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THIRTEENTH ANNUAL REPORT OF THE COMMITTEE ON
ATOMIC WEIGHTS. DETERMINATIONS
PUBLISHED IN 1905.

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THE year 1905 has been remarkably prolific in determinations of atomic weight, and much of the work done was of unusually high quality. Some of the published researches deal with revisions of the more fundamental values, such as the atomic weights of nitrogen, chlorine, iodine, sodium and potassium. These investigations have made it clear that a general revision and recalculation of all the atomic weights is now needed, and the developments of the next year or two are likely to bring about many changes in the accepted table. Meanwhile, the International Committee¹ advocates a conservative policy, and recommends that changes be deferred until important work, now known to be in progress, shall have been completed. Then the table of atomic weights, as presented in their report, can be revised intelligently, whereas such a revision, undertaken now, would be premature. The determinations published during 1905 are given in the following pages.

NITROGEN.

Guye,² from the density and critical constants of nitrous oxide, finds $N = 14.006$. Jaquero and Scheuer,³ from densities and

¹ See report in this Journal for January, 1906.

² Compt. rend. 140, 1241.

³ Ibid. 140, 1384.

compressibilities of several gases, have determined the following molecular and atomic weights:

$$H = 1.0078.$$

$$NO = 30.005, \text{ whence } N = 14.005.$$

$$NH_3 = 17.014, \text{ whence } N = 13.991.$$

Jaquero and Perrot,¹ from the density of nitrogen at 1067°, find $N = 14.008$. Guye and Pintza² determined the normal weight per liter of ammonia, nitrous oxide, and carbon dioxide.³ The figures for NH_3 and N_2O are as follows:

NH_3 .	N_2O .
0.77080	1.97762
0.77069	1.97707
0.77073	1.97760
0.77099	
0.77076	

From nitrous oxide, compared with carbon dioxide in corresponding states, $N = 14.006$. From the critical constants, $N = 14.008$. Lord Rayleigh,⁴ from the density of nitrous oxide under very small pressures, found $N_2O = 43.996$, whence $N = 13.998$.

Guye and Davila⁵ prepared nitric oxide by three different methods, and determined its density. The weight of one liter, at Geneva, under normal conditions, is given below. The three columns relate to the three preparations.

1.	2.	3.
1.3406	1.3403	1.3399
1.3402	1.3398	1.3403
1.3401	1.3400	
1.3407	1.3408	
1.3398	1.3402	
1.3402	1.3402	

If the weight of one liter of oxygen is 1.4290 grams, the ratio $NO:O_2$ gives $NO = 30.012$. Corrected by physico-chemical methods, $N = 14.006$ to 14.010, according to the method employed.⁶

Nitric oxide was also the substance chosen by R. W. Gray⁷

¹ Compt. rend. 140, 1542.

² Ibid. 141, 51.

³ See under Carbon, later.

⁴ Phil. Trans. 204, 369; Pr. Roy. Soc. 74, 446.

⁵ Compt. rend. 141, 826.

⁶ For the method of correction by critical constants, see Guye: J. chim. phys. 3, 321.

⁷ J. Chem. Soc. 87, 1601.

for his determinations of the atomic weight of nitrogen. First, its density was determined in comparison with oxygen, by weighing both gases in the same bulb under corresponding conditions. The following weights were observed at Bonn, where the bulb was filled at 0° and 760 mm.

	NO.	O ₂ .
Series I. {	0.35845	0.38230
	0.35852	0.38229
	0.35851	0.38227
	0.35849	0.38225
	0.35848	0.38226
	0.35856	0.38230
	Mean,	0.38228
Series II. {	0.35851	
	0.35848	
	0.35852	
	0.35850	

Mean, 0.35851

dupplementary	{	0.35848
Seteterminations ¹		0.35855

The direct ratio between these weights is O₂:NO=32:30.010, whence N=14.010. Corrected by the method of limiting densities, N=14.004; by the critical constants, 14.008. Mean value, N=14.006.

Gray effected the gravimetric analysis of nitric oxide by burning finely divided nickel in the gas. Two sets of determinations were made, with nickel from different sources. In the first series, occluded nitrogen in the resultant nickel oxide was determined, and a correction for it was applied. In the second series the occluded gas was expelled by heating. Only the *corrected* weights are given below.

