Values of w_1 and w_2 for different salt types in which the anion and cation have equal mobilities are given in the following table. w_1 varies with the relative mobilities of the two ions; w_2 is independent of them.

VALUES OF VALENCY FACTORS.

Salt Type.	w_1.	w_2.
KCl	1	1
K_2SO_4	4·24	1·41
$MgSO_4$	8	2

It will be seen that the above equation is in general agreement with the experimental results for strong electrolytes, as the fall in λ is proportional to the square root of the concentration, and is dependent on the dielectric constant of the solvent and on the valencies of the ions. The best test of the theory is to see how nearly the equation enables us to calculate the conductivity of a salt in different solvents. The observed and calculated

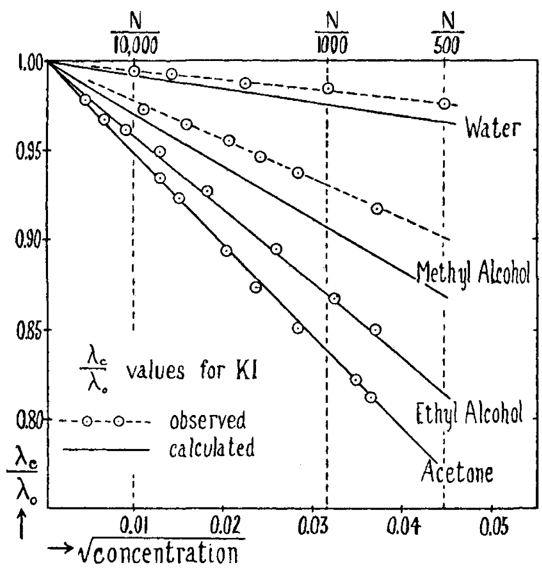

FIG. 1.

results for potassium iodide are plotted in Fig. 1, the values of b required being calculated by means of Stokes's equation from the mobilities of the ions at infinite dilution. In water and methyl alcohol the calculated slope of the λ_c/λ_o curve is greater than the observed slope; in ethyl alcohol and acetone the agreement is very close. The salt was chosen at random; others would have given better agreement in some solvents and worse in others, but looking at the results generally, it is a striking achievement that Debye and Hückel's theory is able to predict so closely the variation of the equivalent conductivity in dilute solutions in different solvents from a knowledge of the physical properties of the solvent and the mobilities of the two ions at infinite dilution.

The mathematical theory is not yet in a final form even for dilute solutions; it takes no account of the changes in the solvent due to the high pressures produced locally by the electrical attractions between the ions, or of the change in the dielectric constant with the concentration of electrolyte. There is, too, some uncertainty as to the exactness with which Stokes's equation is obeyed; nevertheless, in its present form it gives us ample support for the belief that strong electrolytes are completely dissociated in dilute solution, and that the interionic forces may be responsible for their changes in properties with dilution.

Even, however, in dilute salt solutions, specific chemical interaction between the ions may be of importance, in addition to the normal electrical attraction between them. It is true that in dilute aqueous solutions there is a surprisingly close agreement between the behaviour of salts of the same valency type, although the salts of mercury form a striking exception to the rest, but when we pass to non-aqueous solvents with a lower dielectric constant, the purely physical aspect of the ionic relationship becomes more limited in its application, while the specific interaction of the ions begins to play a more important part. For example, in water the slopes of the equivalent conductivity curves of uni-univalent salts are nearly the same, while in methyl alcohol the results are far less regular; most nitrates have a different slope from that of the chlorides, and the values for silver nitrate fall much more rapidly than those for any other salt.

These differences are too great to be accounted for, on Debye's theory, by differences in the sizes or relative mobilities of the ions; and they indicate in some cases incomplete dissociation owing to interaction between the ions. With divalent ions the discrepancies in non-aqueous solvents are still more marked. In methyl alcohol, calcium chloride and perchlorate are normal in slope while calcium nitrate behaves like a weak electrolyte; with zinc, on the other hand, the perchlorate and nitrate are normal while the chloride is abnormal. Whether this is due to the formation of complex ions or of molecules is not yet known, but it is evident that in dilute non-aqueous solutions the specific interactions of the ions—in fact, their chemical affinities—may dominate the situation.

Obituary.

SIR GEORGE GREENHILL, F.R.S.

THE death of Sir George Greenhill will be greatly regretted by some generations of Artillery officers who were instructed by him in the mathematics of their profession as they passed through the 'Advanced Class' of the school at Woolwich which has had several names but is now known as the Artillery College. When the present writer joined that class in the spring of 1880, Greenhill had already been the mathematical professor there for several years. He went there after a short service at Coopers Hill and followed in succession Bashforth, Hirst, and Niven.

