[For the Scientific American.]

FACTS AND FIGURES CONCERNING THE EARTH AND ITS ATMOSPHERE.

It has recently been to me a matter of surprise that there are no published analyses of the atmosphere in the United States, or indeed in America, by an American. It is not that any notable difference is observable in the composition of American air, as compared with that of Europe, but because the intimate relations of the atmosphere to health and climate are assuming daily a more universally acknowl dged importance.

A little more than half a century ago, Lord Cavendish bestowed his unsurpassed experimental skill upon the problem, to the extent of making five hundred determinations of the percentage of oxygen. With methods which now appear entirely inadequate, he finally settled upon the number 20·833, as expressing the average. The best mean result of the present day is 20·95, a little more than one tenth of one per cent over the number obtained by Cavendish. And yet Lord Cavendish could not satisfy himself that his experiments showed any difference between the air in London and in the country. Sufficient is now known to render it probable that the air in no two contiguous places is precisely the same. With all the mighty apparatus of winds and mountains, of diffusion and changes of temperature, the homogeneous mixture of the constituents of the atmosphere is never perfectly achieved.* The difficulty is better understood when the vast quantities of matter involved are considered, quantities not adequately realized when hundredths of one percent only are discussed in the analytical results. I could not lay my hand upon these figures in a convenient form; and after calculating them from the best data available, the thought occurred of giving them a permanent form.

In his "Meteorology," Sir John Herschel states that, if the diameter of our globe be taken as 7,926 miles, the weight of the atmosphere is 11·67085 trillions of lbs., or, making allowance for the space occupied by the land above the sea level, 11x10^{18}, that is, 11 trillions of lbs. A little closer approximation can be obtained by using the most recent determinations of the earth's dimensions. These are as follows:

	Polar radius in feet.	Equatorial radius in feet.
Bessel..........	20,853,662	20,923,596
Airy..........	20,853,810	20,823,713
Clarke..........	20,852,429	20,923,171

According to the last named authority, the equator also is elliptical, its major axis being 41,852,700, and minor axis 41,839,944 feet. Taking Clarke's figures as a basis, the volume of the earth is 38,239·43x10^{18} cubic feet. By combining the results given above, we obtain 41,707,268 feet for a mean polar, and 41,846,980 for a mean equatorial diameter, and for the earth's mean diameter 41,777,124 feet or 7912·36 miles. If the earth's volume be calculated as a spheroid, on the former supposition, it amounts to 38113·3084x10^{18}, or trillions cubic feet: if a sphere, to 38178·1x10^{18} cubic feet which is 64·79x10^{18} cubic feet in excess over the former somewhat more exact calculation. Accepting the latter number, however, as sufficiently correct for our purpose and much more convenient in the following calculations, we obtain for the volume of the earth 259,350·52 millions of cubic miles, its surface 196·68 millions of square miles, or 5483·1x10^{12} square feet, or 7895·68 billions square inches. Multiplying this figure by the average pressure the atmosphere exerts at 32° Fah. on every square inch of surface at the level of the sea, or 14·7304 pounds avoirdupois, we have a result not widely different from that given by Herschel, namely: 11·63065x10^{18} pounds, or 5192·5523x10^{12} tuns.

If we assume that the weight of the atmosphere is approximately 11x10^{18} lbs., the weight of that portion of it displaced by the elevation of the continents is 630,658 billions of lbs. In fact it is not so much; it is 125,238 billions lbs. This calculation is readily made by recurring to the mean hights, obtained by Humboldt and other eminent geographers, for the elevation of the continents above sea level. We shall have, putting the results in tabular form:

Surface of	Area in square miles	Mean Elevation. As calculated	As spread over entire continental area	As spread over earth's surface
Europe	3·5 millions	670 feet	45·98 feet	11·923 feet
Asia	17 "	1,150 "	383·33 "	99·402 "
North America / South America	15 "	748 "	201·17 "	75·503 "
Africa	11·5 "	1,600 "	360·78 "	93·553 "
Australia	8 "	500 "	29·41 "	7·627 "
Land	51 "		1110·67 "	
Water	145·68 "			
Earth	196·68 "			288·008 "

It will be seen from the above that if the excess of land in America above sea level were spread over 51 millions of square miles, the mean elevation of the continents would be increased 291 feet, and, if over the surface of the globe, 75 feet. The mean elevation of the continents is 1,111 feet, and that of the entire earth's surface 288 feet.

