

THE JOURNAL

OF THE

American Chemical Society

FIFTEENTH ANNUAL REPORT OF THE COMMITTEE ON ATOMIC WEIGHTS. DETERMINATIONS PUBLISHED DURING 1907.

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Received January 24, 1908.

Although the number of new atomic weight determinations published during the year 1907 has not been large, the quality of the work done was remarkably high. Some of the determinations are of fundamental importance, as, for example, those of hydrogen, nitrogen, sulphur, potassium and lead. Sulphur and lead are especially noteworthy, on account of their divergence from the older measurements. The data now available are as follows:

Hydrogen.

Noyes¹ has made complete syntheses of water in five series of determinations. The first series was defective, and is therefore not published by the author. For the other series very complete details are given, which would take too much space for repetition here. Noyes's corrected and final data are as follows:

SECOND SERIES, HYDROGEN FROM SULPHURIC ACID, WEIGHED TWICE.

Weight H.	Weight O.	Weight H ₂ O.	At. wt. H.	
			H : O.	H : H ₂ O.
3.72565	29.57891	33.30408	1.00765	1.00767
3.80318	30.18400	33.98748	1.00800	1.00799
3.75873	29.83358	33.59127	1.00792	1.00795
2.96328	23.51987	26.48379	1.00792	1.00790
2.11395	.....	18.89214	.....	1.00795
3.53136	28.02910	31.56024	1.00791	1.00792
3.53959	28.09619	31.63554	1.00785	1.00786
		Mean,	1.00787	1.00789

¹ This Journal, 29, 1718.

THIRD SERIES, HYDROGEN FROM SULPHURIC ACID, OXIDIZED BY COPPER OXIDE.
At. wt. H.

Weight H.	Weight O.	Weight H ₂ O.	H : O.	H : H ₂ O.
2.44279	19.39757	21.84042	1.00746	1.00746
2.18739	17.36305	19.55117	1.00784	1.00780
2.75129	21.84345	24.59389	1.00764	1.00768
4.00062	.....	35.75073	.....	1.00803
4.04057	32.07689	36.11762	1.00772	1.00772
Mean,			1.00767	1.00774

FOURTH SERIES, HYDROGEN AND OXYGEN FROM SULPHURIC ACID COMBINED BY
PALLADIUM.
At. wt. H.

Weight H.	Weight O.	Weight H ₂ O.	H : O.	H : H ₂ O.
2.27916	18.08455	20.36128	1.00823	1.00830
4.12734	32.76527	36.89043	1.00774	1.00780
4.17556	33.13449	37.30787	1.00818	1.00821
4.19346	33.27384	37.46453	1.00822	1.00831
2.30746	18.30863	20.61357	1.00825	1.00839
4.59692	36.48543	41.08162	1.00795	1.00797
4.63625	36.79354	41.42905	1.00806	1.00808
4.57274	36.28696	40.85834	1.00813	1.00817
Mean,			1.00809	1.00815

FIFTH SERIES, HYDROGEN AND OXYGEN FROM BARIUM HYDROXIDE, COMBINED BY
PALLADIUM.
At. wt. H.

Weight H.	Weight O.	Weight H ₂ O.	H : O.	H : H ₂ O.
4.61180	36.60909	41.22105	1.00779	1.00779
4.62358	36.69575	41.31647	1.00798	1.00806
4.59853	36.50484	41.10212	1.00776	1.00780
4.55832	36.17887	40.73904	1.00795	1.00790
4.20399	33.37000	37.57336	1.00782	1.00786
Mean,			1.00786	1.00788

The mean of all four series, assigned equal weight, is $H = 1.00789$.

The mean of the 48 determinations, as a single series, is $H = 1.00793$.

The series, however, are not of equal weight, the second and fourth being better than the others. According to Noyes, the value $H = 1.00787$ is the most probable value to be derived from his determinations. Morley's classical syntheses of water, recalculated, give $H = 1.00762$. Combining this with Noyes's results, the average is 1.00775, which is perhaps better than the determinations of either chemist taken alone.

Silver-Nitrogen.

Richards and Forbes,¹ in a most careful investigation, have effected the synthesis of silver nitrate from pure silver, and so measured the

¹ This Journal, 29, 808.

ratios between Ag and AgNO_3 . The vacuum weights are given below, together with the ratio $\text{Ag} : \text{AgNO}_3 :: 100 : x$:

Weight Ag.	Weight AgNO_3 .	Ratio.
6.14837	9.68249	157.481
4.60825	7.25706	157.480
4.97925	7.84131	157.480
9.07101	14.28503	157.480
9.13702	14.38903	157.481
9.01782	14.20123	157.480
		Mean, 157.480

A small correction for a trace of water retained by the nitrate reduces this figure to 157.479, which is identical with that obtained by combining all the older data. If now, $\text{Ag} = 107.930$, $\text{N} = 14.037$; but if the recent value for N, 14.008, is correct, then Ag becomes 107.880.

