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REPORT OF THE INTERNATIONAL COMMITTEE ON ATOMIC WEIGHTS, 1906.

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DURING the year 1905 there has been unusual activity in the determination of atomic weights, and some of the work done relates to the most fundamental values. The entire system of atomic weights is thus affected, more or less profoundly; and a general revision of the table would seem to be needed within the near future. Neglecting minor investigations, the more important determinations published since our last report are briefly as follows:

Cadmium.—Atomic weight determined by Baxter and Hines,[1] by analysis of the chloride. Three measurements of the ratio $CdCl_2 : 2AgCl$ gave in mean Cd = 112.476. Six measurements of the ratio $CdCl_2 : 2Ag$ gave in mean Cd = 112.462. General mean of both series, 112.469, when Ag = 107.93 and Cl = 35.473. As additional determinations are promised, based upon a study of cadmium bromide, a change in the atomic weight of cadmium as given in our table may properly be deferred.

Carbon.—From the ratios published in 1904, relative to the basic acetate and acetylacetonate of glucinum, Parsons[2] has computed the atomic weight of carbon. The values obtained by treating the two ratios algebraically are Gl = 9.112 and C = 12.007. As the latter figure is quite independent of all previous determinations it has distinct corroborative significance.

[1] This Journal, **27**, 222.

[2] Ibid. **27**, 1204; Z. anorg. Chem. **46**, 215.

Chlorine and Sodium.—In a very elaborate investigation upon the atomic weights of chlorine and sodium, Richards and Wells[1] have shown that the data furnished by Stas are affected by appreciable errors. Ten syntheses of silver chloride gave, in mean, Cl = 35.473 when Ag = 107.93. From ten measurements of the ratio Ag: NaCl, and ten of the ratio AgCl: NaCl, with the foregoing values for silver and chlorine, Na = 23.008. The Stas values are Cl = 35.455 and Na = 23.048.

The results just cited are obviously indirect, for they depend upon the atomic weight of silver. The experiments published by Dixon and Edgar[2] are therefore of peculiar interest, for they involve the intervention of no intermediate quantities between the atomic weights of chlorine and hydrogen. Hydrochloric acid was directly synthetized from weighed amounts of hydrogen and chlorine, and nine concordant determinations gave, in mean, Cl = 35.195 $\pm$ 0.0019, referred to the hydrogen standard. With O = 16, Cl becomes 35.463, a value nearly midway between that found by Stas and the new figure given by Richards and Wells. Considering the difficulties of the work, the agreement between this and the previous investigations is as close as could be reasonably expected.

Gadolinium.—Urbain,[3] from ten analyses of the octohydrated sulphate, finds Gd = 157.23, when H = 1.007 and S = 32.06. This value is more than a unit higher than that given in the table, and is probably more trustworthy.[4]

Iodine.—Baxter has continued his research of 1904 upon the atomic weight of iodine, and has published a second memoir upon this subject.[5] First, from eight conversions of silver iodide into bromide, by heating in bromine, he found I = 126.985. Two series of measurements, of five experiments in each, of the ratio AgI to AgCl, gave respectively 126.982 and 126.984. Eight determinations of the direct ratio between silver and iodine, weighed separately, gave in mean 126.987. Five determinations of the ratio I: AgI gave 126.983, and four of the ratio Ag: AgI

[1] Published by the Carnegie Institution of Washington, 70 pp., April, 1905. See also this Journal, 27, 459.

[2] Chem. News, 91, 263. Memoir read before the Royal Society.

[3] C. R. 140, 583.

[4] See Eberhard, Z. anorg. Chem. 45, 374, "On the Spectroscopic Purity of the Rare Earth Oxides Studied by Urbain and Others."

[5] This Journal, 27, 876.

gave 126.989. The average of all six series is I = 126.985, when Ag = 107.93, Cl = 35.473, and Br = 79.955. The last of these antecedent values was checked by a direct comparison of AgBr with AgCl, and the mean of six experiments gave Br = 79.953. The value previously found by Baxter was 126.975 for iodine, and the difference is partly due to his use, in the later investigation, of the new figure obtained for chlorine by Richards and Wells. The iodine work, therefore, is confirmatory of the latter.

Nitrogen.—R. W. Gray, in a preliminary notice,[1] gives the results of his experiments upon nitric oxide. Ten determinations of the density of the gas, corrected by the formula of D. Berthelot, give a molecular weight of 30.005, whence N = 14.005. Six analyses of nitric oxide, effected by burning finely divided nickel in it, gave N = 14.006. The investigation was to be continued farther.

