on June 23, in which he suggests a connection between the red sunsets and the frequent rains. During the latter half of the past winter the rains were incessant in the Atlantic States of America, and the writer suggested that they were due to the volcanic dust in the atmosphere, in a letter published in the *Philadelphia Public Ledger* of February 23. In a subsequent issue, March 8, he called attention to Dr. Aitken's researches. Subsequently Prof. Heilprin, of the Philadelphia Academy of Natural Sciences, offered a similar suggestion.

Philadelphia, July 16 CHAS. MORRIS

THE SALTNESS AND THE TEMPERATURE OF THE SEA[1]

PROFESSOR DITTMAR'S researches, an account of which forms Part I. of this volume, have finally proved that, so far as the most refined analysis can go, the mixture of salts dissolved in ocean water has attained a state of chemical equilibrium. But, although there is constancy of proportion between the various salts, the ratio of the total salts to the water varies considerably in different parts of the ocean.

The great evaporation in the dry tropical areas and the removal of water by freezing in the Polar seas tends to increase the salinity in these places, while in the tropical zones of continual rain and in the Polar fringes where the icebergs melt, there is constant dilution going on. The determination of the salinity at different places and depths is of great oceanographic importance, and the problem of finding the salinity has been attacked in various ways. The most simple and straightforward is to evaporate a weighed portion of the water to dryness and weigh the residue, but this cannot be done without chemical change taking place. The magnesium chloride present decomposes with the water into magnesia and hydrochloric acid, and all the carbonic acid of the carbonates is driven off. Gay-Lussac showed long ago how to avoid the error due to the dissociation of magnesium chloride, but no means have yet been suggested for taking account of the carbonates in a total salt determination. Direct weighing being thus found inexpedient, the next best method would appear to be to find the exact amount of any one element present, and by means of a table of complete analysis, taking advantage of the constancy of composition of ocean salts, to convert that into the salinity by multiplication with a constant factor. This is the method which Prof. Dittmar prefers, and for the purpose he estimates the chlorine or rather the total halogen by means of his refinement of Volhard's process. When the salinity of water has to be determined at sea, this delicate method cannot be conveniently employed, and it has been customary hitherto to measure the specific gravity of the water very carefully and afterwards to reduce the results to salinities. An attempt has been made with considerable success in the United States to substitute the determination of the refractive index of water for that of the density, and thence to deduce the salinity by a formula. This method is pre-eminently adapted for use at sea, but it appears not to possess the necessary delicacy.

The only method by which the specific gravity of a fluid can be ascertained on board ship is by means of hydrometers, and as the extreme values for sea-water are, according to Mr. Buchanan, 1·02780 and 1·02400, apparatus of great delicacy must be employed. A very delicate glass hydrometer was used on the *Challenger*, yet in spite of its fragility and the thousands of observations that Mr. Buchanan made with it in all weathers, he succeeded in carrying the one instrument which he had used during the entire voyage back to this country unbroken. His description of the hydrometer is as follows :—

[1] "The Physics and Chemistry of the Voyage of H.M.S. *Challenger*." Vol. i. Part ii. "Report on the Specific Gravity of Ocean Water." By J. Y. Buchanan, M.A., F.R.S.E. Part iii. "Report on the Deep-Sea Temperature Observations obtained by the Officers of H.M.S. *Challenger* during the Years 1873-76." (London: Longmans and Co., 1884.) See NATURE, July 24, p. 292.

"Preliminary calculations showed that convenient dimensions would be about 3 mm. for the diameter of the stem and about 150 c.c. for the volume of the body, and from 10 to 12 cm. for the length of the stem. The tube for the stem was selected with great care from a large assortment, and no want of uniformity in its outward shape could be detected with the callipers. The tube for the body of the instrument was also selected from a number, in order to secure such a diameter as would give the instrument a suitable length. In order to provide against accidents, I had four instruments made from the two lengths of tubing. The glass work of the instrument being finished—except that the top of the stem, instead of being sealed up, was slightly widened out into a funnel—the instrument was loaded with mercury, until the lower end of the stem was just immersed in distilled water of 16° C. A millimetre scale on paper was then fixed in the stem, and the calibration carried on by placing decigramme weights on the funnel-shaped top, and noting the consequent depression on the scale. The whole length of the scale was 10 cm., and this portion of the stem proved to be of perfectly uniform calibre. Several series of observations were made in order to determine accurately the volume of any length of the stem. . . . When this operation of calibration was finished, the end of the stem was carefully closed before the blowpipe."