Potassium.

Richards and Mueller¹ have redetermined the atomic weight of potassium by analyses of the bromide. First, the ratio between silver bromide and the potassium salt was measured, with the subjoined results:

Weight KBr.	Weight AgBr.	At. wt. K.
2.19027	3.45617	39.114
4.19705	6.62285	39.113
2.06723	3.26206	39.112
2.58494	4.07889	39.115
		Mean, 39.1135

Second, the ratio between potassium bromide and metallic silver was determined by the usual titration method, as follows:

Weight KBr.	Weight Ag.	At. wt. K.
4.33730	3.93164	39.113
4.18763	3.79587	39.115
4.15849	3.76943	39.116
3.67867	3.33450	39.116
3.60484	3.26776	39.110
4.78120	4.33387	39.118
5.67997	5.14860	39.116
6.41587	5.81571	39.115
2.88134	2.61184	37.113
3.64383	3.30309	39.111
3.12757	2.83504	39.113
		Mean, 39.1143

The value for K was computed with $\text{Ag} = 107.93$ and $\text{Br} = 79.953$. All weights were reduced to a vacuum standard. The final value, ob-

¹ This Journal, 29, 639. The paper is preceded by that of Richards and Staehler on potassium chloride, which was noticed in the report of this committee for 1906. It originally appeared in the *Berichte*.

tained by combining these results with those of Richards and Staehler, is $K = 39.1139$. Clarke, in his "Recalculation of the Atomic Weights," 1897, from a combination of all the older data, found $K = 39.112$. The two values are nearly identical.

Sulphur.

The atomic weight of sulphur has been redetermined by Richards and Jones,¹ who employed an entirely new method. Silver sulphate was transformed into silver chloride by heating in gaseous hydrochloric acid. The weights, reduced to a vacuum, are subjoined. In the third column the chloride formed from 100 parts of sulphate is given:

Weight Ag_2SO_4 .	Weight AgCl.	Ratio.
5.21962	4.79859	91.934
5.27924	4.85330	91.932
5.08853	4.67810	91.934
5.36381	4.93118	91.934
5.16313	4.74668	91.934
5.08383	4.67374	91.933
5.13372	4.71946	91.931
5.16148	4.74490	91.929
5.19919	4.77992	91.936
5.37436	4.94088	91.934

		Mean, 91.933

From this ratio, if $\text{Ag} = 107.930$ and $\text{Cl} = 35.473$, $\text{S} = 32.113$.

If $\text{Ag} = 107.88$ and $\text{Cl} = 35.457$, then $\text{S} = 32.069$.

Incidentally, the authors discuss the older values for sulphur, and especially those derived from gaseous densities. The latter they regard as subject to serious errors.

Lead.

In a preliminary paper, Baxter and Wilson² give the results of their analyses of lead chloride. The data, with vacuum weights, are as follows:

Weight PbCl_2 .	Weight Ag.	Weight AgCl.	Atomic weight.	
			Ag. ratio.	AgCl ratio.
4.67691	3.62987	4.82273	207.179	207.188
3.67705	2.85375	.....	207.189	.....
4.14110	3.21408	4.27016	207.173	207.192
4.56988	3.54672	.....	207.185	.....
5.12287	3.97568	5.28272	207.201	207.181
3.85844	2.99456	3.97949	207.186	207.136
4.67244	3.62628	.....	207.189	.....
3.10317	2.40837	3.19909	207.188	207.261
4.29613	3.33407	4.42982	207.202	207.204
			-----	-----
			Mean, 207.188	207.193

¹ This Journal, 29, 826.

² Proc. Amer. Acad., 43, 365.

The mean of both series is $Pb = 207.190$,¹ when $Ag = 107.93$ and $Cl = 35.473$. This value is much higher than the usually accepted 206.9.

Palladium.

The determinations of Woernle² were based upon analyses of palladosamine chloride, $Pd(NH_3Cl)_2$. Two reductions in hydrogen gave the following results:

Weight chloride.	Weight Pd.	At. wt. Pd.
2.94682	1.48493	106.68
1.83140	0.92296	106.70

Five electrolytic determinations yielded the subjoined figures:

Weight chloride.	Weight Pd.	At. wt. Pd.
1.02683	0.51749	106.71
1.22435	0.61708	106.72
1.46735	0.73944	106.69
0.59796	0.30139	106.73
2.64584	1.33329	106.69

Mean, 106.708

All weights were reduced into vacuum. The antecedent values for H, N, and Cl are not stated.

