THE WEATHER OF 1912.

THE almost complete absence of summer weather and the frequent rains at almost all seasons have rendered 1912 memorable. The bad weather was more noticeable by contrast with the magnificent weather of 1911. The summer contrast for the two years was dealt with in NATURE for September 19, 1912, pp. 71–73.

LONDON RESULTS.

1912	Temperature Means						Rainfall			Sunshine	
	Max.	Min.	Max. and Min.	Diff. from average	Days above average	Frosty nights	No. of rainy days	Total fall	Diff. from average	Daily mean	Diff. from average
	°	°	°	°				In	In.	Hours	Hours
January	44·9	36·0	40·4	+2·0	19	8	18	3·03	+1·15	0·89	−0·51
February	48·6	38·6	43·6	+3·8	23	7	21	1·73	+0·25	1·33	−0·78
March	53·3	40·5	46·9	+4·4	26	1	19	2·58	+1·06	2·97	−0·39
April	59·8	39·4	49·6	+1·5	17	2	2	0·04	−1·53	7·47	+2·44
May	67·5	46·5	57·0	+3·2	24	—	12	1·29	−0·63	6·15	−0·26
June	69·5	49·3	59·4	−0·9	11	—	18	2·35	+0·31	7·29	+0·81
July	74·9	54·4	64·6	+0·9	15	—	11	1·24	−1·16	5·34	−1·91
August	66·7	50·1	58·4	−4·5	1	—	26	4·27	+1·93	3·69	−3·09
Sept.	60·8	46·5	53·7	−4·5	4	—	5	2·11	−0·04	3·96	−1·26
October	57·1	39·3	48·2	−2·2	9	2	14	1·88	−0·90	3·96	+0·88
Nov.	48·3	39·3	43·8	+0·4	17	6	16	1·55	−0·67	0·89	−0·83
Dec.	50·5	40·7	45·6	+5·8	26	2	21	2·82	+0·99	0·86	+0·07
Year	58·5	43·4	50·9	+0·8	192	28	183	24·89	+0·76	3·73	−0·40

The Greenwich observations given in the foregoing table are taken from the reports of the Meteorological Office. The mean temperature for the year is 50·9°, which is 0·8° in excess of the average. From June to October inclusive July was the only warm month. In both August and September the deficiency was 4·5°, and in the two months combined there were only five warm days. December, with the mean of 45·6°, was 5·8° in excess of the average. There have only been two Decembers since 1841 with a higher mean; these were 46·2° in 1852, and 45·8° in 1868. The excess of temperature in March was 4·4°, and the month in some districts was the mildest during forty years. There were only twenty-eight days with frost during the year.

The wettest months of the year were August, January, December, and March. There were only five days without rain in August, and only ten dry days in December. The driest month was April, with a total rainfall of 0·04 in., and at some places in the south-east of England the month was rainless.

The year's sunshine was 1364 hours, and the sunniest month was April, with a duration of 225 hours, which is 85 hours in excess of the average, and it was double the duration registered in August, which, with its 114 hours, was the least sunny month of any from April to October inclusive.

The summary for the year given by the Meteorological Office from the results for the fifty-two weeks ended December 28 shows that the greatest excess of rain in any district was 9·57 in. in the south-west of England, whilst in all the English districts, except the north-west, the excess was more than 5 in. The west of Scotland was the only district with a deficiency of rain and there it was less than an inch short of the average. The duration of bright sunshine was deficient over the entire kingdom; the greatest deficiency amounted to 0·9h. per day for the year in the north-east of England, and 0·8h. per day in the east of Scotland, the south-west of England, the south of Ireland, and the Channel Islands.

CHAS. HARDING.

