“Challenger” cruise adopted Jacobsen’s method. Of the 164 samples which he sealed up successfully 69 came from the surface and 95 from depths varying from 5 to 4575 fathoms. A good number of these he analysed himself after his return ; the majority, however, were analysed and all were measured by Dittmar. The latter, in order to be able to interpret the results, also investigated the absorption of oxygen and nitrogen gas from air by sea water. The following table (VI.) gives the result of his investigations. One litre (1000 volumes) of ocean water when saturated with con­stantly renewed air at Z°, and a pressure of 760 millimètres1 plus tension of steam at *f* C., takes up the following volumes, measured dry at 0° C. and 760 millimètres pressure, @@1 of the pure gases.

|  |  |  |  |
| --- | --- | --- | --- |
| Tempera­  ture. | Dissolved Nitrogen and Oxygen in Cubic Centimètres (volumes). | | Percentage of Oxygen in Dissolved Gas. |
| C.  0° | Nitrogen.  15∙60 | Oxygen.  8∙18 | 34∙40 |
| 5° | 13∙86 | 7∙22 | 34∙24 |
| 10° | 12∙47 | 6∙45 | 34∙09 |
| 15° | 11∙34 | 5∙83 | 33∙93 |
| 20° | 10∙41 | 5∙31 | 33∙78 |
| 25° | 9∙62 | 4∙87 | 33∙62 |
| 30° | 8∙94 | 4∙50 | 33∙47 |
| 35° | 8∙36 | 4∙17 | 33∙31 |

The method used for obtaining these numbers adapted itself closely to the one which Buchanan had employed for extracting the gas samples. In the calculations it was assumed that atmo­spheric air contains 21∙0 volumes of oxygen for 79Ό volumes of nitrogen, the slight variation in this ratio, which is known to occasionally present itself, being neglected. From the table we can calculate approximately the limits between which the propor­tions of dissolved oxygen and nitrogen in the water of the ocean must be presumed to oscillate in nature. The pressure of the atmosphere at the sea-level, though by no means constant, is never far removed from that of 760 mm. of mercury. The temperature of the surface water (with rare exceptions) may be said to vary from - 2° C. (in the liquid part of the ocean in the arctic and antarctic regions) to about 30° C. (in the tropics). The ocean receives all its dissolved oxygen and nitrogen from the surface ; neither gas comes in from below, except perhaps a relatively insignificant quantity of nitrogen derived from the decay of dead organisms, which may safely be neglected. Hence the ocean can contain nowhere more than 15·6 c.c. of nitrogen or more than 8.18 c.c. of oxygen per litre, and the nitrogen will never fall below 8·55 c.c. We cannot make a similar assertion in regard to the oxygen, because its theoretical minimum of 4·30 c.c. per litre is liable to further diminution by processes of life and putrefaction and by oxidation generally. @@2

At any point in the surface of the ocean the water constantly tends to assume the composition demanded for the prevailing temperature by the laws of gas absorption. But it is rarely possible for it to assume this composition, owing to the water being in a continual state of motion ; and, supposing a certain area of the ocean surface were in a state of stagnation, the temperature would vary in diurnal cycles, and even the calculated volume of nitrogen per litre would be a periodic function of time, exhibiting its maxi­mum at the hour of minimum temperature, and *vice versa.* The process of absorptiometric exchange, however, even at the constantly oscillating surface of the ocean, is slow ; it could not keep pace with the change of temperature, and the actual nitrogen curve would never go as high up or as low down as the theoretical one. In addition to this, the lower strata of the water constantly add to, or take away from, the surface nitrogen by diffusion and occasional intermixture. All this holds for the oxygen likewise, except that it is liable to constant diminution by oxidation. On the whole we may assume that all the disturbing influences will only modify, not efface, the course of events as prescribed by the laws of gas-absorption.

In regard to non-surface water we have to confront a greater complexity of phenomena. The gas-contents of deep-sea water, of course, have nothing to do with the low temperature and the high pressure which in general prevail there. For the purpose of a preliminary survey, let us imagine a deep-sea water formed from one kind of surface water, which took up its air at a constant temperature (Z), and then sank down unmixed with other waters. The volumes of the oxygen and nitrogen per litre have at first the values assigned to them by the laws of gas absorption. But, while the nitrogen (as long as the water remains unmixed with other water) remains constant, the oxygen will become less and less through the processes of oxidation which go on in the deep with­out compensation. Hence if there were absolute stagnation in the ocean anywhere the proportion of oxygen there might be reduced ultimately to nothing. Among the many “Challenger” deep-sea specimens which were analysed for their gas-contents none was

found quite free from absorbed oxygen ; and this confirms the conclusion that absolute stagnation exists nowhere in the ocean, not even at its greatest depth. Occasionally, however, the oxygen was found to have sunk down to very little, as shown by the following two examples :—

No. of C.e. per Litre of C.c. of Oxygen calculated Depth in

Sample. Nitrogen. Oxygen. from Nitrogen. Fathoms.