	Weight NO.	Weight O.	Weight N.
Series I. {	0.31384	0.16729	—
	0.64304	0.34300	0.29920
	0.50672	0.27025	—
Series II. {	0.54829	0.29221	—
	0.61862	0.32981	0.28885
	0.62622	0.33401	0.29234
	0.62128	0.33111	—
	0.54469	0.29029	0.25432
	0.52001	0.27715	0.24270
	0.62103	0.33103	0.28998

¹ Made in London, but corrected to the latitude of Bonn.

From these weights the following values for the atomic weight of nitrogen are derived:

	Ratio NO : O ₂ .	Ratio N ₂ : O ₂ .	Ratio NO : N ₂ .
I.	14.016	—	—
	13.996	13.999	14.001
	14.000	—	—
II.	14.022	—	—
	14.011	14.013	14.015
	13.998	14.004	14.009
	14.021	—	—
	14.009	14.017	14.014
	14.020	14.011	14.003
	14.017	14.012	14.011

Mean of all, 14.010

The gas remaining after the combustion of the nickel, was pure nitrogen, and two density comparisons of it with oxygen were made:

Weight N ₂ .	Weight O ₂ .
0.32286	0.36889
0.32275	0.36879
<hr/> Mean, 0.32280	<hr/> 0.36884

From direct comparison of these figures, $N = 14.003$. Corrected by the method of limiting densities, $N = 14.008$. From the mean of all his determinations Gray puts $N = 14.0085$, or, rounded off, 14.01.

The agreement between all these new values for N, whether gravimetric or physico-chemical, is very striking. In a very complete summary of all the data relative to the atomic weight of nitrogen, Guye¹ has discussed the sources of error in the different methods of determination, and has made it quite clear that the true figure cannot exceed 14.01. The Stas value, 14.04, seems certainly to be high, although the source of error in it remains to be ascertained. The higher value, however, was obtained in two analyses of silver trinitride, AgN₃, by A. W. Browne,² who promises further determinations. In Guye's summary the possibility of a change in the atomic weight of silver is indicated;

¹ Bull. soc. chim. August, 1905, with independent pagination. Another paper by Guye is in Compt. rend. 140, 1387.

² This Journal, 27, 554.

but that, so far, is only a suggestion. Hinrichs,¹ in a brief criticism of recent work, argues in favor of $N = 14$.

CHLORINE.

Two important memoirs on the atomic weight of chlorine appeared during 1905. First, Dixon and Edgar² have effected a direct comparison between hydrogen and chlorine. Hydrogen was weighed in palladium. Chlorine, prepared by the electrolysis of fused silver chloride, was weighed in liquid form. The two elements, with chlorine slightly in excess, were made to unite in a glass bulb; the excess of chlorine remaining after union was caused to liberate iodine from a solution of potassium iodide, and then determined by titration with sodium thiosulphate. The corrected data, reduced to a vacuum standard, are given in the following table:

Weight H.	Weight Cl.	Atomic weight Cl.
0.9993	35.1666	35.191
1.0218	35.9621	35.195
0.9960	35.0662	35.207
1.0243	36.0403	35.185
1.0060	35.4144	35.203
0.9887	34.8005	35.198
1.0159	35.7639	35.204
1.1134	39.1736	35.184
1.0132	35.6527	35.188

Mean, 35.195 ± 0.0019

This, of course, refers to hydrogen as unity. If $O = 16$, $Cl = 35.463$. Additional determinations, to include the weight of the hydrochloric acid produced, are promised.

These determinations by Dixon and Edgar have the peculiar merit of directness. Chlorine is referred to one of the fundamental standards, without the intervention of any other element, although the method employed is one of great experimental difficulty, and therefore subject to undiscovered errors. On their face, however, the results are entitled to receive very high weight.

The work of Richards and Wells,³ on the other hand, is indirect, at least so far as the atomic weight of chlorine is concerned. In

¹ Compt. rend. 140, 1590.

² Phil. Trans. 205, 169. Series A.

³ This Journal, 27, 459. Original in Publication 28 of the Carnegie Institution.

their research the synthesis of silver chloride was effected, by two distinct processes, and from the data so obtained, the atomic weight of silver being assumed, that of chlorine was calculated.

Some of the syntheses were performed by dissolving silver in nitric acid, precipitating as chloride, and weighing the latter in a Gooch crucible. In other cases the nitrate was converted into chloride in a quartz dish, dried therein, and weighed without transfer of material. All weights, of course, were reduced to a vacuum, and many corrections were carefully determined and applied. The corrected results from two series, are as follows: For details the original memoir must be consulted. The brackets indicate sub-series involving the use of different samples of silver.

