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NINETEENTH ANNUAL REPORT OF THE COMMITTEE ON ATOMIC WEIGHTS. DETERMINATIONS PUBLISHED IN 1911.

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During the year 1911 a fair number of investigations relative to atomic weights appeared, some of them being of a fundamental character. The actual data obtained are, briefly, as follows:

Chlorine.—Burt and Gray[1] continued their research upon the density of hydrochloric acid, confirming their earlier conclusions. For the weight of a normal liter of the gas at 0°, 760 mm., and the latitude of London they give the following figures:

1.63977	1.63999	1.64016
1.63999	1.64049	1.64037
1.64007	1.63982	1.64030
	1.64009	
	Mean,	1.64011

Reduced to latitude 45° this mean becomes 1.63915, whence Cl = 35.460.

Chlorine and Potassium.—Since the time of Berzelius the analysis of potassium chlorate has been of fundamental importance in the determination of atomic weights. The data, however, were discordant, and not in harmony with recent investigations. Now, with all modern precautions, Staehler and Meyer[2] have reanalyzed the compound, with the subjoined results. Absolute weights are given.

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[1] *Chem. News*, **103**, 161, 170. Their former determinations appear in the report of this committee for 1909.

[2] *Z. anorg. Chem.*, 71, 368.

PRELIMINARY.

Weight $KClO_3$.	Weight KCl.	Ratio.
12.38248	7.53218	1.643943
11.28213	6.86340	1.643811
12.22480	8.65366	1.643791
11.52268	7.00963	1.643835
12.44913	7.57331	1.643816
	Mean of the last four,	1.643813

Hence KCl = 74.5558. The first experiment was rejected.

FINAL SERIES.

Weight $KClO_3$.	Weight KCl.	Ratio.
10.26355	6.24370	1.643824
10.08261	6.13362	1.643826
10.03177	6.10269	1.643828
10.63651	6.47073	1.643786
12.05095	7.33096	1.643842
	Mean,	1.643819

Hence, KCl = 74.5551. From this the authors deduce K = 39.097, and Cl = 35.458, values in accord with the results obtained by other methods.

Sodium.—Some interesting analyses of sodium chloride and bromide are due to Goldbaum.[1] The salts were electrolyzed with a mercury cathode and a weighed silver anode, and on the latter the halogen was fixed in weighable form. Omitting a preliminary series of analyses of the chloride, the following data, with vacuum corrections, are given:

SODIUM CHLORIDE.

Weight NaCl.	Weight Cl.	At. wt. Na.
1.02234	0.62014	22.997
1.02221	0.62006	22.997
2.43474	1.47692	22.996
1.46370	0.88789	22.995
0.56934	0.34534	22.999
1.00793	0.61141	22.995
1.06501	0.64600	22.999
2.16720	1.31460	22.997
2.75219	1.66939	22.999
0.92900	0.56349	23.000
1.83527	1.11324	22.998
	Mean,	22.997

Computed with Cl = 35.458. If Na = 23.00, Cl = 35.462.

[1] THIS JOURNAL, **33**, 35.

SODIUM BROMIDE.

Weight NaBr.	Weight Br.	At. wt. Na.
1.05343	0.81803	22.998
1.33360	1.03561	22.997
1.95652	1.51936	22.995
5.02976	3.90586	22.997
2.09332	1.62554	22.998
6.46697	5.02178	23.000
5.54733	4.30768	22.999
7.03901	5.46606	22.998
	Mean,	22.998

Computed with Br = 79.92. If Na = 23.00, Br = 79.927.

Sulfur.—The ratio between nitrogen and sulfur has been determined by Burt and Usher,[1] through analyses of nitrogen sulfide, N_4S_4. The substance was decomposed by passing its vapor at a red heat over quartz wool in a quartz tube, and from the volume of nitrogen so liberated its weight was computed. The following abbreviated table gives the essential data:

Weight N_4S_4.	Weight N_2.	Ratio, N/S.
0.469455	0.142726	0.43685
0.442787	0.134627	0.43688
0.456326	0.138736	0.43684
0.470072	0.142919	0.43686
0.466918	0.141969	0.43690
0.491307	0.149380	0.43688
0.484307	0.147257	0.43690
	Mean,	0.43687

Hence, if N = 14.009, S = 32.067. In short, the new ratio confirms the accepted values for both nitrogen and sulfur.