1001 1508 0∙6 8'21 2875

1645 13'38 2 04 6 95 1500

There must have been an approximation to absolute rest at these two places at any rate. On the whole, the results of the gas analy­sis, as interpreted on the basis of Dittmar's absorptiometric deter­minations, agreed fairly well with the inferences which we have just been deducing from physical laws. There was no lack of anomalous results, but it was not found possible to trace them to natural causes. The equilibrium in regard to the absorbed nitrogen and oxygen in the ocean is maintained by the atmosphere ; and, from the fact that the air contained in surface water is always richer in oxygen than is atmospheric air, one naturally concludes that the ocean should constantly add to the percentage of oxygen in the air in the tropics and constantly diminish it in the colder latitudes. But Regnault’s numerous air-analyses do not confirm this. Nor need this be wondered at, since, as we have seen, even the corresponding influence on the atmospheric carbonic acid has so far defied the powers of chemical analysis.

*Salinity of Ocean Water.—*Even in the open ocean the “ salinity ” —meaning in a given quantity the ratio between the weight of dissolved salt and the weight or volume of the whole—is subject to considerable variation ; and it obviously is one of the foremost duties of observing oceanographers to collect the data by means of which it may be possible one day to represent that quantity mathe­matically as a function of geographic position, depth, and time. For the quantitative determination of the salinity an obvious, easy, and sufficient method is to determine the specific gravity S at a convenient temperature *t* ; this in fact is the method which has so far been employed by all observers almost to the exclusion of every other. Buchanan used it during the “Challenger” cruise perhaps more extensively than any of his predecessors had done. Of the arithmetical relation between salinity on the one hand and S and *t* on the other the successive researches of Ekman (as supplemented by Tornoe), Thorpe and Riicker, Dittmar, and others have given us a practically sufficient knowledge. According to Dittmar the function (within the limits of Buchanan’s values) coincides practically with the formula

4St - 4Wt — χ(α + *bt* + ci2),

where 4Si means the specific gravity at to C. referred to that of pure water of + 4oC. as equal to 1000 ; 4Wt has a similar meaning in reference to pure water ; χ stands for the weight of total halogen calculated as chlorine per 1000 parts, by weight, of sea water ; and α = l-45993, δ=-0-005592, c=+0O0Ö0649. For oceanographic purposes, however, it is not necessary to go back to χ ; it suffices from series of values 4Sf to deduce the corresponding values 4Sfθ for a convenient standard temperature, and to reason on these reduced numbers as if they measured the salinity, just as we take the readings of a thermometer as in themselves representing ,' temperatures.” This, in fact, is always done ; only unfortunately different standard temperatures have been chosen by different observers; Buchanan adopted 15o∙56 C. =60° Fahr. Before going further, let us observe that the specific gravity of sea water, taking it as it is *in situ,* has an important oceanographic signi­ficance, even as such. But this quantity in the case of deep-sea waters is influenced very largely @@3 by the pressure of the super­incumbent layer of water—which in itself is a complex function of the successive temperatures and salinities—and unfortunately we still lack the constants and formulæ for making the necessary reductions with adequate exactitude. Meanwhile all our statistics of sea water specific gravities, valuable as they are, constitute statistics of only salinities and nothing else.

At the surface of the ocean the salinity is liable chiefly to three influences,—(1) concentration by formation of ice or by the action of dry winds ; (2) dilution through the melting of ice or the falling of rain ; (3) concentration or dilution through the virtual addition of salt or water by inflowing currents of salter or fresher water respectively. The effect of the formation or melting of ice, though great within the arctic circles, does not tell much on the non-polar seas. More important in regard to these is the effect of the south-east and the north-east trade winds, which in the Pacific blow between about 3° and 21° S. lat. and between about 2° and 20° N. lat. re­spectively, leaving between the two a belt of 5o of a region of calms (see more exactly, Meteorology, vol. xvi. p. 144). In the Atlantic the limiting lines of both trades oscillate annually, so that the equatorial boundary of the north-east trade shifts from 3° to 11° N. lat., and that of the south-east trade from about 1° to 3° N. lat.

@@@1 Theoretically any number may be substituted for 760 ; for calculating pur­poses read “1 millimetre."

@@@2 In calculating these limit values the tension of the vapour of water is taken into account ; hence the apparent non-agreement with the entries in the table.

@@@3 According to Grassi’s experiments, if sea water under the pressure of one atmosphere has the specific gravity 1026, it assumes at depths = 1000, 2000, 3000 fathoms a density of 1026 + 1, 2, 3 times 7-9 units=1033∙9, 1041'8, 1049-7 respectively.