The constants necessary for making a specific gravity observation were all determined with the utmost care. They included the exact weight *in vacuo* of the instrument, the volume of the body, the volume of each division of the stem, and the expansion of the whole instrument for a degree Centigrade. These data were fully tabulated, and in addition tables were made of the total weight when each of a set of brass weights was placed on a small table that could be slipped over the top of the stem. These weights were necessary, as, without them, the stem would require to be of great length in order to serve for waters of different density.

In making an observation Mr. Buchanan always kept the water sample in the laboratory for a night in order that it might have time to attain the temperature of the surrounding air. He then placed about 800 c.c. in a glass jar supported on a swinging table, and immersed the hydrometer in it after ascertaining its temperature exactly. To insure the greatest possible accuracy two readings were frequently made with different weights on the table, the results separately reduced, and the mean taken as the density. The density was calculated in every case by ascertaining the weight of the loaded hydrometer and dividing it by the immersed volume, which is calculated from the temperature and stem-reading.

Prof. Dittmar examined very particularly into the probable error in reading Buchanan's hydrometer, and after a long series of experiments, described in the chapter on Salinity in Part I., he came to the conclusion that the difference between the salinity as calculated by it and by his direct chlorine determinations (*i.e.* $\chi_1 - \chi$ where χ stands for the permilleage of chlorine) amounted to $-·042 \pm \delta$, δ being a variable the chances of which being greater or less than ·06 are equal, and are 4 to 1 in favour of its being less than ·12. The value of χ is usually between 19 and 20.

At first Mr. Buchanan reduced his specific gravities to the temperature of 15°·56 C. by Hubbard's tables, but Prof. Dittmar, in the course of his investigation of "The specific gravity of water as a function of salinity, temperature, and pressure," succeeded in constructing a much better table in which the variation of the coefficient of expansion with the salinity of the water is taken account of, and all Mr. Buchanan's results published in this volume have been calculated by it. A very ingenious graphic method of comparing Hubbard's results with Dittmar's and converting one into the other is given in Plate I. of Part II.

In the course of his work Prof. Dittmar hit upon an elegant method of determining densities, which was found to be very satisfactory. He filled a water-bath with a particular sea-water that had been selected as a standard, and kept it at a constant temperature. A specific-gravity bottle was filled with the same water, stoppered, hung in the bath to the balance-pan, and weighed accurately. To compare any number of samples of water it was sufficient to fill up the bottle with the water in question, and again weigh it immersed in the standard. Prof. Dittmar confined himself to making out the relation between salinity, specific gravity, and temperature, leaving the relation of specific gravity and pressure for subsequent treatment by Prof. Tait, whose great chain of experiments on the compressibility of sea-water is now drawing to a close, and the results of which will shortly be published in the *Challenger* Reports. The conclusion Prof. Dittmar comes to is summed up in the formula—

$$\chi = \frac{{}_4S_t - {}_4W_t}{a + bt + ct^2},$$

where χ is the "salinity" or permilleage of halogen; ${}_4S_t$ the specific gravity of sea-water at $t°$ relatively to pure water at 4° C.; ${}_4W_t$ is the specific gravity of pure water in the same way; a, b, and c are constants which have been determined once for all.

In the chapter on Salinity in Part I. Prof. Dittmar gives a table dealing with 300 samples, collected in all parts of the ocean and from all depths. These tables show the position, the depth of the ocean at the station, the depth from which the sample was drawn, the permilleage of chlorine (χ), the mean deviation of the mean χ from the individual results, and the difference between the amount of chlorine as calculated from Buchanan's observations of specific gravity, and as found directly by Dittmar.

Mr. Buchanan gives in his report all his observations classified according to geographical position and depth, and arranged in eighteen large tables. These record the specific gravity of water from all depths in the North and South Atlantic, the Southern Indian Ocean, the North and South Pacific, and the interesting inclosed seas of the Malayan Archipelago. The numbers are simply given as they were observed, only corrected for temperature by Dittmar's table, and all discussion of their oceanographic significance has been deferred until a subsequent occasion.