From these figures, we can readily obtain quite a close approximation to the true weight of the earth's atmosphere. In the first place the weight of that portion resting upon the sea is found and added to that resting upon the continents, which give us a correct total. The pressure on each square inch of the sea, at 32° and at mean barometric pressure, being 14·7304 lbs., the corresponding weight of that portion of atmosphere is 8·61475x10^{18} lbs. At 1110·67 feet of altitude the barometer stands at 28·755 inches and represents a pressure of 14·119 lbs. The corresponding weight is 2·89067x10^{18} lbs.; 11·50542 trillions of lbs., then, is the total. Or, in the second place, the entire surface of the globe, at a mean elevation above sea level of 288 feet, may be multiplied by the mean pressure at that altitude. This, at a barometric hight of 29·672 inches, is 14·5631 lbs. The result is 11·503461 trillions of lbs., very slightly differing from that given above.

The weight of a cubic foot of air at standard pressure and temperature being 0·080066 lb., we get from the weights previously found 142·64x10^{18} cubic feet or 142·6166x10^{18} cubic feet for the entire volume of the atmosphere. This result is best understood by calculating the thickness of the envelope which such an atmosphere would form around the globe. It would be either 25,982 or 25,978 feet, according as the former or latter number is taken as representing the true volume of the atmosphere. A simple way of arriving at the thickness is by finding the relative hights of a column of mercury and a column of air at mean temperature and pressure. These would evidently be as the relative weights, which are as 1 to 10,513½, and the corresponding hight of the atmosphere is 26,214 feet above sea level.

At an altitude of 288 feet, the hight of the barometric column is 29·672 inches, and the hight of the atmosphere, above the mean elevation of the continents, 25,996 feet. Lubricating 288 feet from 26,214, the difference, 25,926, is less than the former numbers. This is to be expected from the increase of density as we go towards the earth's surface. The mean of the three values is 25,985 feet, and represents very nearly the actual hight of the atmosphere of uniform density. This is 415 feet less than five miles. The very careful experiments made to determine the earth's density have shown that its weight cannot be very far from 5·56 times that of a globe of water of equal bulk, and this would be 5900·8681 trillions of tuns. As the atmosphere weighs 5134·5 billions of tuns, the weight of the latter is to that of the former, as 1 to 1,149,000. Their relative volumes are as 1 to 267. If the relative weights and volumes are represented by circles, the diameters of the circles in the first case are as 1 foot to 1,071 feet, and in the second, as 1 foot to 16·35 feet

When we come to calculate the amounts of the many various bodies which make up the atmosphere, the variations in the results of the observers, depending in part upon the different methods of analysis employed and in part upon the actual variations in composition of the specimens of air analyzed, present us with a long array of figures to choose from. Besides the four principal constituents of the atmosphere, there are various compounds of nitrogen and oxygen, of carbon and hydrogen, of nitrogen and hydrogen, of hydrogen and sulphur, of hydrogen, nitrogen, and sulphur, to say nothing of salts of chlorine, sulphuric acid, nitrates, etc., diffused throughout the atmosphere by processes of combustion and evaporation, or set free by the agency of decay and putrefaction. It is only through its great complexity of composition that the atmosphere is qualified to discharge the multitude of services required of it by the vegetable and animal kingdoms, and in the general economy of the globe. We may fairly assume, from the vast accumulation of the results obtained by many eminent analysts, that the volume of oxygen in the atmosphere rarely exceeds 21·1 per cent or falls below 20·1. But the range of variation actually falls within extremely narrow limits; and if the oxygen either exceeds 20·99 per cent, or faces below 20·9 per cent, there is reason to look for accidental circumstances modifying the average composition. This was strikingly shown by the 100 analyses of the air of Paris made by Régnault, the oxy gen percentage varying from 20·913 to 20·999, giving a mean of 20·96. Of 9 specimens of air from the neighborhood of Lyons, 30 from Berlin, 10 from Madrid, 23 from Switzerland 15 from the Mediterranean, 5 from the Atlantic Ocean, and 3 from South America, the extremes were comprised between 20·908 and 20·998 per cent.