PRELIMINARY SERIES.

Weight Ag.	Weight AgCl.	Ratio, 100 Ag : AgCl.
{ 9.06483	12.04365	132.861
{ 8.39217	11.14985	132.860
{ 5.37429	7.14056	132.865
{ 8.08222	10.73869	132.868
{ 7.08517	9.41362	132.864
{ 7.97715	10.59837	132.859
{ 8.11978	10.78767	132.857
{ 8.53452	11.33907	132.861
{ 6.73284	8.94511	132.858
{ 8.91366	11.84240	132.857
{ 9.72295	12.91769	132.858
{ 8.63961	11.47862	132.860
11.13795	14.79849	132.865

Mean, 132.861

FINAL SERIES.

Weight Ag.	Weight AgCl.	Ratio, 100 Ag : AgCl.
{ 7.24427	9.62508	132.865
{ 8.30502	11.03484	132.870
{ 7.29058	9.68676	132.867
{ 8.58472	11.40614	132.866
{ 8.01318	10.64648	132.862
{ 9.77160	12.98335	132.868
{ 7.98170	10.60528	132.870
11.49983	15.27964	132.868
{ 6.25318	8.30834	132.866
{ 7.72479	10.26360	132.866

Mean, 132.867

Stas found, 132.848

From the final series, if $\text{Ag} = 107.92$, $\text{Cl} = 35.470$. If $\text{Ag} = 107.93$, $\text{Cl} = 35.473$. The authors indicate a preference for the lower value for silver. In either case the value for chlorine is higher than the hitherto accepted 35.455; and its adoption will compel many corrections to be made in the general atomic weight table. The research of Richards and Wells is a model of painstaking accuracy.

From the density and critical constants of hydrochloric acid, Guye¹ finds the molecular weight $\text{HCl} = 36.484$, whence $\text{Cl} = 35.476$. A new determination of the density of chlorine gas has lately been published by Treadwell² but not yet applied to the calculation of its molecular weight.

BROMINE.

In his research upon the atomic weight of iodine, Baxter³ made a series of experiments upon the conversion of silver bromide into chloride, by heating in a current of dry chlorine. Vacuum weights are given in the following table, and reduced with $\text{Ag} = 107.93$ and $\text{Cl} = 35.473$.

Weight AgBr.	Weight AgCl.	Atomic weight Br.
10.92091	8.33538	79.955
13.88062	10.59457	79.951
8.21484	6.27006	79.952
7.87887	6.01352	79.956
6.90106	5.26735	79.951
9.53704	7.27926	79.952

Mean, 79.953

This is sensibly identical with the generally accepted value, 79.955.

IODINE.

An important continuation of the research upon iodine, which was reported in 1904, has been published by Baxter.⁴ First, silver iodide was converted into bromide by heating in bromine. The corrected data are as follows:

¹ Compt. rend. 140, 1241.

² Z. anorg. Chem. 47, 446.

³ This Journal, 27, 884.

⁴ Ibid. 27, 876.

Weight AgI.	Weight AgBr.	Atomic weight I.
13.65457	10.92091	126.985
17.35528	13.88062	126.987
9.70100	7.75896	126.982
10.27105	8.21484	126.983
9.85688	7.88351	126.986
8.62870	6.90106	126.991
11.92405	9.53704	126.981
7.56933	6.05389	126.987

Mean, 126.985

Atomic weights calculated with Ag = 107.93, Br = 79.955.

Two new series of determinations were made of the ratio AgI:AgCl. The first of these was upon the weights of iodide given in the foregoing table. That is, the bromide, after weighing, was transformed into chloride.

SERIES II.		
Weight AgI.	Weight AgCl.	Atomic weight I.
13.65457	8.33538	126.985
17.35528	10.59457	126.983
10.27105	6.27006	126.980
8.62870	5.26735	126.985
11.92405	7.27926	126.976

Mean, 126.982

SERIES III.		
Weight AgI.	Weight AgCl.	Atomic weight I.
9.26860	5.65787	126.990
6.72061	4.10259	126.984
11.31825	6.90912	126.987
10.07029	6.14754	126.979
13.49229	8.23649	126.980

Mean, 126.984

Three additional series of measurements relate to the ratio between silver and iodine. In the first one, iodine and silver were weighed separately; the iodine was then converted into hydriodic acid, and precipitated by known quantities of silver.