Calcium.—Richards and Hönigschmid[2] have analyzed calcium chloride, and confirmed their former determinations of the atomic weight of calcium. The ratio $2Ag : CaCl_2$ was measured, by the usual Harvard methods, with the results given in the next table. Vacuum weights are stated, and the reductions are based upon Ag = 107.88 and Cl = 35.457.

Weight $CaCl_2$.	Weight Ag.	At. wt. Ca.
4.60350	8.94908	40.075
4.82401	9.37780	40.074
4.81846	9.36688	40.076
5.29799	10.29911	40.076
5.40550	10.50832	40.073
5.24539	10.19715	40.073
5.34110	10.38328	40.072
	Mean,	40.074

Hence, Ca = 40.074. The earlier bromide analyses gave Ca = 40.070.

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[1] *Proc. Roy. Soc.*, **85A**, 82.

[2] THIS JOURNAL, **33**, 28.

A very rough determination of the atomic weight of calcium is due to Oechsner de Coninck.[1] He ignited calcium formate, and in four experiments found values for CaO from 55.94–56.11. In one other experiment he dissolved calcium carbonate in hydrochloric acid, precipitated the lime as oxalate, and finally ignited the latter. The mean of his five discordant values is Ca = 40.02.

Cadmium.—In order to determine the atomic weight of cadmium, Perdue and Hulett[2] have analyzed the hydrated sulfate electrolytically. The salt was electrolyzed over mercury, in which the liberated cadmium dissolved. The water of the sulfate was also determined at temperatures between 670° and 700°. The data, with vacuum weights, are as follows:

PERCENTAGE OF WATER.

Weight $CdSO_4.{}^8/_3H_2O$.	Weight H_2O.	Per cent. H_2O.
6.32863	1.1856	18.734
6.72493	1.25986	18.734
6.87537	1.2886	18.742
5.65027	1.05822	18.729
6.81125	1.27557	18.727
7·34977	1·37703	18.736
7·74837	1·3572	18.727
7·8843	1·47713	18.734
6.6100	1.2480	18.730
	Mean,	18.733

PER CENT. OF CADMIUM IN $CdSO_4.{}^8/_3H_2O$.

Weight sulfate.	Weight Cd.	Per cent. Cd.
7·90902	3·46335	43·790
9.07468	3·97434	43·796
7·32787	3·20936	43·796
6.48847	2.84186	43·799
5.11684	2.24157	43·808
8.02954	3·51755	43·807
5.08743	2.22827	43·799
	Mean,	43·799

PER CENT. Cd IN $CdSO_4$.

Weight $CdSO_4$.	Weight Cd.	Per cent. Cd.
5·14303	2.77196	53·897
5·46507	2.94566	53·898
5·58677	3.01076	53·891
5·53568	2.98276	53·883
6.29717	3·39295	53·880
6.40718	3·45255	35·887
5·37196	2.89457	53·883
	Mean,	53·888

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[1] *Compt. rend.*, 153, 1579.

[2] *J. Physic. Chem.*, 15, 147.

From these data, when S = 32.07 and H = 1.008, the authors deduce Cd = 112.30, a value lower than that generally accepted. These new determinations have been criticized by Richards,[1] who suggests that the cadmium sulfate possibly contained an excess of water in "solid solution." Hulett is continuing his research with other cadmium compounds, and therefore judgment may well be suspended until the new evidence is published.

Iron.—Atomic weight redetermined by Baxter, Thorvaldson and Cobb[2] from analyses of ferrous bromide. The figures obtained are as follows, with all corrections applied:

Preliminary Series.

Weight $FeBr_2$.	Weight Ag.	At. wt. Fe.	Weight AgBr.	At. wt. Fe.
3.45339	3.45481	55.840	6.01358	55.853
3.04933	3.05055	55.840	5.31029	55.844
2.9007	2.9019	55.839	....	......
3.0873	3.0885	55.844	....	......
3.50278	3.50426	55.837	6.10033	55.831
4.05239	4.05404	55.840	7.05752	55.831
4.08516	4.08683	55.840	....	......
	Mean,	55.840	Mean,	55.840

Final Series.