It may seem of little consequence that the amount of oxygen should be diminished by one tenth of one per cent, and it would be, were not the loss in oxygen replaced by other and generally less beneficial ingredients. Many curious facts have been ascertained from a close observation of these changes in composition. The younger De Saussure, who devoted many years to this work, established the fact that the amount of carbonic acid in the atmosphere during the three summer months was considerably greater than that in December, January, and February, the relative amounts being as 100 to 77. From multitudes of determinations continued during fourteen years, he concluded that the ordinary range of variations in the volume of carbonic acid was included between 6·2 and 3·7 parts in 10,000, and that 4·9 parts in 10,000 fairly represented the mean. A similar remark applies to the extreme multiplication of these carbonic acid determinations as to those of oxygen: that single experiments are often quite at variance with the general results, and that the analyses must be repeated until the laws affecting the composition of the atmosphere are established beyond doubt. What, for example, could be more surprising than the fact, indicated by many experiments, that the percentage of car bonic acid about the tops of mountains is greater than at their feet: and this, too, notwithstanding carbonic acid is more than half as heavy again as air, so powerful appears to be the agency of plants in decomposing the carbonic acid near the surface of the ground and replacing it by a corresponding amount of oxygen? The solution of carbonic acid and its precipitation upon the ground dissolved in rain likewise assists its removal. During calm weather the atmosphere appears to contain more carbonic acid at night than in the day; but when disturbed by violent winds, causing a down rush from the upper strata, the percentage of oxygen at the earth's surface may temporarily undergo an increase much beyond the average.

One of the principal sources of the increase of carbonic acid in the atmosphere is the process of respiration by animals. If the number of respirations by an adult be reckoned at 15 per minute, and an average amount of 32 cubic inches of air is expired, containing 4½ per cent of carbonic acid, there is thrown into the atmosphere daily by each individual about 20 cubic feet of this gas. The population of the globe would annually increase the volume of carbonic acid 7,300,000,000,000 cubic feet, and diminish the oxygen by the same amount. This again would at least be doubled by the respiration of the lower animals and by the agencies of decay and combustion. The volume of the atmosphere is 968,870,000 cubic miles; and of this, if four hundredths of one per cent be taken as the average volume of carbonic acid, 387,510 cubic miles consist of the latter. If 20·96 per cent is the mean for oxygen, it amounts to 203,076,600 cubic miles. About 100 cubic miles of carbonic acid are annually added to the atmosphere, at which rate the amount of carbonic acid would be doubled in 3,731 years and all the oxygen consumed in two million years, were not the carbonic acid decomposed by vegetation in an inverse proportion. The weight of a cubic foot of carbonic acid is a little more than one tenth of a pound, and of a cubic mile about eighty and a half million of tuns. The total amount of carbonic acid in the atmosphere is three billion tuns, containing 27·28 per cent or 851·870 millions of tuns of carbon. The computed area of the coal measures on the earth's surface is 260,000 square miles, with a present annual production of 250,000,000 tuns of coal. If 75 per cent of this coal is estimated as carbon, the amount of carbonic acid in the atmosphere would be doubled by burning this amount of coal annually for 4,500 years. The total amount of coal is 4·83 billions of tuns, which, if burnt, would increase the amount of carbonic acid in the atmosphere four and a half times, or raise its percentage to 0·18. This percentage is smaller than is frequently present in the air of crowded rooms like theaters, and which people endure, at least for some time, without serious consequences. If all the coal of the carbonaceous era were formerly a part of the atmosphere, the earth need not necessarily have been untenantable by air-breathing animals. These results appear surprising until we reflect how small a portion of the earth's bulk is made up of carbonaceous deposits. The whole annual production of coal would make a bar 12 feet square passing from east to west through the earth's center. But if spread over the earth, it would amount to 0·015 cubic inch for each square yard of surface, hardly enough, when rubbed over a square yard of drawing paper, to fairly blacken it. The entire bulk of the coal measures, even when estimated at double the available amount of coal now known, probably does not exceed 450 billions of cubic feet, which would form a layer about an inch thick over the earth's surface.