Weight I.	Weight Ag.	Atomic weight I.
3.29308	2.79897	126.983
3.70132	3.14584	126.988
3.75641	3.19258	126.991
3.24954	2.76186	126.988
4.12541	3.50639	126.984
3.53166	3.00165	126.988
2.99835	2.54842	126.985
2.00015	1.69991	126.993

Mean, 126.987

In five of these experiments the silver iodide was collected and weighed, with the subjoined results.

Weight I.	Weight AgI.	Atomic weight I.
3.75641	6.94913	126.987
3.24954	6.01137	126.989
4.12541	7.63204	126.977
3.53166	6.53351	126.979
2.99835	5.54682	126.983

Mean, 126.983

Finally, in order to determine the ratio Ag:AgI, the filtrate and washings from the previous sets of analyses were examined for the silver they might contain. This gave a small correction to the weights already cited, with results as follows:

Weight Ag.	Weight AgI.	Atomic weight I.
3.19249	6.94877	126.990
2.76175	6.01110	126.986
3.00189	6.53399	126.993
2.54833	5.54659	126.986

Mean, 126.989

The final value, adopted by Baxter, is $I = 126.985$, when $Ag = 107.93$ and $Cl = 35.473$. Vacuum weights are given throughout the memoir. Two short critical papers on iodine, by Ladenburg¹ and Koethner² respectively, have also appeared during the year. They contain no new determinations.

SODIUM.

The determinations of the atomic weight of sodium by Richards and Wells,³ cover the measurement of two ratios. It goes without saying that in all of Richards' work every conceivable precaution is taken, and every correction applied. The data obtained appear in the two following tables:

¹ Ann. 338, 259.

² Ibid. 338, 262.

³ This Journal, 27, 459. Original in Publication 28 of the Carnegie Institution.

RATIO NaCl : AgCl.

Weight NaCl.	Weight AgCl.	Ratio, 100 AgCl : NaCl.
3. 27527	8. 03143	40. 781
5. 56875	13. 65609	40. 779
4. 18052	10. 25176	40. 779
4. 54319	11. 14095	40. 779
1. 97447	4. 84190	40. 778
3. 97442	9. 74547	40. 782
6. 69495	16. 41725	40. 780
2. 88692	7. 07955	40. 778
5. 56991	13. 65833	40. 780
5. 85900	14. 36693	40. 781

Mean, 40. 780

RATIO Ag : NaCl.

Weight NaCl.	Weight Ag.	Ratio, 100 Ag : NaCl.
3. 96051	7. 30896	54. 187
2. 32651	4. 29355	54. 186
5. 36802	9. 90699	54. 184
4. 00548	7. 39210	54. 186
4. 69304	8. 66101	54. 186
3. 27189	6. 03842	54. 185
5. 08685	9. 38795	54. 185
3. 66793	6. 76952	54. 183
5. 48890	10. 12993	54. 185
3. 55943	6. 56909	54. 185

Mean, 54. 185

Two supplementary analyses for fixing the foregoing ratio were made with salt and silver which had both been fused in vacuo.

NaCl.	Ag.	Ratio.
3. 38684	6. 25046	54. 185
4. 68529	8. 64634	54. 188

With Ag = 107.92 and Cl = 35.470 we have for Na, from AgCl ratio, Na = 23.004. From Ag ratio, Na = 23.007. With Ag = 107.93 and Cl = 35.473, Na = 23.008.

POTASSIUM.

Atomic weight redetermined by Archibald,¹ from analyses of the chloride. Two ratios were measured. The data given below represent vacuum weights.

¹ Trans. Roy. Soc. Canada, 1904, Section III, p. 47.

RATIO AgCl : KCl.			
Weight AgCl.	Weight KCl.	Ratio.	Atomic weight K.
4.25916	2.21586	52.028	39.142
3.83250	1.99379	52.023	39.138
5.57396	2.89977	52.025	39.139
9.10362	4.73606	52.026	39.140

RATIO Ag : KCl.			
Weight Ag.	Weight KCl.	Ratio.	Atomic weight K.
3.20598	2.21586	69.116	39.142
2.88479	1.99379	69.114	39.140
4.19557	2.89977	69.115	39.141
6.85280	4.73606	69.111	39.137

In mean, $K = 39.140$, when $Ag = 107.93$ and $Cl = 35.455$. With $Cl = 35.473$ this becomes $K = 39.122$.

CARBON AND GLUCINUM.

