

In 1829 he was appointed lecturer on Chemistry at the Mechanics' Institution, Glasgow, in place of Dr. Clark; but the decisive step of his life was in the subsequent year. It was in 1830 that he was appointed Professor of Chemistry at the Andersonian University, Glasgow; and it is said that his mother, who was on her deathbed, lived to hear the glad tidings of his appointment. He was now more favourably circumstanced for experimental labours, and we find that the seven years spent at the Andersonian University were years of great activity.

In 1837 he was appointed Professor of Chemistry in the London University, now called University College, London, and he occupied that chair with great distinction till the year 1855, when he succeeded Sir John Herschel as Master of the Mint, which appointment may be considered an acknowledgment on the part of the Government of his scientific services and of his high character.

His numerous discoveries have been much quoted. Some of their theoretical bearings claim a brief notice here.

His investigation of the phosphates is remarkable in many ways. It was known that solutions of phosphoric acid in water vary in their properties; and chemists were satisfied with giving a name to the changes without investigating their nature. These solutions contained phosphoric acid and water, and were assumed to have like composition. They were accordingly called isomeric. Graham observed that they differ from one another in the proportion of water combined with the acid, and constitute in reality different compounds.

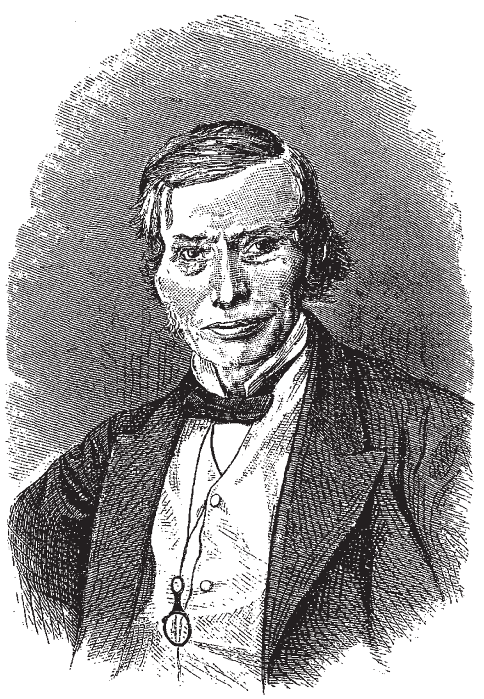
He knew that water combines with acids as other bases do, and he showed that the various compounds of phosphoric acid and water constitute distinct salts, each of which admits of its hydrogen being replaced by other metals without disturbance of what we should now call the type. Thus, to use our present notation, the three hydrates PO_4H_3, $P_2O_7H_4$, PO_3H, correspond to the following proportions of acid and water:—

$$P_2O_5 + 3H_2O = 2PO_4H_3$$
$$P_2O_5 + 2H_2O = P_2O_7H_4$$
$$P_2O_5 + H_2O = 2PO_3H$$

Graham observed that the hydrate PO_4H_3 is constituted like a salt, inasmuch as its hydrogen can be replaced atom for atom by other metals, like sodium, potassium, &c., forming such compounds as PO_4NaH_2, PO_4Na_2H, &c.

In order to appreciate duly the powers of mind of the author of this admirable research, we ought to compare his methods of reasoning with those generally prevalent among contemporary chemists, and on the other hand with the methods of to-day. One would fancy that Graham had been acquainted with the modern doctrines of types and of polybasic acids, so clearly does he describe the chemical changes in matter-of-fact language, and so consistently does he classify the compounds by their analogies. At that early period we find Graham considering hydrogen, in various salts, as a basylous metal; an idea which (in spite of its undeniable truth) some chemists of the present day have not fully realised.

Amongst minor chemical researches may be mentioned a series of experiments on the slow oxidation of phosphorus by atmospheric air. He discovered that this process (and the faint light which accompanies it) is arrested by the presence in the air of a trace of olefiant gas, $\frac{1}{150}$ of the volume of the air being sufficient for the purpose. Still smaller proportions of some other vapours were found capable of producing this same effect; spirits of turpentine being particularly remarkable, as less than a quarter of a thousandth of its vapour with air was found sufficient to prevent the slow oxidation of phosphorus.