Guye, in an interesting lecture before the Chemical Society of Paris,[2] has given a complete summary of the researches relative to this atomic weight, which have been conducted by him and his associates at Geneva. He also discusses, somewhat fully, all previous determinations of the constant, and concludes, mainly from the physical evidence, that the atomic weight of nitrogen is not far from 14.01, and that the Stas value, 14.04, is no longer tenable. Going still farther, he reverses the ordinary gravimetric ratios from which the accepted atomic weight of nitrogen was derived, and applying to them the new value for N, he deduces the atomic weight of silver. The latter is thus reduced from 107.93 to below 107.89, ranging even as low as 107.871. For these low values Guye cites much confirmatory evidence, which is not to be lightly disregarded. To this point we shall recur later.

Potassium.—Atomic weight redetermined by Archibald,[3] through analyses of the chloride. Four measurements of the ratio AgCl : KCl gave K = 39.139, and four of the ratio Ag : KCl gave 39.140, when Ag = 107.93 and Cl = 35.455. If Cl = 35.473, then K becomes 39.122.

Silicon.—W. Becker and J. Meyer[4] have determined the atomic

[1] Pr. Chem. Soc. 21, 156.

[2] Bull. soc. chim., August 5, 1905, with independent pagination. Compare Richards: Proc. Amer. Phil. Soc. 43, 116 (1904).

[3] Trans. Roy. Soc. Canada [2] 10 (Section III), 47.

[4] Z. anorg. Chem. 43, 251; 46, 45.

weight of silicon by conversion of the chloride into the oxide. Eight determinations were made, and in sum, 46.82400 grams of $SiCl_4$ gave 16.58236 of SiO_2. Hence, with $Cl = 35.45$, $Si = 28.207$. With the Richards-Wells value for chlorine, 35.473, Si becomes 28.257. Additional determinations, by a different method are promised. This paper is preceded by an essay by Meyer on the calculation of atomic weights,[1] which deserves careful consideration.

Strontium.—From four measurements of the ratio $2Ag : SrCl_2$, Richards[2] finds $Sr = 87.661$, when $Ag = 107.93$ and $Cl = 35.473$. This confirms the earlier value, derived by Richards from experiments upon strontium bromide.

Tellurium.—Gallo[3] has determined electrolytically the ratios between silver and tellurium. From twelve experiments, in mean, $Te = 127.61$, when $Ag = 107.93$. Incidentally to this work, as a check upon the method employed, four comparisons between silver and copper were made. In mean, $Cu = 63.58$.

Thorium.—R. J. Meyer and Gumperz[4] have attempted to separate ordinary thorium into fractions of different atomic weights, and have failed to verify the observations of Baskerville. The fractions obtained by various processes gave atomic weights varying from 232.2 to 232.7, values which are essentially identical with that given in the table.

From the foregoing summary of results it becomes evident that a far-reaching series of changes will soon be needed in our system of atomic weights. A change in chlorine or nitrogen implies many other changes in the table, and if the accepted value for silver should be modified, the alterations would be most sweeping. The atomic weights of silver, chlorine and bromine enter into the calculation of nearly all other atomic weights, and form, so to speak, the platform upon which the entire structure stands.

The changes, however, which are suggested at present are not final. Work is in progress in several laboratories, which may confirm or modify many of the accepted values, and until that work is finished, at least so far as the fundamental data are con-

[1] Z. anorg. Chem. p. 242.
[2] Pr. Am. Acad. **40**, 603.
[3] Atti Accad. Lincei [5] **14**, 23 and 104.
[4] Ber. 38, 817.

cerned, it is wisest for us to suspend judgment and await developments. Were we to reconstruct the table of atomic weights on the basis of the evidence now before us, we should do it imperfectly, and a new revision would be demanded next year or the year after. Confusion would inevitably follow. Fortunately, the matter is not urgent, for the corrections which now seem desirable are not large, and the existing figures are accurate enough for all ordinary purposes. We therefore recommend that the table for 1905 be continued in use without change during 1906, even though some modifications are theoretically desirable. A year hence we shall be in a better position for a critical adjustment of the data, and no harm can follow from the delay. In accordance with the expressed wish of a majority of the larger committee, we also recommend that the table based upon the oxygen standard be made official. So far as this committee is concerned, the private opinions of its members will be subordinated to the desires of the majority, and the table referred to hydrogen will no longer appear as a part of its report.

For the present, a few suggestions which follow from an examination of the lecture by Guye may not be inacceptable. Rayleigh, Leduc, Guye, Gray and others, from their studies of nitrogen and its oxides, have accumulated a mass of strong evidence in favor of a lower value for nitrogen. The data furnished by Stas, on the other hand, point to the higher value which has heretofore been generally adopted. Can we abandon the one in favor of the other, and accept the new figure without reserve?