Parsons¹ has rediscussed his analyses of the basic acetate and acetylacetonate of glucinum, which were noticed in the report for 1904. Combining the two equations yielded by the two observed ratios, and solving algebraically, the following values were simultaneously determined:

$$Gl = 9.112.$$

$$C = 12.007.$$

From the density and critical constants of CO_2 , Guye² finds $C = 12.003$, and from C_2H_2 , $C = 12.002$. Jaquerod and Perrot,³ by comparing the densities of gases at 1067° , find the molecular weight of CO to be 28.009, and of CO_2 43.992. Hence $C = 12.009$ and 11.992.

Guye and Pintza⁴ have also determined anew the density of carbon dioxide. One liter at normal temperature and pressure weighs—1.97684, 1.97676, 1.97681 grams.

Lord Rayleigh,⁵ studying the compressibility of gases, has deduced several molecular weights from measurements of density at ordinary pressures and very small pressures. The subjoined data refer to carbon monoxide and dioxide, when $O_2 = 32$.

	Atmospheric P.	Very small P.
Carbon monoxide.....	28.000	28.003
Carbon dioxide.....	44.268	44.014

¹ This Journal, 27, 1204.

² Compt. rend. 140, 1241.

³ Ibid. 140, 1542.

⁴ Ibid. 141, 51.

⁵ Phil. Trans. 204, 369.

From the figures in the second column CO—O gives C = 12.003. CO₂—O₂ = 12.014, 2CO₂—CO = 11.992. From the density of hydrogen at very small pressures, H₂ = 2.0173.

STRONTIUM.

In 1894 Richards published his determinations of the atomic weight of strontium, which were based upon analyses of the bromide. A little later he made another set of measurements upon the chloride, which did not accord sufficiently well with the bromide series. The discrepancy is now explained by the discovery that the then accepted value for chlorine was too low, and the actual work upon strontium chloride has proved to be satisfactory. The data now published by Richards¹ are given below. They represent vacuum weights, and refer to Ag = 107.93 and Cl = 35.473.

Weight SrCl ₂ .	Weight Ag.	Ratio, 100 Ag ₂ to SrCl ₂ .
4.2516	5.7864	73.476
2.4019	3.2688	73.480
3.5184	4.7886	73.475
3.0264	4.1189	73.476

Mean, 73.477

Hence Sr = 87.661 as compared with 87.663 from the bromide.

COPPER.

Incidentally to his work on the atomic weight of tellurium, Gallo² made a few electrolytic precipitations of copper in comparison with silver. The corrected data are as follows:

Weight Cu.	Weight Ag.	Atomic weight Cu.
0.21805	0.73937	63.66
0.27153	0.92062	63.65
0.19001	0.64571	63.52
0.39585	1.34578	63.50

Mean, 63.58

CADMIUM.

Baxter and Hines,³ in redetermining the atomic weight of cadmium, have made use of the chloride. Both of the usual ratios were measured, and the corrected data reduced to vacuum weights are given below.

¹ Pr. Am. Acad. 40, 603; Z. anorg. Chem. 47, 145.

² Gazz. Chim. Ital. 35, 261. Atomic weight computed with Ag = 107.93.

³ This Journal, 27, 222.

RATIO CdCl₂ : 2AgCl.

Weight CdCl ₂ .	Weight AgCl.	Atomic weight Cd.
5.53241	8.65356	112.475
7.77758	12.16166	112.471
8.87917	13.88344	112.481
		Mean, 112.476

RATIO CdCl₂ : 2Ag.

Weight CdCl ₂ .	Weight Ag.	Atomic weight Cd.
4.92861	5.80063	112.463
3.86487	4.54891	112.454
5.08551	5.98569	112.451
5.84335	6.87704	112.468
5.99952	7.06084	112.468
3.73092	4.39095	112.467
		Mean, 112.462

The calculations were made with Ag=107.93 and Cl=35.473. Additional data are promised, relative to cadmium bromide. The mean of the two series, as given by Baxter and Hines, is Cd=112.469.

ALUMINUM.

The work of Kohn-Abrest on the atomic weight of aluminum was noticed in the report for 1904. It has since been published in detail.¹ Impure aluminum, but containing known impurities, was dissolved in hydrochloric acid, and the hydrogen evolved was burnt over copper oxide and weighed as water. The following, uncorrected amounts of water were furnished by 100 parts of the metal.

98.08
 98.20
 97.86
 98.10
 98.44
 98.03
 97.98

The mean, corrected for the impurities in the aluminum, is 99.151. Hence Al=27.05 when H=1. With O=16, Al=27.25.