THOMAS GRAHAM (from a recent Photograph)

On another occasion Graham investigated phosphuretted hydrogen, and made some remarkable observations concerning the conditions of the formation of the spontaneously inflammable gas. One of these deserves especial notice in connection with the action of olefiant gas, and in preventing the oxidation of phosphorus. He found that phosphuretted hydrogen is rendered spontaneously inflammable by the admixture of a very small proportion of an oxide of nitrogen, probably nitrous acid.

One of the most obscure classes of combinations are those which water forms with various salts. These bodies are characterised by the chief peculiarities which belong to definite chemical compounds; but chemists are as yet unable to explain them.

Water so combined is called water of crystallisation, and is said to be physically, not chemically, combined. A very convenient way of getting rid of a difficulty, by passing it on to our neighbours.

Graham examined the proportion of such water of crystallisation in a considerable number of salts, and he moreover examined the properties which it has when so combined. He found that some of the water in an important class of sulphates is held far more firmly than the remainder, and with force equal to that with which water is held in various chemical compounds. He showed that such firmly combined water can be replaced by salts in a definite chemical proportion. In fact, he got fairly hold of the subject by chemical methods, and laid the foundation for an explanation of it.

He discovered and examined compounds of alcohol with salts, and derived from them valuable evidence of the analogy between alcohol and water.

On a later occasion he made a series of important experiments upon the transformation of alcohol into ether and water, by the action of hydric sulphate. Liebig had endeavoured to explain the formation of ether in this process, by representing it as due to the decomposition at a high temperature of a compound of ether previously formed at a lower temperature; such decomposition being due to the increased tension of the vapour of ether at the higher temperature.

Graham justly argued that if the decomposition were due to the tension of ether vapour, it would not take place, and ether would not be formed, if the tension were not allowed to exert itself. He heated the materials in a closed tube, and proved that ether was formed, although the tension of its vapour was counteracted by the pressure thus obtained.

The line of research which occupied most of his attention, and in which his results were perhaps the most important, was that of diffusion; and it would be difficult to over-estimate the importance to molecular chemistry of his measurements, of the relative velocities of these spontaneous motions of particles of matter, whether in the state of gas or in the liquid state.

It was known that 1 part by weight of hydrogen occupies the same volume as 16 parts by weight of oxygen when measured at like temperature, and under like pressure. Chemical investigations prove that these equal volumes of the two gases contain the same number of atoms. We also know that the atoms in such a gas are in rapid motion, and resist the pressure to which the gas is at any particular time exposed, by striking against the surface which presses them together with force equal to that which presses them together.

Thus a given volume of hydrogen is maintained against the atmospheric pressure by an energy of atomic motion, equal to that of the same volume of oxygen. Each atom of hydrogen accordingly exerts a mechanical energy equal to that of each atom of oxygen; but we have seen that the hydrogen atom is much lighter than the oxygen atom, and accordingly it must move with much greater velocity than the oxygen atom.

Now Graham allowed hydrogen to escape through a very small hole in a plate of platinum; and allowed oxygen to escape under similar circumstances. He found that each hydrogen atom moves out four times as fast as each oxygen atom. His experiments were so arranged as to enable him to measure the relative velocities of certain motions of the atoms—motions not imparted to them by any peculiar or unnatural conditions, but belonging to them of necessity in their natural state. He found, moreover, that heat increases the velocity of these atomic motions, whilst increasing the force with which a given weight of the gas resists the atmospheric pressure.

The study of the condensation of gases by solids, and the combination of soluble compounds with membranes led him to discoveries which are likely to be of great value to physiologists in explaining processes of absorption and secretion.

Thus he found that oxygen is absorbed to a greater extent than nitrogen by caoutchouc, and that when a bag made of a thin membrane of this substance is exhausted by means of a good air-pump, the oxygen and nitrogen diffuse through it (probably as condensed liquids), and evaporate inside the bag in different proportions from those in which they are present in air; the oxygen rising to over 40 per cent. of the diffused air. Again, a mixture of hydrogen and oxygen was separated almost completely by the action of palladium, which condensed the hydrogen in very large quantity, and the oxygen very slightly.