On behalf of the new figure for nitrogen we must admit that the determinations are remarkably concordant, and that they rest upon a direct comparison of the element with oxygen. The Stas values, with their confirmations by other chemists, are also very concordant, but they are indirect. They all rest primarily upon the atomic weights of silver, chlorine and bromine, and these were connected with oxygen through experiments upon chlorates and bromates. Our whole system of atomic weights, with only a few exceptions, is based to-day upon the analyses of several oxy-halogen salts. Their accuracy is assumed, and all anomalies which appear in determinations based upon other lines of research, are commonly ascribed to undiscovered errors.

The assumption may be sustained, but it is not yet beyond the reach of criticism.

Consider, for example, the well-known ratio $Ag:AgNO_3 = 100:157.479$. If $Ag = 107.93$, as determined through the analyses of chlorates and bromates, then $N = 14.037$, or 14.04 as given in our table. If, on the other hand, $N = 14.009$ as given by Guye, Ag becomes 107.881. The difference between the two values for silver evidently represents a difference in our methods of connecting the element with oxygen, the latter being taken as the standard. For each method strong arguments are possible, and for each value other corroborative testimony can be cited. Neither procedure is wholly free from objections, and the final conclusion, therefore, is one of uncertainty. We cannot safely reject either line of evidence, nor can we accept one as surely more exact than the other. Concordant values for silver can be derived from either method of discussion, as Guye has shown, and through them the entire system of atomic weights is affected.

In this condition of affairs the position of the committee can only be one of conservatism. It is better to retain the table we have until at least some of the doubts which now affect it have been eliminated. It seems to be essential that the foundations of the atomic weight table should be both broadened and strengthened, and that new lines of research connecting the fundamental values with oxygen should be investigated. Some work of this kind is already promised from the laboratory of Harvard University, to be carried out by Richards and his colleagues; but that need not exclude other activities. It is to be hoped that a number of investigators may take up the consideration of this problem, and that the methods of attack upon it shall be multiplied. The careful study of such salts as the sulphates, carbonates and nitrates might perhaps be profitable. Whether the organic salts of silver could be utilized for good atomic weight determinations is still uncertain.

(Signed)

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INTERNATIONAL ATOMIC WEIGHTS. 1906.

Aluminum	Al	27.1	Neodymium	Nd	143.6
Antimony	Sb	120.2	Neon	Ne	20
Argon	A	39.9	Nickel	Ni	58.7
Arsenic	As	75.0	Nitrogen	N	14.04
Barium	Ba	137.4	Osmium	Os	191
Bismuth	Bi	208.5	Oxygen	O	16.00
Boron	B	11	Palladium	Pd	106.5
Bromine	Br	79.96	Phosphorus	P	31.0
Cadmium	Cd	112.4	Platinum	Pt	194.8
Caesium	Cs	132.9	Potassium	K	39.15
Calcium	Ca	40.1	Praseodymium	Pr	140.5
Carbon	C	12.00	Radium	Rd	225
Cerium	Ce	140.25	Rhodium	Rh	103.0
Chlorine	Cl	35.45	Rubidium	Rb	85.5
Chromium	Cr	52.1	Ruthenium	Ru	101.7
Cobalt	Co	59.0	Samarium	Sa	150.3
Columbium	Cb	94	Scandium	Sc	44.1
Copper	Cu	63.6	Selenium	Se	79.2
Erbium	Er	166	Silicon	Si	28.4
Fluorine	F	19	Silver	Ag	107.93
Gadolinium	Gd	156	Sodium	Na	23.05
Gallium	Ga	70	Strontium	Sr	87.6
Germanium	Ge	72.5	Sulphur	S	32.06
Glucinum	Gl	9.1	Tantalum	Ta	183
Gold	Au	197.2	Tellurium	Te	127.6
Helium	He	4	Terbium	Tb	160
Hydrogen	H	1.008	Thallium	Tl	204.1
Indium	In	1.15	Thorium	Th	232.5
Iodine	I	126.97	Thulium	Tm	171
Iridium	Ir	193.0	Tin	Sn	119.0
Iron	Fe	55.9	Titanium	Ti	48.1
Krypton	Kr	81.8	Tungsten	W	184
Lanthanum	La	138.9	Uranium	U	238.5
Lead	Pb	206.9	Vanadium	V	51.2
Lithium	Li	7.03	Xenon	Xe	128
Magnesium	Mg	24.36	Ytterbium	Yb	173.0
Manganese	Mn	55.0	Yttrium	Yt	89.0
Mercury	Hg	200.0	Zinc	Zn	65.4
Molybdenum	Mo	96.0	Zirconium	Zr	90.6

Note.—Since this report was written and signed, several important memoirs upon atomic weights have appeared. Gray's complete research upon N, Amberg's work upon Pd, and Birckenbach's dissertation upon Bi are the most noteworthy of these additions to the 1905 list of determinations. F. W. C.