Two additional experiments were made upon the conversion of aluminum into oxide, as follows:

0.3429 Al gave 0.6444 Al₂O₃. Al=27.09.
 0.4168 Al gave 0.7850 Al₂O₃. Al=27.03.

¹ Bull. soc. chim. [3] 33, 121.

The degree of concordance shown by these determinations is not satisfactory; neither were the methods by any means unimpeachable.

SILICON.

The determination of the atomic weight of silicon by W. Becker and J. Meyer,¹ was effected through the conversion of silicon tetrachloride into the dioxide. The chloride was decomposed by ice water, under suitable precautions, which are fully described. After decomposition the mixture was evaporated to dryness, and the silica was ignited and weighed. In a supplementary investigation by Meyer² the possible retention of chlorine by the silica was carefully examined, and that impurity was proved to be absent. The final data, referred to vacuum weights, are given below, as published in the second of the two papers. The atomic weight was computed with $Cl = 35.470$.

Weight $SiCl_4$.	Weight SiO_2 .	Atomic weight Si.
4.16733	1.47597	28.259
4.69585	1.66304	28.253
4.91918	1.74204	28.248
5.37434	1.90349	28.260
5.93985	2.10364	28.254
6.73605	2.38570	28.257
7.16361	2.53606	28.220
7.82779	2.77242	28.259
<hr/>	<hr/>	<hr/>
Sum, 46.82400	16.58236	Mean, 28.251

The value adopted by Meyer is $Si = 28.25$. This is lower than the 28.4 derived from Thorpe and Young's analyses of the bromide.

LEAD.

In an interesting paper upon the lead voltameter, Betts and Kern³ give two series of determinations of the electrochemical equivalent of lead. The metal was deposited in direct electrolytic comparison with silver, from an acid solution of lead fluosilicate. The weights deposited and the corresponding equivalents were as follows, the atomic weight of silver being taken as 107.93.

¹ Z. anorg. Chem. 43, 251.

² Ibid. 47, 45.

³ Trans. Amer. Electrochem. Soc. 6, 67.

FIRST SERIES.		
Weight Ag.	Weight Pb.	Equivalent Pb.
5.8958	5.6221	102.90
5.8958	5.6396	103.24
5.7863	5.5246	103.04
5.7863	5.5450	103.43
7.8408	7.5108	103.39
7.8408	7.5168	103.47
7.6253	7.3191	103.59
7.6253	7.3221	103.62
6.2287	5.9600	103.27
6.2287	5.9605	103.28
16.6804	15.9996	103.52
16.6804	16.0014	103.54
6.8652	6.5815	103.47
6.8652	6.5812	103.46
9.3253	8.9390	103.46
9.3253	8.9419	103.49
6.8566	6.5695	103.41
6.8754	6.5877	103.41

SECOND SERIES.		
Weight Ag.	Weight Pb.	Equivalent Pb.
9.0470	8.6678	103.41
9.0470	8.6663	103.39
13.4113	12.8607	103.49
13.4113	12.8558	103.46
7.2780	6.9716	103.39
7.2780	6.9755	103.44
7.2738	6.9695	103.41
7.2738	6.9698	103.42
6.5278	6.2550	103.42
6.4864	6.2168	103.44

The mean of the determinations in the first series gives an equivalent of 103.39, or $\text{Pb} = 206.78$. From the second series $\text{Pb} = 207.86$. As the object of the investigation was to ascertain the availability of the lead voltameter for exact work, and not to determine an atomic weight, these values cannot be utilized directly. They show, however, some promise, and indicate that the process used might be developed into a good method of determination. The suggestiveness of the data warrants their reproduction here.

TELLURIUM.

The electrochemical equivalent of tellurium has been determined by Gallo,¹ in comparison with silver taken as $\text{Ag} = 107.93$.

¹ Atti Accad. Lincei, [5] 14, 23, 104; Gazz. chim. ital. 35, 245.

Three series of determinations are given, with weights reduced to a vacuum. The data are as follows:

Weight Ag.	Weight Te.	Atomic weight Te.
0.74117	0.218412	127.22
1.03801	0.304514	126.65
0.91704	0.27256	128.30
1.041101	0.307117	127.35
1.09064	0.321952	127.42
1.16302	0.34582	128.16
0.968903	0.28646	127.64
1.518712	0.44767	127.28
0.906561	0.26836	127.76
0.995511	0.29586	128.28
0.86596	0.25656	127.90
1.11282	0.328318	127.44

Mean, 127.617

Although these values are widely variable, the mean approaches closely to the atomic weight as determined by other investigators.