Good judges have been of opinion that Greenhill excelled in the application of dynamics to the problems of everyday life. The questions which, during many years, he contributed to test the candidates for the Mathematical Tripos and other examinations at Cambridge give ample evidence of this. They were concerned largely with the motion of trains and ships, and were recognised as being more in correspondence with actual facts on the engineering side than the academic type of question that had been previously in vogue. He was thus, clearly, the right man in the right place at Woolwich. He was able to treat artillery problems from the engineering point of view and to inspire his pupils to get as far as possible down to the actual facts of gunnery.

During the whole time that Greenhill was at Woolwich, more than thirty years, he was engaged in original investigations both pure and applied. In pure, he had a great liking for the elliptic functions, based on admiration of the classical works of Abel and Jacobi. His best work here had to do with the difficult subject of complex multiplication. In this and in similar investigations he was never satisfied with *theoretical* solutions. Abel having shown that certain equations could always be solved in radicals, Greenhill laboured actually to exhibit such solutions, and in this he was very successful. This was promptly recognised abroad, and his papers on the subject were translated into foreign languages. He was also concerned with the importance of having tables of theta-functions calculated. One of his last acts was to inspire Col. Hippisley, R.E., to carry out this work, which had been in abeyance since the death of Henry Stephen Smith.

Greenhill's leaning towards numerical results from complicated equations was assisted by uncommon algebraical power, which is constantly in evidence in his long series of papers in the *Proceedings of the London Mathematical Society*. The only book that he wrote that was entirely on pure mathematics was his "Differential and Integral Calculus" (1885). In this he is content to obtain results that are necessary for the practical applications. He had no liking for the modern refinements which are based upon the theory of functions. He was wont to speak of these as being "the morbid pathology" of the subject. He was aware, no doubt, that this "morbid" work had to be done by some one, but he was frankly out for practical applications, and was content to be in the company of many of the mathematical physicists of the day who, for example, use Taylor's theorem in practical questions and have little sympathy with a series of lectures on the cases in which Taylor's theorem fails.

Greenhill's "Applications of Elliptic Functions" is a work which exhibits many new results and much algebraical facility in getting out actual numbers. The "Hydrostatics" (1894) is probably his best book, as it is distinctly a new departure. Before its appearance the text-books were mostly on familiar academic lines and treated hydrostatic machines from a diagrammatic point of view. Greenhill's work deals, on the other hand, with the machines actually in use. He spared no pains to get down to reality. The *Transactions* of various institutions of naval architects were ransacked to supply him with problems old and new and their practical solutions. This material is arranged, described, illustrated, and treated by a consummate master of the subject. The result is a book which is unique and of exceptional value to all those who look for information on practical hydrostatics and pneumatics. It has met, it is believed, with universal approval.

Although he drew much of the material for this book from the work of others, Greenhill himself made considerable contributions to the subject. He wrote the article on hydromechanics for the "Encyclopædia Britannica." He defines it as the science of the mechanics of water and fluids in general, including fluids both in equilibrium and in motion. He made several contributions to the publications of the Institution of Naval Architects. In one of these (*Trans.*, 1894) he gave a remarkable demonstration of the theorem of Leclert which expresses the radius of curvature of the curve of flotation of a ship in terms of the radius of the curve of buoyancy, the volume of displacement, and the moment of inertia of the water-plane. It is accompanied by geometrical theorems, of much elegance, connected with stability. In another paper (*Trans.*, 1888), he writes upon the action of the marine propeller. Rankine (1865) assumed that the propeller impresses change of motion upon the water without change of pressure except such as is caused by the rotation of the race. Greenhill takes the converse view and assumes that it is obtained by change of pressure, the only changes of motion being the circumferential velocity due to the rotation of the screw, and a sufficient sternward momentum to equalise the radial and axial pressures.

Greenhill's most important contribution to practical gunnery appears to have been in regard to the rifling of ordnance. The first rifled gun-barrels came from the hands of two Nuremberg men, Kottee (1520) and Danner (1552). There exists at the Rotunda, Woolwich, a muzzle-loading barrel, dated 1547, rifled with six fine grooves. Robins, Copley medallist in 1746 of the Royal Society, experimented with rifled guns and elongated shot in England, but the question did not come seriously to the front until after the Crimean War, when the increased muzzle-velocities and the high pressures in the powder chambers and barrels caused the subject to be urgent. Armstrong's firm, and in particular Capt. (afterwards Sir Andrew) Noble, was the pioneer, and by proposing an increasing twist in the rifling from the powder chamber to the muzzle, directed the attention of the world of science to the problem. Greenhill worked at the subject independently. He established that the pitch of the rifling necessary to keep a projectile in steady motion is independent of the muzzle-velocity, of the calibre, and of the length of the gun; depending principally on the length of the shell and on its description, so that, for similar projectiles, one pitch would do for all guns. The importance of this work and its value to Great Britain are beyond all question.