SCIENCE TEACHING IN PUBLIC SCHOOLS.[1]

IN the period of more than sixty years during which I have watched the progress of education in this country, no feature seems to me to stand out more prominently in that progress than the entrance and establishment of science in a recognised place in the tuition of our public schools. At the beginning of the period the teaching of even the rudiments of a knowledge of nature formed no part of the ordinary curriculum of study. Here and there, indeed, there might be found an enlightened headmaster or other teacher who, impressed with the profound interest and the great educational value of the natural sciences, contrived to find time amid his other duties to discourse to his pupils on that subject, and sought to rouse in them an appreciation of the infinite beauty, the endless variety, the ordered harmony, and the strange mystery of the world in which they lived. He might try to gain their attention by performing a few simple experiments illustrative of some of the fundamental principles of physics or chemistry, or by disclosing to their young eyes some of the marvels which they might discover for themselves among the plants and animals of the countryside. Such broad-minded instructors, however, were rare, and were far ahead of their time.

There were then no special science teachers, no school laboratories, no proper school museums. The range of instruction in the public schools still lay within literary lines, pretty much as it had existed for centuries; excellent, indeed, so far as it went, but somewhat out of date, and no longer in keeping with the modern advance of knowledge and culture all over the world. Boys left school, for the most part, profoundly ignorant of nature, save in so far as they had been able to pick up information by the way, from their own observation, reading, or reflection. At the universities they fared little better. Chairs for the cultivation of various branches of science had indeed been founded there. But the duties of the professors were usually considered to consist chiefly or solely in the delivery of lectures, which were sometimes dull enough, and, where not required in reading for degrees, would attract but scanty audiences. An enthusiastic or eloquent professor might gather around him a goodly company of listeners as, in geology, Buckland used to do at Oxford and Sedgwick at Cambridge. But the laboratory work and experi-

[1] From the presidential address delivered to the Association of Public School Science-masters on January 8 by Sir Archibald Geikie, K.C.B. Pres.R.S.

mental demonstrations, now admitted to be so essential, had scarcely begun to be instituted in the universities. Lord Kelvin's famous physical laboratory, one of the earliest institutions of the kind in this country, was started by him only about the year 1850, and that of his friend Tait at Edinburgh some years later.

But the discoveries of modern science last century and the far-reaching effects of their practical applications in everyday life were arousing rapidly increasing attention in the community. Natural knowledge was seen to be both of supreme interest in itself and of paramount importance on account of the many ways in which it could minister to the welfare of man. It was impossible that education could long remain unaffected by this widespread appreciation. Alike on the schools and on the universities the force of public opinion began to make itself felt. Ere long a momentous step was taken by a Royal Commission which was appointed to inquire into the public schools, and which, in its report, "strongly recommended the introduction and fostering of natural science in these schools." The Public Schools Act, which embodied the recommendations of the Commission, was passed in 1868, and may be regarded as marking the definite starting point of this great reform.

Of course, the adoption of science teaching in the public schools has not everywhere made the same progress throughout the country. As was to be expected, it has been unequal, depending as it did on the disposition of the authorities at each school, as well as on the accommodation and funds available. In one or two schools the position of science is perhaps nearly as good as is at present required, and the rest are gradually improving. Everywhere the spirit of compromise and amity has prevailed, and there seems to be on all sides a general desire to meet the requirements of the science side, so far as the circumstances of each school will permit.

If from the schools we turn to the universities, we see that the advance of the provision for the sciences has there been still more rapid. Not only have the older seats of learning widened their range of studies and largely increased the facilities for scientific research, but newer universities have sprung up in different centres of population, with the dominant purpose of developing scientific training and promoting the prosecution of original investigation. As a further and significant proof that the community at large has awakened to the importance of making natural science one of the branches of education, we must also take account of the multiplication of secondary schools having a scientific element, and the rise of technical schools and colleges.

This retrospect of the past half-century and the outlook which it discloses for the future cannot, I think, be contemplated without considerable satisfaction by the reasonable advocates of science who are not swayed by an inborn spirit of iconoclasm. The advance which has been made may not have been as rapid as these reformers desire, or as we all hoped for But it has been real, it is still in progress, and we may believe that it will now advance more equally and rapidly over the whole country.

