are given for determining each individual of the group, then the methods for separating the different members of the group from each other. This is a better plan than the more common one of giving all the determinations first and afterwards all the separations.

The descriptions and directions are decidedly concise, but sufficient for the needs of fairly advanced students. Beginners will need and should in any case have considerable supplementary instruction. The non metals are treated according to the same general plan. A chapter of "operations and examples" follows, which might perhaps have been put with more profit at the beginning instead of at the end of the section.

Volumetric analysis is taken up according to the same plan as pervades the whole work. One very commendable thing about this and other parts of the book is that the student is not bewildered by a multitude of methods, but is simply made acquainted with such as have earned their right to existence. The section devoted to organic analysis is valuable and complete.

The translation is fully up to the average of such work. It reads for the most part smoothly and at least does not require retranslation into English, which is more than can be said of some recent efforts in this line. JOSEPH TORREY, JR.

ON THE DENSITIES OF OXYGEN AND HYDROGEN, AND ON THE RATIO OF THEIR ATOMIC WEIGHTS. BY EDWARD W. MORLEY. 1895: Smithsonian Contributions to Knowledge. 4°. Forty cuts. xii., 117 pp. Price, $1.00.

The ratio between oxygen and hydrogen is, to speak figuratively, the base-line upon which our entire system of atomic weights depends. But few of the other elements can be readily compared with hydrogen directly; practically all of them are referred to hydrogen through the intervention of oxygen; and so the atomic weight of the latter needs to be known with the utmost accuracy. A small error here becomes cumulative when introduced into the computation of higher values, and in the case of uranium it is multiplied to fifteen times its original magnitude.

Ten years ago the atomic weight of oxygen seemed to be pretty well known, and stood very nearly at 15.96. This, however, was near enough to the round number 16 to suggest that the difference might be due to error, and therefore reinvestigation began. First came Cooke and Richards, then Keiser, Noyes, Rayleigh, Dittmar and Henderson, and Leduc. Of these, Keiser alone approximated to the old value, finding O = 15.95. All of the others obtained results ranging from 15.866 to 15.897, with an outstanding uncertainty still larger than could long be tolerated. This uncertainty, thanks to Professor Morley, is now thrown into the third or fourth decimal place, and need no longer be troublesome.

The first and second divisions of Morley's monograph relate to the densities of the two gases, and are most elaborate in their details. Every precaution was taken to insure the purity of the material used, the methods of manipulation were varied, and every conceivable source of error seems to have been foreseen and guarded against.

For oxygen, three series of determinations are given. In the first series, the pressure and temperature of the gas to be weighed were determined by mercurial thermometers and a manobarometer. In the second series, pressure and temperature were not observed for each experiment, but were made equal to the temperature and pressure of a standard volume of hydrogen, comparison being made by means of a differential manometer. In the third series the temperature was that of melting ice, and pressure alone was observed. For the weight of one liter of oxygen, at 0°, 760 mm., at sea level and in latitude 45°, the three series give as follows, in grams:

Series 1,	9 experiments,	1.42879 ± 0.000034
" 2,	15 "		1.42887 ± 0.000048
" 3,	17 "		1.42917 ± 0.000048

On experimental grounds, Morley regards the third series as the best, and assigns it double weight. On this basis the general mean becomes

$$1.42900 \pm 0.000034.$$

The oxygen used was prepared partly from potassium chlorate, and partly by the electrolysis of dilute sulphuric acid.

For hydrogen, five series of determinations were made. In the first, the manipulations were like those of the first oxygen series, with which it was strictly parallel. In the second, the weighing globes were surrounded by melting ice, and pressure was measured with a siphon barometer. In the third series the hydrogen was weighed, not in the globes where its pressure, temperature, and volume were taken, but before its introduction into them. Globes having a joint capacity of forty-two liters were connected together, for this series, and the hydrogen was weighed in palladium, of which 600 grams were used. The fourth and fifth series resembled the third. The hydrogen used was electrolytic. The results are subjoined, for the weight of one liter of hydrogen, in grams:

Series 1.	15	experiments,	0.089938 ± 0.000007
" 2,	19	"	0.089970 ± 0.000011
" 3,	8	"	0.089886 ± 0.0000049
" 4,	6	"	0.089880 ± 0.0000088
" 5,	11	"	0.089866 ± 0.0000034

In series 1 and 2, which Morley rejects, the hydrogen may have been contaminated by traces of mercurial vapor. In the remaining series that impurity was not present in the weighing of the gas, and exerts no influence upon the final result. Furthermore, in these series, stop-cocks were not used, and the connections were made by fusing the glass tubes into an unbroken continuity. The mean of series 4, 5, and 6 is

$$0.089873 \pm 0.0000027,$$

and this is undoubtedly the best value yet found for the weight of a liter of hydrogen. Dividing this into the weight of oxygen, we have as the ratio of densities,

$$O = 15.9002.$$

In order to derive from this value the atomic weight of oxygen, the volumetric composition of water must be known. This subject forms the third part of Morley's memoir. He decomposed water by electrolysis, determined the density of the electrolytic mixed gases, and from that calculated the datum sought. The result is that in water, hydrogen and oxygen are combined in the ratio by volume of

$$2.00269 : 1.$$

Applying this ratio to the correction of the density ratio, we have

$$O = 15.879,$$

for the atomic weight of oxygen as given by the density method.

In the fourth part of the memoir Morley describes his gravimetric syntheses of water, which are the first really complete syntheses yet recorded. That is, nothing is taken by difference ; hydrogen was weighed, oxygen was weighed, and the water formed was weighed, and all directly. By weighing the hydrogen in palladium, over three and eight-tenths grams could be taken in one experiment, a quantity which would be unmanageable in any attempt to weigh it in globes. Globes, however, were used for weighing the heavier oxygen ; and the two gases were caused to combine by sparking in a suitable combustion apparatus. After combustion was complete, the apparatus containing the water was weighed, and the residual excess of gases left unburned was analyzed. The use of stop-cocks, in transferring the gases to the combustion apparatus, was completely avoided. Errors due to leakages, therefore, did not occur.

In all, twelve syntheses were made. Each one gives two values for the atomic weight of oxygen, except in one case, when the apparatus was broken. One value is derived from the weights of hydrogen and oxygen, the other from the weights of hydrogen and water. They are as follows :

	H : O.	$H : H_2O$.
	15.878	15.877
	15.881	15.878
	15.878	15.873
	15.880	lost
	15.877	15.881
	15.877	15.876
	15.877	15.875
	15.878	15.879
	15.879	15.881
	15.881	15.883
	15.881	15.883
	15.882	15.878
Mean,	15.8792	15.8785

The average of these two means is 15.87885, a result practically identical with that derived from the gaseous densities. The value, 15.879, then, is to be taken as the nearest approximation to the true atomic weight of oxygen, and this, for ordinary purposes, may be rounded off to 15.88.

It is hard to express on opinion concerning this great investigation, without seeming to be extravagant. In thoroughness, foresight, and manipulative skill it stands in the very front rank of chemical investigations, and on the same plane with the classical researches of Stas. In short, it is doubtful whether any better work of its kind has ever been published, and it has very few peers. To fully appreciate the memoir it must be studied in detail and at first hand ; even Morley's own abstracts in various chemical journals fail to give an adequate impression of the magnitude of his achievement. The paper may at once take its place among "the classics of the exact sciences."

F. W. CLARKE.

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