Weight $FeBr_2$.	Weight Ag.	At. wt. Fe.	Weight AgBr.	At. wt. Fe.
5.03555	5.03744	55.834	8.76950	55.837
6.06309	6.06557	55.840	10.55889	55.839
5.59258	5.59482	55.482	9.73974	55.834
5.89767	5.90014	55.838	10.27507	55.844
4.48546	4.48742	55.834	....	......
5.41562	5.41799	55.834	9.43171	55.830
6.50002	6.50277	55.837	11.31958	55.843
3.56564	3.56719	55.834	6.20987	55.829
5.32434	5.32642	55.844	9.27237	55.839
6.38845	6.39094	55.844	11.12536	55.842
6.37952	6.38213	55.840	11.10971	55.844
8.51818	....	......	14.83468	55.836
	Mean,	55.838	Mean,	55.838

In a second paper Baxter and Thorvaldson[3] give another series of determinations, like the foregoing, but starting with meteoric rather than terrestrial iron. The results obtained are essentially the same, as is shown by the subjoined figures.

[1] THIS JOURNAL, 33, 888.

[2] *Ibid.*, 33, 319.

[3] *Ibid.*, 33, 337.

Weight $FeBr_2$.	Weight Ag.	At. wt. Fe.	Weight AgBr.	At. wt. Fe.
3.95460	3.95631	55.835	6.88720	55.831
4.66954	4.67177	55.825	8.13282	55.818
4.75335	4.75550	55.831	8.27855	55.824
6.95582	6.95854	55.844	12.11329	55.844
3.20762	3.20904	55.833	5.58632	55.830
	Mean,	55.834	Mean,	55.829

The authors reject the second and third of these pairs of determinations, leaving to be accepted the means 55.837 and 55.835. The calculations are based upon Ag = 107.88 and Br = 79.916.

Tantalum.—The determinations of this atomic weight by Chapin and Smith[1] were made by the hydrolysis of the pentabromide. The weights given below are corrected to a vacuum. Br = 79.92.

Weight $TaBr_5$.	Weight Ta_2O_5.	At. wt. Ta.
0.86837	0.33117	181.68
1.50903	0.57570	181.80
1.56554	0.59718	181.75
1.23239	0.47030	181.91
1.31815	0.50295	181.85
1.31702	0.50244	181.80
1.20090	0.45830	181.91
1.04050	0.39688	181.74
	Mean,	181.80

This value is higher than that previously found by Balke, 181.52, from similar analyses of tantalum pentachloride.

Selenium.—Kuzma and Krehlik[2] have redetermined the atomic weight of selenium by reduction of SeO_2 with SO_2. Special precautions were taken to secure a perfect reduction, and to avoid losses or impurities. The essential figures are as follows:

Weight SeO_2.	Weight Se.	At. wt. Se.
0.44245	0.31523	79.290
0.61918	0.44122	79.338
1.39106	0.99109	79.292
0.66740	0.47544	79.257
0.65154	0.46414	79.255
0.96042	0.68417	79.253
1.21088	0.86256	79.243
0.75468	0.53760	79.249
0.38577	0.27486	79.302
1.51040	1.07594	79.249
	Mean,	79.273

Reduced to a vacuum standard, Se = 79.26.

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[1] THIS JOURNAL, **33**, 1497.

[2] *Trans. Bohemian Acad. of Emperor Francis Joseph*, **19**, No. 13 (1910). In Bohemian. I am indebted for the details to the kindness of Professor Brauner, at whose suggestion the work was done.

Tellurium.—Harcourt and Baker[1] have criticized the work of Flint[2] upon the supposed complexity of tellurium, and conclude that the portions of low atomic weight which Flint obtained were contaminated by some impurity. They suggest that the basic nitrate employed in Flint's determination probably contained tellurium trioxide. Repeating his process of fractionation, they used the fourth fraction for atomic weight determinations, with the results shown below. The bromide method of Baker was employed.

Weight Te.	Weight $TeBr_4$.	At. wt. Te.
0.87822	2.20103	127.55
0.59706	1.49640	127.55
0.69189	1.73442	127.53
0.62732	1.57254	127.53
0.58307	1.46162	127.53
	Mean,	127.54

I am informed that Flint is continuing his investigation, so that the question at issue still remains open. The value now given by Harcourt and Baker agrees with that found by Baker and Bennett in 1907.

