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FOURTH ANNUAL REPORT OF THE COMMITTEE ON ATOMIC WEIGHTS. RESULTS PUBLISHED IN 1896.

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To the Members of the American Chemical Society:

DURING 1896 the activity in the determination of atomic weights was only moderate. Comparatively few papers on the subject appeared, but some of these were of excellent quality. The question is often asked, Why are new determinations important? Are not those we have good enough for all practical purposes? To this question I have an interesting answer, such as has not hitherto been published.

There are two rival values for the atomic weight of chromium. One, 52.5 approximately, based on the old work of Berlin, is still used by European analysts. The other, 52.1, depends upon later and more accurate researches, and is used in this country. Mr. William Glenn, of the Baltimore Chrome Works, informs me that that establishment imports chrome iron ore by the shipload, the value being determined by a volumetric assay in which the atomic weight of chromium is involved. It is assayed in Glasgow, with the older value for chromium, and in Baltimore with the modern datum. A cargo amounts to about 3500 tons; and the difference in price due to the difference between 52.1 and 52.5 for chromium, amounts to about $367.50 per shipload. This difference is large enough to show the importance of accurately determined constants from a commercial point of view, and suggests that other similar cases might be found by a careful scrutiny of our analytical processes.

The following new determinations of atomic weights represent the work published during the year:

Oxygen.—In the report for 1895, J. Thomsen's gravimetric measurements of the H : O ratio were cited. Early in 1896 the same chemist,[1] by a novel method, determined the ratio of densities. First, he found the volume of hydrogen in liters, liberated by the solution of one gram of aluminum, to be as follows:

	1.24297
	1.24303
	1.24286
	1.24271
	1.24283
	1.24260
	1.24314
	1.24294
Mean,	1.24289 ± 0.00004

In his earlier research Thomson found the weight of hydrogen corresponding to one gram of aluminum to be 0.11190 ± 0.000015 gram. Hence one liter of hydrogen at 0°, 760 mm., and 10.6 meters above sea-level is 0.090032 ± 0.00012 gram; or at sea-level in latitude 45°, 0.089947.

For the volume of one gram of oxygen at 0°, 760 mm., and at Copenhagen Thomsen found, in liters:

	0.69902
	0.69923
	0.69912
	0.69917
	0.69903
	0.69900
	0.69901
	0.69921
	0.69901
	0.69922
Mean,	0.69910 ± 0.00002

At sea-level, latitude 45°, 0.69976 ± 0.00002.

Hence one liter weighs 1.42906 ± 0.00004 gram. Dividing this by the value found for hydrogen we have for the ratio desired

$$15.8878 \pm 0.0022.$$

[1] *Ztschr. anorg. Chem.*, 12, 4.

Correcting this by the known data for the volumetric composition of water we get

$$O = 15.8690 \pm 0.0022,$$

a value identical with that found gravimetrically, and very close to the measurement by Morley.

Silver.—The atomic weight of silver has been determined electrolytically by Hardin.[1] The nitrate, acetate, and benzoate, mixed in aqueous solution with solutions of pure potassium cyanide, were electrolyzed in platinum dishes. The data are as follows, with vacuum weights, and reduced with $N = 14.04$, $C = 12.01$, $H = 1.008$, and $O = 16$.

NITRATE SERIES.

Weight $AgNO_3$.	Weight Ag.	Atomic weight Ag.
0.31202	0.19812	107.914
0.47832	0.30370	107.900
0.56742	0.36030	107.923
0.57728	0.36655	107.914
0.69409	0.44075	107.935
0.86367	0.54843	107.932
0.86811	0.55130	107.960
0.93716	0.59508	107.924
1.06170	0.67412	107.907
1.19849	0.76104	107.932
	Mean,	107.924

ACETATE SERIES.

Weight salt.	Weight Ag.	Atomic weight Ag.
0.32470	0.20987	107.904
0.40566	0.26223	107.949
0.52736	0.34086	107.913
0.60300	0.38976	107.921
0.67235	0.43455	107.896
0.72452	0.46830	107.916
0.78232	0.50563	107.898
0.79804	0.51590	107.963
0.92101	0.59532	107.925
1.02495	0.66250	107.923
	Mean,	107.922

[1] This Journal, 18, 990.

BENZOATE SERIES.