Nickel and Cobalt.

Barkla and Sadler,³ studying the absorbability of secondary Röntgen radiations from various metals, which is an atomic function, find regularities to which nickel is an exception. If, however, nickel be given a higher atomic weight than that now assigned to it, the anomalies disappear. Ten measurements of absorbability, compared with the absorbability of rays from other metals, gave, by interpolation, values for Ni between 61.15 and 61.6. These figures can hardly be assigned much weight in comparison with the excellent and more direct chemical determinations.

Parker and Sexton,⁴ in a brief note, announce that 15 electrolytic comparisons of cobalt with silver give, in mean, $Co = 57.7$. The details of this investigation are yet to appear.

Indium.

Mathers,⁵ in determining the atomic weight of indium, employed two methods. First, the ratio between $InCl_3$ and $3AgCl$ was measured gravimetrically, with the following results:

¹ With $Ag = 107.88$ this becomes 207.090. See this Journal, 30, 194.—EDITOR.

² Sitzungsber. phys. med. Soz. Erlangen, 38, 296.

³ Phil. Mag. [6], 14, 408. Preliminary notice in *Nature*, Feb. 14, 1907. In *Nature* for April 4, Hackett questions the conclusions stated by Barkla.

⁴ *Nature*, Aug. 1, 1907.

⁵ This Journal, 29, 485.

Weight InCl ₃ .	Weight AgCl.	At. wt. In.
2.1156	4.11421	114.80
4.95920	9.64176	114.85
1.98175	3.85125	114.95
5.54540	10.77904	114.90
1.46361	2.84557	114.86
4.08602	7.94054	114.96
		Mean, 114.88

Secondly, similar analyses were made of indium tribromide, as follows:

Weight InBr ₃ .	Weight AgBr.	At. wt. In.
2.73494	4.34550	114.89
7.69880	12.23341	114.86
6.27450	9.96917	114.89
5.36642	8.52741	114.85
5.16112	8.20128	114.85
4.98336	7.92009	114.81
		Mean, 114.86

The calculations were made with Ag = 107.93, Cl = 35.473, and Br = 79.953. The author favors In = 114.9 as the value to be accepted.

Tellurium.

The research upon tellurium, by Baker and Bennett,¹ was primarily to determine the homogeneity of the element. Various fractionating processes were employed, but tellurium of the same atomic weight was produced in every case. Two methods, both new, were adopted for the atomic weight determinations. First, TeO₂ was heated with sulphur in tubes of glass, the two ends of the tube being packed with pure silver leaf. Sulphur dioxide was expelled, and from its amount, as measured by the loss of weight, the percentage of oxygen in the TeO₂ was computed. For this purpose the value S = 32.06 was assumed. The determinations by this method fall into three principal series, as follows, representing differences in the source of the initial substance: 1. Fractional crystallization of telluric acid from barium tellurate. 2. Fractional crystallization of telluric acid from oxidation of the element. 3. Tellurium dioxide prepared from tellurium hydride. Vacuum weights are given throughout. The data are as follows:

SERIES 1.			
Fraction.	Weight TeO ₂ .	Loss SO ₂ .	Per cent. O in TeO ₂ .
1	1.51509	0.60838	20.055
2	1.09875	0.44074	20.034
3	1.02150	0.40993	20.046
4	0.90835	0.36472	20.053
5	1.00702	0.40451	20.062
6	1.01515	0.40733	20.044

¹ J. Chem. Soc., 91, 1849.

SERIES 2.

Fraction.	Weight TeO ₂ .	Loss SO ₂ .	Per cent. O in TeO ₂ .
1	1.56837	0.62938	20.046
2	1.07852	0.43257	20.035
3	1.72627	0.69296	20.052
4	2.09253	0.83927	20.032
5	0.83335	0.33465	20.059
6	1.15372	0.46284	20.041
7	1.68618	0.67661	20.045
8	0.90835	0.36472	20.053

No.

SERIES 3.

1	1.02217	0.41050	20.064
2	0.80697	0.32322	20.051
3	1.32003	0.52992	20.053
4	1.05207	0.42221	20.047
5	1.37043	0.54969	20.032
6	0.95944	0.38511	20.048

Several other experiments, concordant with these, are cited, but without the detailed weighings.

