SEA WATER. @@1 The ocean covers very nearly eight- elevenths of the total area of the globe ; its average depth may be estimated as 2000 fathoms, and its total mass at 1·322 × 1018 (*i.e.*, 1·3 million million millions) tons. Its general configuration must be assumed to have been sub­stantially the same as it is now for thousands of years ; hence we may safely conclude that the absolute composi­tion of the ocean as a whole is constant in the sense of being only subject to very slow progressive millennial variation, and that, taking one part of the ocean with another, the percentage composition of the fixed part of the *solutum* can oscillate only within narrow limits. The composition of this solutum is very complex. According to Forchhammer, ocean salt in addition to the chlorides and sulphates of sodium, magnesium, potassium, and cal­cium—which had long been known to be its principal components—includes silica, boric acid, bromine, iodine, fluorine as acid, and the oxides of nickel, cobalt, manganese, aluminium, zinc, silver, lead, copper, barium, and strontium as basic components. Arsenic, gold, lithium, rubidium, cæsium have been discovered since Forchhammer wrote. But all these subsidiary components, as that investigator found, amount to very little,—so little that in his numerous quantitative analyses of waters which he had procured from all quarters of the globe he confined himself to the determination of the chlorine, sulphuric acid, magnesia, lime, potash, and soda. The soda, however, he determined only by difference, assuming that the muriatic and sul­phuric acids are united with the bases into perfectly neutral salts. As a general result he found that, in the open ocean, the ratio to one another of the several acids and bases named is subject to only slight variations. But his samples had all been collected at the surface ; the potash had been determined by an insufficiently exact method ; and the assumed neutrality of the total salt had not been proved. With the view primarily of supplementing Forchhammer’s work, Dittmar made complete analyses of 77 of the samples brought home by the “ Challenger,” so selected that 34 out of the 77 represented depths of 1000 fathoms or more. His analyses brought out a small surplus of base, prov­ing the presence of carbonate in all the waters ; but the numerical values thus found for the “alkalinity,” being charged with the observational errors of the whole series of determinations, could not be relied on. Dittmar there­fore subsequently availed himself of a very easy and yet exact method for the direct determination of this quantity, which meanwhile had been discovered by Tornöe, and ap­plied it to over 130 “Challenger” samples. He besides made a special inquiry into the relation between the quantity of lime and the depth at which the water had been collected, and a similar inquiry in regard to the bromine. As a general summary he gives the following three tables. The total salts contained in ocean water amount on an average to about 3·5 per cent., thus leaving 96·5 per cent. for the water proper.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Table I.—*Average Composition of Ocean-Water Salts.* | | | | |
|  |  | Per 100 parts of | Per 100 of Halogen calculated | |
|  |  | Total Salts. | as Chlorine. | |
|  |  | Dittmar. | Dittmar. | Forchhammer. |
|  | Chlorine | 55∙292 | 99·848 |  |
|  | Bromine | 0188@@2 | 0∙340 |  |
|  | Sulphuric acid, SO3 | 6∙410 | 11·576 | 11·88 |
|  | Carbonic acid @@3, CO„ | 0∙152 | 0∙274 | Not determined. |
|  | Lime, CaO | 1∙676 | 3·026 | 2∙93 |
|  | Magnesia, MgO | 6∙209 | 11∙212 | 11∙03 |
|  | Potash, K2O | 1·332 | 2∙405 | 1·93 |
|  | Soda, Na20 | 41∙234 | 74∙462 |  |
|  | (Basic oxygen, equi- |  |  |  |
|  | valent to the halo- |  |  |  |
|  | gens) | (-12∙493) | (-22∙559) |  |
|  | Total salts | 100·000 | 180∙584 | 181·1 |

|  |  |
| --- | --- |
| Table II.—*Results from combining Acids and Bases* (Dittmar). | |
| Chloride of sodium 77·758  Chloride of magnesium ...10·878 Sulphate of magnesium ... 4·737 Sulphate of lime 3·600 | Sulphate of potash 2·465  Bromide of magnesium 0·217  Carbonate of lime 0·345 |
| Total salts... 100·000 |