Weight salt.	Weight Ag.	Atomic weight Ag.
0.40858	0.19255	107.947
0.46674	0.21999	107.976
0.48419	0.22815	107.918
0.62432	0.29418	107.918
0.66496	0.31340	107.964
0.75853	0.35745	107.935
0.76918	0.36247	107.936
0.81254	0.38286	107.914
0.95673	0.45079	107.908
1.00840	0.47526	107.962
	Mean,	107.938

The mean of all three series is

$$Ag = 107.928.$$

This value agrees well with the values found by Stas and by Marignac, and so creates a presumption in favor of the electrolytic method, which Hardin has also applied to determining the atomic weights of mercury and cadmium.

Nitrogen.—Among the ratios measured by Penny and by Stas relative to the atomic weights of nitrogen, those connecting the chlorides and nitrates of potassium and sodium were highly important. These are now redetermined by Hibbs[1] in a different way. The nitrates were heated in gaseous hydrochloric acid, and so converted easily into chlorides, with considerable accuracy. The data are as follows, with vacuum weights, and reduced with $O = 16$, $K = 39.11$, $Na = 23.05$, and $Cl = 35.45$.

Weight KNO_3.	Weight KCl.	Atomic weight N.
0.11090	0.08177	14.011
0.14871	0.10965	14.010
0.21067	0.15523	14.013
0.23360	0.17223	14.011
0.24284	0.17903	14.014
	Mean,	14.0118

Weight $NaNO_3$.	Weight NaCl.	Atomic weight N.
0.01550	0.01066	14.011
0.20976	0.14426	14.011
0.26229	0.18038	14.014
0.66645	0.45829	14.014
0.93718	0.64456	14.008
	Mean,	14.0116

[1] Doctoral Dissertation, University of Pennsylvania, 1896, by J. G. Hibbs. This Journal, 18, 1044.

These results seem to be exceedingly good, and the process has the advantage of great simplicity. The work was done under the direction of Prof. E. F. Smith.

Arsenic.—In the dissertation already cited Hibbs gives some determinations of the atomic weight of arsenic. Sodium pyroarsenate was heated in gaseous hydrochloric acid and so converted into chloride. The latter was perfectly white, unfused, and showed no trace of arsenic. I subjoin the vacuum weights, and the values found for arsenic when O = 16, Na = 23.05, and Cl = 35.45.

Weight $Na_4As_2O_7$.	Weight NaCl.	Atomic weight As.
0.02177	0.01439	74.904
0.04713	0.03115	74.921
0.05795	0.03830	74.927
0.40801	0.26981	74.901
0.50466	0.33345	74.916
0.77538	0.51249	74.917
0.82897	0.54791	74.917
1.19124	0.78731	74.926
1.67545	1.10732	74.928
3.22637	2.13267	74.901
	Mean,	74.9158

Magnesium.—Atomic weight determined by Richards and Parker,[1] who studied the carefully purified chloride. First, a gravimetric series, with all weights reduced to a vacuum.

Weight $MgCl_2$.	Weight AgCl.	Atomic weight Mg.
1.33550	4.01952	24.368
1.51601	4.56369	24.350
1.32413	3.98528	24.369
1.40664	4.23297	24.386
1.25487	3.77670	24.373
	Mean,	24.369

The remaining series of experiments are of the usual volumetric character.

SECOND SERIES.

Weight $MgCl_2$.	Weight Ag.	Atomic weight Mg.
2.78284	6.30284	24.395
2.29360	5.19560	24.379
2.36579	5.35989	24.366
	Mean,	24.380

1 *Ztschr. anorg. Chem.*, 13, 81.

To this series the authors attach less importance than to the others.

THIRD SERIES.

Weight $MgCl_2$.	Weight Ag.	Atomic weight Mg.
1.99276	4.51554	24.349
1.78870	4.05256	24.363
2.12832	4.82174	24.368
2.51483	5.69714	24.372
2.40672	5.45294	24.369
1.95005	4.41747	24.377
	Mean,	24.365

FOURTH SERIES.

Weight $MgCl_2$.	Weight Ag.	Atomic weight Mg.
2.03402	4.60855	24.360
1.91048	4.32841	24.364
2.09932	4.75635	24.362
1.82041	4.12447	24.362
1.92065	4.35151	24.363
1.11172	2.51876	24.363
	Mean,	24.362

These values are computed with O = 16.

When O = 15.88, Mg = 24.179. The last series outweighs all the others.