Gutbier's¹ redetermination of the atomic weight of tellurium is based upon the reduction of scrupulously purified tellurium dioxide by two distinct methods. In the first series of experiments the dioxide, mixed with finely divided silver and quartz sand, was reduced by pure hydrogen. In the second series, hydrazine was the reducing agent. The data, with vacuum weights, are as follows:

HYDROGEN SERIES.

Weight TeO ₂ .	Weight Te.	Atomic weight.
2.99688	2.39585	127.55
1.30740	1.04527	127.60
2.04325	1.63380	127.68
2.61725	2.09249	127.59
3.61725	2.89222	127.65

Mean, 127.614

HYDRAZINE SERIES.

Weight TeO ₂ .	Weight Te.	Atomic weight.
1.90601	1.52390	127.62
1.03532	0.82784	127.67
2.2200	1.77480	127.55

Mean, 127.613

¹ Ann. 342, 266.

Gutbier thus reaches the same value for tellurium as Gallo, which may be rounded off to 127.6. This is the value adopted in the international table.

BISMUTH.

In a doctoral dissertation by Lothar Birckenbach,¹ some experiments are described involving the synthesis of bismuth trioxide from the metal, and also the reduction of the oxide to metal. The bismuth was from several distinct sources, and included material received from Classen, whose determinations of this atomic weight were published several years ago.

In the first part of the research, bismuth was oxidized by means of nitric acid, in porcelain crucibles. The oxide was tested for occluded gases, which were proved to be absent, or at least present in only insignificant traces. Three series of determinations are given, representing different samples of bismuth, with the subjoined results.

Weight Bi.	Weight Bi ₂ O ₃ .	Atomic weight.
{ 9.63289	10.74328	208.22
{ 10.41101	11.61288	208.04
{ 10.97914	12.24528	208.11
{ 10.1199	11.2880	208.10
{ 18.96770	21.15541	208.08
{ 11.99601	13.38001	208.01
{ 27.23022	30.37392	207.88
{ 24.9817	27.86431	207.99
{ 10.11284	11.27998	207.94
{ 28.35991	31.63053	208.10

Mean, 208.05

By reduction of bismuth trioxide in a stream of ammonia gas, with precautions which are fully described in the original memoir, the following determinations were made:

Weight Bi ₂ O ₃ .	Weight Bi.	Atomic weight.
{ 1.45827	1.30751	208.14
{ 2.12432	1.90461	208.04
{ 3.0021	2.6918	207.92
{ 2.1012	1.8840	208.17
{ 3.0182	2.70620	208.16
{ 1.9091	1.71171	208.02

Mean, 208.08

¹ Ueber das Atomgewicht des Wismuths. Inaugural-Dissertation, Erlangen, 1905.

Birckenbach concludes, from all the determinations, that $\text{Bi} = 208$ approximately, and not 209 as measured by Classen.

The foregoing investigation was conducted under the direction of Gutbier, who has carried the work still farther. In a preliminary notice Gutbier¹ states that eight analyses of bismuth bromide gave values for Bi ranging from 207.89 to 208.24, in mean 208.05. Additional determinations are being made.

PALLADIUM.

In the elaborate memoir by Amberg² on the atomic weight of palladium, several methods of determination are described; but all relate to analyses of palladosammine chloride, $\text{Pd}(\text{NH}_3\text{Cl})_2$.

First, palladium was precipitated by electrolysis, and the chlorine in the remaining solution was weighed as AgCl . From the following data, the atomic weight A is determined by the proportion of Pd, B by the ratio between the original salt and AgCl .

Weight salt.	Weight Pd.	Weight AgCl .	A.	B.
1.06045	0.53609	107.38
1.00028	0.50528	1.35867	107.28	106.09
1.66386	0.84085	2.25437	107.33	106.59
0.83195	0.42092	1.12282	107.56	107.45
1.91591	0.96886	2.59799	107.44	106.45

In a second series of experiments the palladium was thrown down by hydrazine sulphate; in other respects this series is like the first.

Weight salt.	Per cent. Pd.	Weight AgCl .	Atomic weight.
1.32423	50.12	1.78656	107.52
1.02642	50.29	1.39247	106.35
1.30335	50.36	1.76875	106.28
1.59709	...	2.16641	106.37
1.88622	50.49	2.55028	107.06
2.59665	50.68	3.51783	106.64

From the sum of all the chlorine determinations, $\text{Pd} = 106.67$, when $\text{Ag} = 107.93$, $\text{Cl} = 35.45$, $\text{N} = 14.04$ and $\text{H} = 1.008$. The weights are referred to a vacuum.