Reducing to the absolute mass of the ocean as given above, we arrive at the following numbers :—

|  |  |  |  |
| --- | --- | --- | --- |
| Table III.—*Absolute Composition of the Salts of the Ocean.* Unit=l million million = 1012 tons. | | | |
| Chloride of sodium | ..35990 | Sulphate of potash | 1141 |
| Chloride of magnesium | .. 5034 | Bromide of magnesium ... | 100 |
| Sulphate of magnesium | .. 2192 | Carbonate of lime | 160 |
| Sulphate of lime | .. 1666 |  | 46283 |
| Total bromine .. |  | 87·2 (Dittmar). |  |
| Total iodine |  | 0·03 (Köttstorfer). |  |
| Total chloride of rubidium | | 25·0 (C. Schmidt). |  |

Of the several quantities recorded in columns 2 or 3 of Table I. “carbonic acid” is proved to be subject to variation ; all the rest, including even the bromine, are practically constant. This shows that Forchhammer’s proposition holds for ocean water from all depths, with one important qualification : special research on the lime showed that its quantity increases slightly but appreciably with the depth. Taking *s, m, d* as representing the lime per 100 of chlorine in shallow, medium-depth, and deep- sea water respectively, Dittmar found as mean results of analyses which agreed very well together—

s=3·0175 *m*= 3·0300 *d*=3·0308

Probable error, ±0·0012 ±0·0014 ±0·0011.

But *m*-*s* = 0·0124 and *d-s* = 0·0132. One explanation of this result is that the crustaceans, foraminifera, and molluscs which form carbonate of lime shells live chiefly in surface waters, but after their death sink to the bottom, where—especially in great depths—their carbonate of lime is partially redissolved.

*Oceanic Carbonic Acid.—*It is well known that not only in the neighbourhood of actual volcanoes but in thousands of other places on the dry land carbonic acid gas is constantly streaming forth into the atmosphere, and it is generally admitted now that this supply of telluric carbonic acid amounts to more than all that is furnished by processes of combustion and respiration. That carbonic acid springs should be absent from the bottom of the ocean is too absurd an assumption to be entertained ; hence, supposing even the water of the ocean were perfectly neutral, it could not but contain dis­solved carbonic acid. But such carbonic acid, at the ocean surface at least, would constantly tend to assume, and in general probably actually would come down to, the small limit value prescribed to it by the given proportion by volume of the carbonic acid in the atmosphere and the laws of gas - absorption. This proportion, ac­cording to the best modern researches, is almost constant, every­where amounting to very nearly 0·0003 volume per unit volume of air. The coefficient of absorption by even pure water is 1·8 at 0° and 1·0 at 15° C. Hence, even in the polar regions, the surface water could not hold in permanent solution more than about 0·54 c.c., or say one milligramme per litre of water. Jacobsen, in his

@@@1 All our knowledge of the subject of chemical oceanography—a branch of physical geography which has only lately come to be exten­sively cultivated—is derived from a series of investigations chiefly em­bodied in the following publications:—(1) Forchhammer, “On the Composition of Sea Water,” &c., in *Phil. Trans.,* i. 155, pp. 203-262 (1865); (2) Oscar Jacobsen, *Ann. d. Chem.,* vol. clxvii. p. 1 *sq.* (1873); (3) *Den Norske Nordhavs Expedition, 1876-78: Chemi,* by Tornöe); (4) the *Jahresberichte* of the Kiel committee for the scien­tific investigation of the German Ocean, 1873-82 ; (5) *Physics and Chemistry of the Voyage of H.M.S “Challenger”—*I. “Report on Researches into the Composition of Ocean Water,” &c., by Prof. W. Dittmar, January 1884; II. “Report on the Specific Gravity of samples of Ocean Water,” &c., by J. Y. Buchanan, January 1884 ; III. “Report on Deep-sea Temperature,” &c., by the officers of the expedition. A shorter and more popular exposition of the whole is found in—(6) *Narrative of the Cruise of H.M.S. “Challenger" (1885).* The excellent *Handbuch der Oceanographic* (Stuttgart), by Prof. G. von Boguslawski, may be referred to as being almost up to date.

@@@2 Equal conjointly to 55·376 parts of chlorine, which accordingly is the percentage of “halogen reckoned as chlorine” in the real total solids.

@@@3 Calculating the surplus base as normal carbonate. In Table II, this carbonate is represented as so much CaOCO2.