Cadmium.—Hardin's determinations of the atomic weight of cadmium resemble those which he made upon silver. First, the chloride, in solution with potassium cyanide, was electrolyzed in a platinum dish. The weights in this and the other series are all reduced to a vacuum. Computations made with Cl = 35.45, and O = 16. Data as follows:

Weight $CdCl_2$.	Weight Cd.	Atomic weight Cd.
0.43140	0.26422	112.054
0.49165	0.30112	112.052
0.71752	0.43942	112.028
0.72188	0.44208	112.021
0.77264	0.47319	112.036
0.81224	0.49742	112.023
0.90022	0.55135	112.041
1.02072	0.62505	112.002
1.26322	0.77365	112.041
1.52344	0.93315	112.078
	Mean,	112.038

Secondly, the bromide was treated in the same way. The data were reduced with Br = 79.95.

Weight $CdBr_2$.	Weight Br.	Atomic weight Cd.
0.57745	0.23790	112.031
0.76412	0.31484	112.052
0.91835	0.37842	112.067
1.01460	0.41808	112.068
1.15074	0.47414	112.053
1.24751	0.51392	112.019
1.25951	0.51905	112.087
1.51805	0.62556	112.076
1.63543	0.67378	112.034
2.15342	0.88722	112.041
	Mean,	112.053

In a third series of experiments cadmium was thrown down simultaneously with silver in the same electric current. Weights and results as follows, with Ag = 107.92.

Weight Ag.	Weight Cd.	Atomic weight Cd.
0.24335	0.12624	111.928
0.21262	0.11052	111.991
0.24515	0.12720	111.952
0.24331	0.12616	111.916
0.42520	0.22058	111.971
	Mean,	111.952

Mean of all the twenty-five experiments, Cd = 112.027.

Mercury.—Atomic weight also determined electrolytically by Hardin, in the same paper with his work upon silver and cadmium. With the oxide he obtained unsatisfactory results ; but with the chloride, bromide, and cyanide he did better. With the chloride, when Cl = 35.45, his data, with vacuum weights, are as follows :

Weight $HgCl_2$.	Weight Hg.	Atomic weight Hg.
0.45932	0.33912	200.030
0.54735	0.40415	200.099
0.56002	0.41348	200.053
0.63586	0.46941	199.947
0.64365	0.47521	200.026
0.73281	0.54101	199.988
0.86467	0.63840	200.038
1.06776	0.78825	199.946
1.07945	0.79685	199.912
1.51402	1.11780	200.028
	Mean,	200.006

With the bromide, when Br = 79.95, Hardin found these weights and values:

Weight HBr_2.	Weight H_5.	Atomic weight H_5.
0.70002	0.38892	199.898
0.56430	0.31350	199.876
0.57142	0.31750	199.938
0.77285	0.42932	199.832
0.80930	0.44955	199.814
0.85342	0.47416	199.911
1.11076	0.61708	199.869
1.17270	0.65145	199.840
1.26186	0.70107	199.899
1.40142	0.77870	199.952
	Mean,	199.883

With the cyanide, when C = 12.01 and N = 14.04, Hardin found

Weight HgC_2N_2.	Weight Hg.	Atomic weight Hg.
0.55776	0.44252	200.063
0.63290	0.50215	200.092
0.70652	0.56053	200.038
0.80241	0.63663	200.075
0.65706	0.52130	200.057
0.81678	0.64805	200.103
1.07628	0.85392	200.077
1.22615	0.97282	200.071
1.66225	1.31880	200.057
2.11170	1.67541	200.077
	Mean,	200.071

Finally, Hardin made use of Faraday's law, throwing down mercury and silver simultaneously in the same electric current. The equivalent weights are as follows, reduced with Ag = 107.92.

Weight Hg.	Weight Ag.	Atomic weight Ag.
0.06126	0.06610	200.036
0.06190	0.06680	200.007
0.07814	0.08432	200.021
0.10361	0.11181	200.011
0.15201	0.16402	200.061
0.26806	0.28940	199.924
0.82808	0.89388	199.929
	Mean,	199.996

The general mean of all four series is

$$Hg = 199.989.$$

Tellurium.—In all determinations hitherto made of the atomic weight of tellurium, the material has been derived from metallic tellurides. Chikashige[1] now gives a series of experiments upon tellurium obtained from Japanese native sulphur, using Brauner's method. The tetrabromide was titrated with solutions of silver, and the following data were obtained. Computations were made upon the basis of O = 16.