Uranium.—In three very short notices Oechsner de Coninck[3] gives approximate determinations of the molecular weight of UO_2. First, UO_2Cl_2 was reduced to UO_2 by heating in hydrogen. In mean, $UO_2 = 270.07$. Similar reductions of $UO_2.H_2O$ gave $UO_2 = 270.66$. Another series with $UO_3.2H_2O$ gave $UO_2 = 270.46$. The last value corresponds to $U = 238.46$.

Iridium.—Hoyermann[4] has determined the atomic weight of iridium by reducing $(NH_4)_2IrCl_6$ in a stream of hydrogen. His figures are subjoined, with deductions based upon $H = 1.008$, $N = 14.01$, and $Cl = 35.46$.

Weight chloride.	Weight Ir.	At. wt. Ir.
1.72348	0.77205	192.645
1.77984	0.77654	192.598
1.78837	0.78011	192.533
1.15161	0.50249	192.635
1.73794	0.75838	192.654
	Mean,	192.613

Holmium.—The atomic weight of holmium has been determined by Holmberg,[5] by the well known sulfate method. His syntheses are as follows:

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[1] *Jour. Chem. Soc.*, **99**, 1311.

[2] *Am. J. Sci.*, [4] **30**, 209. Cited in this report for 1910.

[3] *Compt. rend.*, **152**, 711, 1179; **153**, 63.

[4] *Sitz. phys. med. Soz. Erlangen*, **42**, 278

[5] *Z. anorg. Chem* **71**, 226.

Weight Ho_2O_3.	Weight $Ho_2(SO_4)_3$.	At. wt. Ho.
0.3467	0.5687	163.57
0.3400	0.5579	163.40
0.3960	0.6496	163.55
0.7631	1.2524	163.31
0.6877	1.1286	163.33
0.5378	0.8822	163.55
	Mean,	163.45

Argon.—Fischer and Froboese[1] have made numerous fractional distillations of liquid argon, and found its density as gas to be practically constant. The final result is d. 19.94–19.95, and A = 39.9.

Niton.—For the atomic weight of niton, the gaseous emanation of radium, Gray and Ramsay[2] give determinations ranging from 218–227. The mean is 223; but the value Nt = 222.4 is preferred.

Miscellaneous Notes.—Hinrichs[3] has reconsidered all the evidence relative to the atomic weight of hydrogen, and concludes that H = 1.00781. In another paper[4] he discusses the atomic weight of vanadium, which he places at 51 precisely. A brief note by Ter Gazarian[5] defends his work on the density of PH_3. C. Henry[6] has considered the proper mode of calculating atomic weights. Relations between the atomic weights are studied by Loring,[7] by Emerson[8] and by Nicholson.[9] Emerson's "helix chimica" is an arrangement of the elements on a spiral, while Nicholson develops a structural theory of their formation.

THE FREE ENERGY OF DILUTION OF HYDROCHLORIC ACID.

By Richard C. Tolman and Alfred L. Ferguson.

Received December 19, 1911.

1. Introduction.

The free energy of dilution of an electrolyte is usually obtained from measurements of the electromotive force of concentration cells. In the case of hydrochloric acid, apparently accurate measurements have been made by Jahn[10] on concentration cells of the type,

$$\mathrm{Ag : AgCl} \quad \underset{C_1}{\mathrm{HCl}} : \underset{C_2}{\mathrm{HCl}} \quad \mathrm{AgCl : Ag}.$$

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[1] *Ber.*, **44**, 92.

[2] *Proy. Roy. Soc.*, **84A**, 536.

[3] *Rev. gén. chim.*, **13**, 351, 377 (1910).

[4] *Proc. Am. Phil. Soc.*, **50**, 191.

[5] *J. chim. phys.*, **9**, 100.

[6] *C. R. Assoc. Franc. Avance Sci.*, 269 (1909).

[7] *Phys. Z.*, **12**, 107.

[8] *Am. Chem. J.*, **45**, 160 (1911).

[9] *Phil. Mag.*, [6] **22**, 864.

[10] Jahn, *Z. physik. Chem.*, **33**, 545 (1900); **35**, 1 (1900).