A series of coloured charts illustrating the bathymetrical and geographical distribution of specific gravity over the whole world and in the individual oceans accompanies the memoir. These are extremely interesting, and in many cases they tell their own story without explanation, though when the full descriptions are published, the value and interest of the plates will be greatly increased. The track-chart of the *Challenger* coloured to show the surface salinity of the ocean, is especially worthy of notice; its details have been filled in, and the whole rendered more complete, by the incorporation of the results of other exploring expeditions.

The great importance of Mr. Buchanan's specific gravity observations will be more readily recognised by the general reader when they are elucidated by the work of Prof. Tait and Mr. Buchan, and treated more generally than is possible in a mere statement of observed figures.

The third part of the volume is devoted to the temperature observations made during the cruise. The nature of the information contained in the curves which make up this part of the work is very concisely put in the editor's introduction:—

"It has been deemed advisable to publish, for the convenience of scientific men, the whole of the deep-sea observations of temperature made during the voyage of the *Challenger*. These are given in detail in the accompanying series of 263 plates, which show the latitude and longitude of the station; the depth in fathoms of the bottom; the depth at which each temperature was taken; the number of the thermometer; the temperature actually observed read to quarter degrees; the error of the thermometer; and the temperature corrected for instrumental error only."

The temperatures have been plotted by Staff-Commander Tizard, and a free-hand curve drawn through the points. From this the "temperature by curve" which is employed in drawing the diagrammatic sections of the ocean showing the bathymetrical arrangement of the isothermals is taken. These sections will be published in vol. i. of the *Challenger* narrative, and to the general reader they will present a much more intelligible idea of the distribution of oceanic temperature than can be given by the study of tables of figures or curves for separate stations. The separate station curves are, however, of the utmost value to any one who wishes to make a detailed study of ocean temperatures. With a direct view to such a purpose the curves have been drawn with rigid adherence to the numbers in the observation books, even the most obvious cases of observational error being left uncorrected; for the specialist can easily discover and correct them himself, and no one else will notice them.

The temperature observations, like the specific gravity observations, form a rich mine of material with which good work may be done. It is shown by a glance at the charts that there are areas in the ocean of great salinity and areas of great dilution; it is shown that the pressure increases uniformly with the depth; it is known that the surface temperature of the water varies greatly in different latitudes, and that, as the depth increases, the temperature decreases, at first very rapidly, but after the first few hundred fathoms with increasing slowness, until at the bottom the temperature of the open ocean is everywhere the same, between 34° and 35° F.; it is known also that in inclosed seas, or in those where there are submarine barriers cutting them off from the rest of the ocean, the temperature assumes a constant value in its descent, and sometimes the bottom is nearly 20° F. warmer than that of the ocean at the same depth a few miles distant; but this is all that is known. It is evident that there must be an ocean circulation on a magnificent scale going on, a gradual onward sweep of the whole mass of the water, but the direction of this mass motion can only as yet be guessed at, and its rate is utterly unknown. The material for solving this, the great oceanographic problem, is rapidly accumulating, and when the physical and chemical reports of the *Challenger* Expedition have all been made public, it will be strange indeed if a large generalisation cannot be based upon them, and the discovery of the secret of ocean circulation be added to the many discoveries which have been made by the scientific men of the cruise.

The nature of this volume, both on account of the subjects with which it deals and the number of formulæ and long tables of numbers it contains, must have made the task of editing it no light one; and the accuracy of every part, the almost entire absence of typographical errors, and the beauty of the lithographed charts show that authors, editor, engravers, and printers have alike exerted themselves to produce a volume worthy of being the first to record the physical and chemical work of the *Challenger* Expedition. HUGH ROBERT MILL

SPECIALISATION IN SCIENTIFIC STUDY[1]

THERE once was a science called "natural philosophy," which, like some old synthetic types of animals, held in itself all the learning that applied to physical facts. By the beginning of this century this science of natural things had become divided into physics and natural history. These divisions have since spread,

[1] From *Science*.