But a vast amount of carbonic acid is locked up in the earth's strata, combined with various bases, more especially lime and magnesia, forming immense deposits of limestone and dolomite. If this carbonic acid at one time formed a portion of the atmosphere, its bulk must have been prodigious. A very thin stratum of carbonate of lime, when deposited, would yield as much carbonic acid as the atmosphere at present contains. It would require but a thin pellicle, a whitewash of 0·136 inch in thickness over the whole surface of the globe. A similar layer of pure limestone, 28·37 feet in depth, would double the weight of the atmosphere.

The thickness of the stratified rocks extending upward from the Potsdam formation probably averages as much as 38,500 feet, of which three eighths or 14,500 feet may be put down as limestone. This is equivalent to 140 millions of cubic miles of limestone rock, weighing 1·55 trillions of tuns and containing 682 billions of tuns of carbonic acid. This would be to the weight of the earth itself as 1 to 8,652, and would increase the weight of the atmosphere 133 times.

ALBERT R. LEEDS.

* In general the constitution of the atmosphere is regarded as constant, because, after the removal of its carbonic acid and water, the proportion between the oxygen and nitrogen is almost invariable.

The Wonders of the Deep.

In her scientific cruise of three years and a half, the Challenger steamed and sailed 68,930 miles, crossing both the Atlantic and Pacific—the former several times. The deepest soundings were 4,575 fathoms, in the Pacific, between the Admiralty Islands and Japan; and in the Atlantic 3,875 fathoms, ninety miles north of the island of St. Thomas, in the West Indies. We have noticed the principal movements of the expedition from time to time. Its return to England has revived public interest in the work of Professor Wyville Thomson and his associates, and many interesting details concerning it have appeared in the English journals. Many curious crabs were brought home. One very odd specimen, which came to the surface only at night, is described as having a head which is nearly all eye, and a body so transparent as to render visible all the nerves, muscles, and internal organs, while another more lobster-like creature had no eyes at all. Near Amsterdam Island, in the South Indian Ocean, the ship encountered a belt of gigantic seaweed, of which single plants are said to attain a length of a thousand feet and a thickness equal to that of a man's body. A gale of snow, to which the vessel was exposed in the Antarctic Ocean, consisted of exquisite star-like crystals which burned the skin as if they were red hot. The history of the expedition abounds with similar unique experiences.

Indelible Ink without Silver.

Mr. A. J. Foose, of Del Norte, Colorado, sends us the following formula for an indelible ink without the use of nitrate of silver, which, he maintains, is thoroughly efficient and capable of resisting the action of freezing and thawing

No. 1. Extract of logwood, 1 lb.; water, 1 gallon. No 2: Sulph. prot. of iron, 4 ozs.; water, 4 ozs. No. 3. Sulphuret of potassium, ¼ oz.; water, 2 ozs.

After dissolving the logwood by boiling, add No. 3 to No. 2, until the iron assumes a black color; then add this compound to No. 1, and boil a few minutes. Add cyanuret of potassium, ½ oz., which fixes the color. For ink, add gum and alcohol; for dyes, add grease.

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