But while I am of opinion that we have cause to rejoice over what has already been accomplished, I do not wish to draw too roseate a picture of the present state of the science teaching in this country, or of the position and prospects of the science-masters. I well know that these teachers are in many cases confronted with serious difficulties which hamper them in their work. They are, so to say, newcomers into the educational system of the country, and the subjects which they teach have consequently neither the prestige nor the position held by the long-established literary studies. Such a state of matters is obviously one that can only be changed by the lapse of time, and let us hope that this lapse will not be prolonged. In the meanwhile, the science-masters, straining every nerve to make their teaching effective, will, by their success in kindling a love of science among their pupils and demonstrating the educational value of their teaching, take the most effectual way to establish the position of science and to further their own claims for consideration.

The necessity of providing several science-masters, where circumstances permit, raises the difficulty of finding places for them in the already crowded timetable of the school. This is undoubtedly a very serious problem. Each of the various subjects taught contends for what is thought adequate time. And in this competition undoubtedly the older subjects in the curriculum, being already in possession, and having strenuous defenders, are at a considerable advantage over those which have been recently introduced. But the difficulty is one which, in the hands of a sympathetic headmaster and with a spirit of goodwill among the members of his staff, ought not to be insuperable. Even without the curtailment or abandonment of any of the studies already in the field, it should be possible by tactful rearrangement to secure at least the time demanded for the minimum amount of science teaching which is indispensable. In my opinion this minimum should ensure that every boy at a public school shall be given the opportunity of obtaining a broad general idea of the scope and bearings of natural science and of having his apprehension stirred with regard to the manifold interest and charm of nature. This end cannot be properly attained by lectures alone, though these, from an inspiriting teacher and well illustrated with experiments or demonstrations, are invaluable. They require, however, to be supplemented with practical work by the pupils, wherein they can themselves handle apparatus, and thus gain a far more vivid and lasting knowledge of physical and chemical laws and processes than can be acquired in any other way. They must also learn the fundamental elements of biology and geology, studying not only with the teacher in the class-room, but with specimens of plants and animals in the laboratory or museum, and where possible in the field.

The true educator, no matter in what branch of discipline he may be engaged, is not a man whose chief aim is to cram into the minds and memories of his pupils as ample a store of knowledge as these will hold, and whose success is to be judged by the results of competitive examinations. If this is true on the literary, it is not less so on the scientific side. And on the latter the temptation to teach in that unfruitful way is probably greater than on the former. I have known more than one teacher of science possessing a wide acquaintance with his subject, yet quite incapable of making use of it as a stimulating educational instrument. Full of details, he would pour them forth in wearisome iteration, without the guiding thread of logical sequence that would have linked them intelligibly and interestingly together. Men who have within them no store of living fire are hopelessly incompetent to elicit any spark of it in their listeners. I hope such men are rarer now than they were in my younger days. If they have not passed with the dodo and the gare-fowl into the domain of extinct creatures, they should be zealously kept out of our public schools.

In all the educational world I can think of no task more delightful to undertake than that of the science-master. At the same time there are few which demand so wide a range of qualifications. To reach the highest success in his calling the science-master must, of course, be thoroughly versed in his subject, alike theoretically and practically. He should, if possible, be a man who has himself done some original research, or at least is intimately familiar with methods of experimentation and investigation, and able to guide his pupils along the lines of independent research. I am strongly of opinion that his efficiency will be much augmented if he has had a good literary as well as a scientific training. When he enters on his teaching career he will soon find the great advantage of a cultivated style, both in discoursing and in writing. Unfortunately some able men of science who have neglected the literary side of their education cannot arrange their thoughts in proper sequence or express them with clearness and terseness. I would urge the science-master to keep his hold on literature, ancient as well as modern. Many a time when weary with his labours, and discouraged, perhaps, by the difficulties wherewith they are beset, he will find in that delightful field ample consolation and refreshment.

But, above all, the science-master must be thoroughly in love with his subject and possess the power of infusing some of his affection for it into his pupils. His evident and genial enthusiasm should be infectious and become an inspiration that appeals to his boys in everything he does, whether as he lectures and demonstrates to them in the class-room or as he shows them how to work in the laboratory. There are probably few other callings in the educational domain where the personal touch, the stimulating influence that springs from earnest devotion to a subject, has so many opportunities of manifesting itself and tells more promptly and powerfully on the pupils. The teacher who is gifted with such an inspiring power may do more in the way of developing a love of science with the meagre outfit of a parish school than a man without this influence can do with all the resources of a modern laboratory.