The other method employed consisted in converting tellurium into the tetrabromide by direct union with bromine in an atmosphere of nitrogen. Here again, several series of determinations are given. For brevity, the data are combined in one table:

Series.	Weight Te.	Weight TeBr ₄ .	Per cent. Te.
1	0.61273	2.14933	28.508
	0.56866	1.99354	28.525
	0.59884	2.09951	28.523
	0.57894	2.03040	28.514
	0.54743	1.91899	28.527
	0.33859	1.18732	28.517
	0.56866	1.99354	28.526
	0.47643	1.67025	28.525
	0.56622	1.98597	28.511
2	0.44271	1.55205	28.524
	0.41671	1.46177	28.508
	0.50611	1.77489	28.515
3	0.37382	1.31081	28.519
	0.31895	1.11868	28.512
	0.48931	1.71554	28.522
4	0.47156	1.65404	28.510
	0.40748	1.42867	28.523
	0.62013	2.17449	28.518
5	0.37382	1.31081	28.519
	0.50822	1.78207	28.518
	0.12928	0.45354	28.505
6	0.42926	1.50540	28.515
	0.80348	2.81715	28.511
	0.95309	3.34193	28.512

From the dioxide determinations the authors compute that $\text{Te} = 127.609$. From the bromide syntheses, if $\text{Br} = 79.96$, $\text{Te} = 127.601$. They also give, but without details, several determinations based upon analyses of tellurium tetrachloride. Four fractions of the chloride gave for Te the values 127.58, 127.60, 127.64, 127.62. The commonly accepted value, 127.6, thus receives strong confirmation.

On the other hand, quite different results have been announced by Marckwald.¹ He prepared pure telluric acid, H_6TeO_6 , which, by heating under proper precautions, was reduced to TeO_2 . His figures, on the basis of $\text{O} = 16$ and $\text{H} = 1.008$, are subjoined.

Weight acid.	Weight TeO_2 .	At. wt. Te .
8.6277	5.9884	126.93
12.2680	8.5135	126.84
13.0051	9.0244	126.80
8.6415	5.9947	126.65
8.4588	5.8696	126.80
8.0113	5.5599	126.94

Mean, excluding No. 4, 126.86

From the sums of the weights Marckwald, rejecting the fourth determination, computes $\text{Te} = 126.85$. This falls below the atomic weight of iodine, and is in harmony with the periodic law. Since, however, it diverges so widely from many, concordant, higher determinations, it evidently needs corroboration by other experimenters and other methods.

Ytterbium and Lutecium.

According to Urbain,² ytterbium is a mixture of two elements, neo-ytterbium and lutecium. The atomic weight of neo-ytterbium is not far from 170; that of lutecium is perhaps a little above 174. Detailed determinations are yet to be made. In a footnote Urbain remarks that the atomic weight of thulium, which is given as 171 in the tables, is certainly below 168.5.

Radium.

Madame Curie³ has redetermined the atomic weight of radium, with purer material than that used in her former researches, and in larger quantities. The well-known chloride method was employed, with the subjoined results:

Weight RaCl_2 .	Weight AgCl . ⁴	At. wt. Ra .
0.4052	0.3906	226.35
0.4020	0.3879	226.04
0.39335	0.3795	226.15

Mean, 226.18

¹ Ber., 40, 4730.

² Compt. rend., 145, 759.

³ *Ibid.*, 145, 422.

⁴ From the weights of AgCl , 0.00006 gram is to be deducted in each case, representing filter ash.

Calculated with $\text{Ag} = 107.8$ and $\text{Cl} = 35.4$. With $\text{Ag} = 107.93$ and $\text{Cl} = 35.45$, Ra becomes 226.45, or 226.5 in round numbers. It is announced that Thorpe is also engaged upon a redetermination of this constant.

Gaseous Densities.

Gray¹ has determined the density of gaseous hydrochloric acid, and assigns to the weight of one liter, under standard conditions and in latitude 45° , the value 1.6397 grams.

Guye² has discussed the data relative to nitrogen and some of its gaseous compounds, and assigns to it the atomic weight 14.010. D. Berthelot,³ from essentially the same data, finds $\text{N} = 14.005$. In an elaborate discussion of the whole subject, Guye⁴ has finally adopted the following figures for the weight in grams of one liter of each gas considered:

O_2	1.42900	CO_2	1.9768
H_2	0.08987	N_2O	1.9777
N_2	1.2507	HCl	1.6398
CO	1.1504	NH_3	0.7708
NO	1.3402	SO_2	2.9266
	Air....		1.2928

Miscellaneous Notes.