In gunnery Greenhill, at Woolwich, did much to improve the application of the results of Bashforth's experimental work. In external ballistics he did not do anything comparable with the pioneer work of the latter, who laid a foundation stone which, through the years, has never been appreciably disturbed by the workers in any country of the globe.

The War, which disclosed many new problems, found Greenhill in retirement. The questions came before other brains and hands, and enormous progress has been made in every branch. The last occasion upon which he was much in evidence was during the meeting of the British Association and of the International Mathematical Congress at Toronto in 1924. On the passage out in the *Coronia* he was observed to be suffering and failing generally. He was a pathetic sight as he moved slowly about the boat. It will be remembered that he could not be found when the company arrived at Montreal. In answer to a telephone call he was not reported at Toronto, and real anxiety at once existed as to what had befallen him. This lasted for several days until it was discovered that he had really gone on straight to Toronto without telling any one of his intention and without reporting his arrival in that city officially. He was one of the few men of science at the meeting who had accompanied the Association in 1884 when it met at Montreal, for the first time in Canada, under the presidency of the late Lord Rayleigh. He had in his possession a photograph of a group of men taken on that occasion, on the outward voyage. It caused much interest, as it put in evidence the antiquated appearance that a group taken forty years ago can exhibit.

Greenhill was always somewhat eccentric, and as he became older increasingly so. Many of his colleagues or pupils who have travelled with him will recall that he was prone just to catch his train, so that he frequently just missed it. This, of course, is not an eccentricity which works well for the fellow traveller. In the earlier years he was distinctly sociable, certainly so at Woolwich. Later he became less so, and other points in his character—such, for example, as not giving a direct answer to a question—were accentuated. These peculiarities of thought and mind, which were constantly in evidence in social circles, appear to some extent in his mathematical writings and letters; also particularly in the reviews for which he was responsible in NATURE and other periodicals. He was obsessed by the idea that mathematicians were not sufficiently engineers and were too much addicted to the philosophical side of their subject. Scientific engineers have been apt to regard him as being unpractical. Undoubtedly he stood somewhere between mathematicians and engineers, and was probably more of a mathematician and less of an engineer than the late Prof. Perry.

Greenhill's mathematical ability was recognised throughout his life. He was second wrangler in 1870, Pendlebury's year, and was bracketed with the latter for the Smith's Prize. He became a fellow of the Royal Society in 1888 and served in the Council in 1896. He received its Royal medal and also the de Morgan medal of the London Mathematical Society. He was corresponding member of the Paris Academy of Sciences and Officier d'Académie, and a foreign member of the R. Accad. Lincei. Young men who evinced a liking for mathematical research always received encouragement from him when he came across them. This was particularly so when it was a case of one who had not been through the usual scientific 'mill.' By such he is gratefully remembered. P. A. M.

DR. C. D. WALCOTT.

GEOLOGISTS and palæontologists mourn the loss of Dr. Charles Doolittle Walcott, who died on Feb. 8. For the last half-century he had occupied a foremost place in research in North America, and his discoveries in the older Palæozoic rocks had excited universal interest and admiration. At an age when most workers begin to need some repose, he continued his investigations with unabated vigour, and he was active in the pursuit of science almost to the end.

Charles D. Walcott was born in New York Mills, Oneida County, New York State, on Mar. 31, 1850, and was descended from New England settlers who had emigrated from Shropshire in the seventeenth century. When still at school at Utica he had already developed an interest in science, and at the age of thirteen he began to collects systematically both fossils and minerals. From school he proceeded to the Utica Academy, and eventually started life as clerk in a hardware store, where he acquired a practical business training which he always felt had been a real advantage in his later career. At the same time all his spare energies were devoted to scientific studies, and his discovery of Cambrian and Ordovician fossils near his home caused him to resolve that he would spend his life so far as possible in investigating the oldest fossiliferous rocks of the North American continent. In 1871, when visiting Indianapolis, he was encouraged in this resolve by Prof. E. T. Cox, who was at that time making a geological survey of the Indiana coalfields. Walcott therefore abandoned commerce, and spent the next five years on a farm at Trenton Falls, where he arranged to do a certain amount of manual labour in return for his board and lodging, and kept the rest of his time for study and field-work. In 1873 he sold his Trenton fossils to the Museum of Comparative Zoology, Harvard University, and would at the same time have gone to pursue a course of study under Prof. Louis Agassiz, had not that great naturalist just died. He had already discussed his plans for future research with Agassiz, and had decided that one of his main endeavours should be to determine the nature of the trilobites. He began by making polished sections of specimens from the Trenton Limestone, and thus discovered the first evidence of the branchial apparatus and the limbs in this group of fossils.

At last, in November 1876, Walcott found a congenial official appointment which enabled him to start his life's work in earnest. He became