Perhaps the most remarkable substances discovered in the course of his experiments on diffusion, were the soluble modifications of tungstic and molybdic acids, ferric oxide, &c., and the process by which these bodies were obtained was, perhaps, the most instructive part of the result; proving, as it does, that in their salts, these bodies have properties different from those which they normally possess in the free state; and retain them when the other constituent is removed by a sufficiently gentle process.

Another remarkable fact which bears on a most important theory, is the separation effected by Graham of potassic hydrate and hydric sulphate, by diffusion of potassic sulphate in aqueous solution—a fact which requires us to admit that the solution of the salt in water contains those products mixed with one another; just as much as the experiment of diffusing air through a porous clay pipe, and getting its constituent in a different proportion from that of the original air, proved that air is a mixture and not a compound of the two gases.

In his later researches Graham was assisted by Mr. W. C. Roberts, and cordially acknowledged the zeal and efficiency displayed by that able young chemist. Graham's scientific influence extended beyond his researches; for, on the one hand, his lectures for 18 years at University College were remarkable for logical accuracy and clearness of exposition, and were highly valued by those who had the privilege of hearing them. On the other hand, his "Elements of Chemistry" is a masterly exposition of the best known facts of the science and of chemical physics. It was translated into German, and afforded at that time the most philosophical account of the working and theory of the galvanic battery.

In many of his ideas Graham was in advance of his contemporaries, and it might be difficult to find a chemist who has dealt more cautiously with general questions and delicate experimental operations,—or one whose results, in each direction in which he has worked, may more safely be expected to stand the test of future investigations.

A. W. WILLIAMSON

THE MEETING OF GERMAN NATURALISTS AND PHYSICIANS AT INNSBRUCK, TYROL

FROM the 18th to the 24th of September last the little town of Innsbruck wore an air of unwonted bustle and excitement. Its population, already augmented by the usual throng of summer tourists, was swelled by the advent of somewhere about 800 additional visitors—professors, doctors, directors, men of all sciences, often with their wives and daughters, who had come from all parts of Germany to attend the forty-third Meeting of the German Naturalists and Physicians. These meetings resemble those of our own British Association, though they differ in several very characteristic respects. One of the first contrasts to strike an Englishman is the entire absence of private hospitality. Everybody, so far as we can learn, is in private lodgings or in a hotel; and there are no such things as dinner-parties. Although our own customs in these respects are certainly very pleasant, there can be no doubt that the German fashion leaves the visitors more freedom, and allows them much more opportunity of seeing and talking with the friends they most wish to meet. With us it is no easy matter to get together a party of chemists, or geologists, or physiologists, to hold a social gathering after the labours of the sections are over. We are all either staying with friends, or invited to dinner, or engaged in some way. But at the German meetings such social reunions are one of the distinguishing features. One o'clock in the day brings with it the necessity for dining, and numerous dinner parties are improvised there and then; friends of like tastes, who have not met perhaps for a year before, adjourn to a *restauration* or *kaffee-haus*, and while eating the meal have a pleasant opportunity of comparing notes, and discussing questions which have in the interval arisen.

Another feature of contrast is in the length of time devoted to the sitting of the sections. At the British Association the sections open their sittings at eleven in the forenoon; and the work goes on steadily all day without intermission till four or five o'clock in the afternoon. But, in Germany, the sittings commence sometimes as early as 8 A.M., and are frequently over by ten or eleven o'clock, leaving the rest of the day for some short after-dinner excursion, or for general miscellaneous intercourse among the members. In fact, the German meetings are designed less for the purpose of bringing forward new scientific work, than with the view of affording to men of science opportunities of becoming personally acquainted with each other, and of discussing the value and bearing of recent contributions to knowledge. Hence, the papers which are brought before the sections, contain, to a large extent, outlines, summaries or notices of recent researches, and exhibitions of books, maps, memoirs, specimens, experiments, &c., which have recently attracted notice.

In our British Association gatherings, there is probably more hard work than in those of our German brethren, and I daresay there is as much opportunity for sociality as suits our national temperament. For our Association