Watson,⁵ in a brief note, has considered the simultaneous calculation of atomic weights from a group of related ratios. Hinrichs⁶ has proposed a graphic method for achieving the same purpose. He has also published several papers⁷ in which he seeks to establish integral values for the atomic weights of Br , Mn , and Cl .

A number of writers⁸ have discussed relations between the atomic weights. On the question of standards, see Erdmann,⁹ and especially Swarts.¹⁰ The latter proposes two methods by which the atomic weights may be connected with the gas equation, and with the absolute system of units. General papers on the subject of atomic weights are by Brauner¹¹

¹ Proc. Chem. Soc., 23, 119.

² Compt. rend., 145, 1164.

³ *Ibid.*, 145, 65.

⁴ Arch. Sci. Phys. Nat. [4], 24, 34; Journ. Chim. Phys., 5, 203; Compt. rend., 144, 976; Chem. News, 96, 175; This Journal, 30, 143. Other papers, mostly controversial, are as follows: Guye, Compt. rend., 144, 1360; Berthelot, *Ibid.*, 144, 76, 269.

⁵ Nature, 77, 7.

⁶ Compt. rend., 145, 715.

⁷ *Ibid.*, 144, 973; 144, 1343; 145, 58. See also Chem. Zentralb., 1907, 1958.

⁸ See Wilde, Manchester Lit. Phil. Soc., 51 [1], No. 2. Stromeier, *Ibid.*, No. 6. Minet, Compt. rend., 144, 428; Collins, Chem. News, 96, 176; Verschoyle, *Ibid.*, 96, 197; Delaunay, Compt. rend., 145, 1279.

⁹ Chem. Zeitung, 31, 95.

¹⁰ Bull. Acad. Roy. Belg., Classe des Sciences, 1907, No. 3, p. 212.

¹¹ Chem. Zeitung, 31, 483.

and Richards.¹ Richards's paper is in the form of a lecture delivered before the German Chemical Society.

U. S. GEOLOGICAL SURVEY.
WASHINGTON, D. C.

[CONTRIBUTIONS FROM THE RESEARCH LABORATORY OF PHYSICAL CHEMISTRY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY, No. 21.]

THE EQUIVALENT CONDUCTANCE OF HYDROGEN-ION DERIVED FROM TRANSFERENCE EXPERIMENTS WITH NITRIC ACID.

BY ARTHUR A. NOYES AND YOGORO KATO.

Received December 31, 1907.

Contents: 1. Outline of the investigation. 2. Preparation and standardization of the solutions. 3. Description of the experiments. 4. The experimental data. 5. Summary of the transference numbers. 6. Summary and discussion.

1. Outline of the Investigation.

In an article published four years ago by A. A. Noyes and G. V. Sammet² there were described some transference determinations made with 1/20, 1/60 and 1/80 normal hydrochloric acid at 10°, 20°, and 30°, which, when combined with the equivalent conductance of chloride-ion (using the value of Kohlrausch) yielded for hydrogen-ion a much higher equivalent conductance than that which had been derived from the conductivity of acids at high dilutions. Thus the value for hydrogen-ion at 18° derived from the transference experiments was 330, while that of Kohlrausch derived from conductivity was 318. This serious divergence appeared greater than the possible errors in the transference determinations;³ and it seemed as if it must be due either (1) to an error in the extrapolated values of the equivalent conductance of acids at zero concentration, (2) to the formation of complex ions or some other abnormality of the hydrochloric acid, or (3) to a marked difference in the relative velocities of the hydrogen-ion and the anion, at moderate and at very low concentrations. To test the first of these possibilities, a study of the effect of the impurities in the water upon the conductance of very dilute hydrochloric and nitric acids was made in this laboratory by H. M. Goodwin and R. Haskell,⁴ the results of which showed that, after eliminating the effect of impurities as far as possible, a value for the equivalent conductance of hydrogen-ion at extreme dilution (315 at 18°) even lower than that previously derived by Kohlrausch (318) was obtained.

¹ Ber., 40, 2767.

² This Journal, 24, 944-968; 25, 165-168 (1902-3); Z. physik. Chem., 43, 49-74 (1903).

³ The experimental results of Noyes and Sammet have recently been fully confirmed by those of Jahn, Joachim and Wolff (Z. physik. Chem., 58, 641 (1907)).

⁴ Phys. Rev., 19, 369-396 (1904); Proc. Am. Acad., 40, 399-415 (1904) Reviewed in Z. physik. Chem., 52, 630 (1905).