Weight $TeBr_4$.	Weight Ag.	Atomic weight Te.
4.1812	4.0348	127.57
4.3059	4.1547	127.61
4.5929	4.4314	127.58
	Mean,	127.587

Tungsten.—Schneider[2] objects to the determinations published by Pennington and Smith, regarding them as too high. He attributes their highness to the fact that very small quantities of material were handled, and thinks that there may have been mechanical losses of small particles during the long heating of the substance weighed. He now gives new determinations of his own, with tungstic oxide carefully freed from molybdenum, and made partly by reduction of the oxide, partly by oxidation of the metal. Results as follows, with the percentage of tungsten in tungsten trioxide stated in a third column :

					W in WO_3. Per cent.
2.0728	gram	WO_3	gave	1.6450 W	79.323
4.0853	"	"	"	3.2400 "	79.309
6.1547	"	"	"	4.8811 "	79.307
1.5253	"	W	"	1.9232 WO_3	79.311
3.1938	"	"	"	4.0273 "	79.304
3.7468	"	"	"	5.9848 "	79.314
				Mean,	79.311

Hence, with O = 16, W = 184.007.

On the other hand, Shinn,[3] working in Smith's laboratory, obtains some data corroborative of Pennington and Smith. In this series tungsten was oxidized to tungsten trioxide. Results as follows, computed with O = 16.

[1] *J. Chem. Soc.*, **69**, 881.
[2] *J. prakt. Chem.* [2], **53**, 288.
[3] Doctoral thesis, University of Pennsylvania, 1896.

		Atomic weight.
0.22297 gram W gave	0.28090 gram WO_3	184.720
0.17200 " " "	0.21664 " "	184.964
0.10989 " " "	0.13844 " "	184.753
0.10005 " " "	0.12598 " "	185.206
	Mean,	184.910

The cause of the difference between the values found and those of Schneider is yet to be made out.

My own "Recalculation of the Atomic Weights," a new edition of the work published originally in 1882, is now complete and in the printer's hands. It will probably be published early in 1897, and the following table of values represents the results obtained by combining all the best data:

	H = 1.	O = 16.
Aluminum	26.91	27.11
Antimony	119.52	120.43
Argon	?	?
Arsenic	74.44	75.01
Barium	136.39	137.43
Bismuth	206.54	208.11
Boron	10.86	10.95
Bromine	79.34	79.95
Cadmium	111.10	111.95
Calcium	39.76	40.07
Carbon	11.92	12.01
Cerium	139.10	140.20
Cesium	131.89	132.89
Chlorine	35.18	35.45
Chromium	51.74	52.14
Cobalt	58.49	58.93
Columbium	93.02	93.73
Copper	63.12	63.60
Erbium	165.06	166.32
Fluorine	18.91	19.06
Gadolinium	155.57	156.76
Gallium	69.38	69.91
Germanium	71.93	72.48
Glucinum	9.01	9.08
Gold	195.74	197.23
Helium	?	?
Hydrogen	1.000	1.008
Indium	112.99	113.85
Iodine	125.89	126.85
Iridium	191.66	193.12
Iron	55.60	56.02

	H = 1.	O = 16.
Lanthanum	137.59	138.64
Lead	205.36	206.92
Lithium	6.97	7.03
Magnesium	24.10	24.28
Manganese	54.57	54.99
Mercury	198.49	200.00
Molybdenum	95.26	95.99
Neodymium	139.70	140.80
Nickel	58.24	58.69
Nitrogen	13.93	14.04
Osmium	189.55	190.99
Oxygen	15.88	16.00
Palladium	105.56	106.36
Phosphorus	30.79	31.02
Platinum	193.41	194.89
Potassium	38.82	39.11
Praseodymium	142.50	143.60
Rhodium	102.23	103.01
Rubidium	84.78	85.43
Ruthenium	100.91	101.68
Samarium	149.13	150.26
Scandium	43.78	44.12
Selenium	78.42	79.02
Silicon	28.18	28.40
Silver	107.11	107.92
Sodium	22.88	23.05
Strontium	86.95	87.61
Sulphur	31.83	32.07
Tantalum	181.45	182.84
Tellurium	126.52	127.49
Terbium	158.80	160.00
Thallium	202.61	204.15
Thorium	230.87	232.63
Thulium	169.40	170.70
Tin	118.15	119.05
Titanium	47.79	48.15
Tungsten	183.43	184.83
Uranium	237.77	239.59
Vanadium	50.99	51.38
Ytterbium	171.88	173.19
Yttrium	88.35	89.02
Zinc	64.91	65.41
Zirconium	89.72	90.40