RADIATIONS OLD AND NEW [1]

WHEN, therefore, X-rays are projected into any material we must think of them as a stream of separate entities, each one of which has complete independence of its neighbours and pursues a life of its own. It changes to a β ray and back again; as a β ray it is liable to loss of energy and much deflection, so that those rays which do not pass through the body but are held therein end as electrons moving about in the body with the velocities of thermal agitation; that is to say, with those velocities which free electrons in the body must possess on account of the share which they take in carrying the heat of the body.

Now we may ask ourselves what will be the result if transformations continue to take place at these lower energies; for the moment let us assume that they do. Let us consider some substance like a block of metal. Within it we know that there are innumerable electrons travelling to and fro with various speeds. In their motion is stored up energy; the communication of heat to the body makes them dance more quickly. When the quicker motion is begun in one part of the body, diffusion hands on the motion to the rest; that is to say, heat has been conducted through the body. If we try to pass an electric current through the body, it is the movement of the electrons that constitutes the current. This is the accepted theory at the present time. It is even possible—but this is not accepted by all—that the energy of the moving electrons in the body constitutes the main store of heat therein. The electrons do not all move at the same speed, of course; but there is a certain well-known distribution of their energies about a mean value. At any time a certain percentage of the electrons are moving with speeds lying within definite limits, although the individuals possessing such speeds are continually changing. If we now take into account the transformations of which I have been speaking, we find that there must be X-ray quanta—this name will do for them as well as any others—in such numbers as to be in equilibrium with the electrons of every variety of speed. In the case of the X-rays and electrons which we have been handling in our experiment, we find that the greater the energy the larger the number of X-ray quanta required to be in equilibrium with the corresponding electrons, for quanta of large energy are transformed into electrons much more rarely than quanta of small energy, whereas electrons of large energy are transformed as often, and perhaps more often, than those of small energy. Thus the distribution of energy amongst the quanta is not the same as the distribution amongst the electrons; in the former there is a much larger number—relatively—of the quanta of larger energy.

The electrons which we are considering have very little power of penetration or of breaking away from the substances in which they are. At high temperatures, when they move more quickly, there is a considerable emission, an effect which has been much studied recently. But at ordinary temperatures the emission of electrons is small. Recently R. W. Wood has suggested that there must be an "aura" of electrons surrounding a conductor and extending a minute distance away, since only in this way can we account for the fact that electricity passes freely from one conductor to another when they are separated by a space of the order of a wave-length of light. But if the electrons have such difficulty in breaking away from a substance, this is not true of the X-ray quanta. If they behave like those we have been investigating of recent years, they have far greater powers of penetration than the electrons, and every body must be emitting them in streams. Moreover, if bodies be placed near each other, there will be an interchange which will hand energy from one to the other until there is an equilibrium. If a hot body is placed near a cold one, the former contains some electrons and corresponding quanta of great energy, and as these stream over to the cold body, they go through transformations which permit of loss of energy, since for a time they put the energy into electron carriers which can exchange, and do exchange, energies with others—through the mediation of the atoms, it may be. X-ray quanta have not that power of themselves. Thus in time the two bodies are brought to the same temperature.

In this way we have a conception of radiation which on the surface differs from that which is ordinarily held. But does it do so really? May it be that we have merely found a different method of regarding the processes of radiation? If so, that would be a very good thing, for it is one of the best aids to inquiry to have more than one hypothesis which will link together a number of experimental facts. Nor need we be afraid if the hypotheses differ considerably. On the contrary, that means that we have the greater number of interesting things to discover between the two points of view and their final point of convergence.

Now we know that when light falls upon material substances there is an emission of electrons of slow speed; in other words, light radiation resembles

[1] Evening discourse delivered on September 6, 1912, before the British Association at Dundee by Prof. W. H. Bragg F.R.S. Continued from p. 532.