In the final series of determinations, palladium was electrolytically precipitated from a sulphuric acid solution of the palladosammine chloride, with the aid of a rotating anode. Twelve analyses were made, with three separate preparations of the chloride, and with the subjoined results:

¹ Z. Elektrochem. 11, 831.

² Ann. 341, 235.

Weight salt.	Weight Pd.	Per cent. Pd.	Atomic weight.
{ 0.62446	0.31470	50.396	106.70
{ 0.83878	0.42280	50.407	106.75
{ 1.50282	0.75725	50.389	106.67
{ 1.06704	0.53753	50.385	106.66
{ 1.98342	0.99971	50.403	106.74
{ 1.53093	0.77153	50.396	106.71
{ 1.18995	0.59971	50.398	106.71
{ 0.62635	0.31572	50.406	106.75
{ 1.76110	0.88739	50.388	106.67
{ 3.79639	1.91298	50.389	106.68
{ 3.97553	2.00333	50.392	106.69
{ 4.62100	2.32834	50.386	106.66
<hr/> Sum, 23.51777	<hr/> 11.85109		<hr/> Mean, 106.699

From the sums of the weights, Pd = 106.688. The probable value, derived from all the data, is put by Amberg at 106.7. If recalculated with the new values for N and Cl, 14.01 and 35.473, the figure for palladium will be changed very slightly. The changes due to N and Cl respectively are in opposite directions, and nearly compensate each other.

THORIUM.

R. J. Meyer and A. Gumperz¹ have investigated the supposed complexity of thorium, and have failed to confirm the results announced by Baskerville. First, about 700 grams of thorium nitrate were separated into seven fractions by precipitation with potassium chromate. The fractions were converted into the octohydrated sulphate, which was then applied to the atomic weight determinations. It was weighed first as hydrate, then as anhydrous salt after heating to 400°, and finally ignited to oxide. The data thus obtained are as follows:

Fraction.	Weight hydrate.	Weight Th(SO ₄) ₂ .	Weight ThO ₂ .	Atomic weight.
I	1.2463	0.9301	0.5793	232.4
I	1.3261	0.9927	0.6184	232.5
IV	1.3910	1.0344	0.6442	232.3
IV	1.2543	0.9349	0.5821	232.2
VII	0.8934	0.6680	0.4160	232.3
VII	...	0.4296	0.2676	232.5

Secondly, thorium tetrachloride was fractionally sublimed in a stream of chlorine, and divided into three portions, namely: 1, the most volatile portion, "berzelium;" 2, the medium portion,

¹ Ber. 38, 817.

“new thorium;” 3, the unsublimed residue, “carolinium.” These converted into sulphate gave the subjoined data.

Fraction.	Weight hydrate.	Weight Th(SO ₄) ₂ .	Weight ThO ₂ .	Atomic weight.
1	1.2573	0.9199	0.5730	232.5
1	1.0424	0.7647	0.4764	232.6
2	...	1.0650	0.6635	232.4
2	1.0387	0.7758	0.4834	232.7
3	1.1904	0.8824	0.5496	232.4
3	0.7487	0.5545	0.3454	232.4

The mean of all is Th = 232.43. No evidence of a breaking up of thorium was observed, and a spectroscopic examination of the products by Eberhard¹ led to the same conclusion. A brief reply to Meyer and Gumperz was published by Baskerville,² in which he urged the importance of observing the exact conditions of his experiments, conditions from which his critics seem to have departed.

The radiothorium described by Ramsay³ and Hahn⁴ should be taken into account in any discussion of the atomic weight of thorium. It was extracted in very small amount from thorianite, and gave about 700,000 times as much emanation as an equal weight of ordinary thoria. Its atomic weight remains to be determined.

METALS OF THE RARE EARTHS.

A considerable number of memoirs upon the rare earths have appeared in the course of the year, with incidental data on the subject of their atomic weights. In only two of them was the determination of atomic weight the principal feature, the paper by Urbain⁵ on gadolinium being the most important. Urbain prepared his material by many fractionations of gadolinium nickel nitrate, and analyzed a number of distinct preparations of the octohydrated gadolinium sulphate. According to Eberhard,⁶ who has studied several rare earths spectroscopically, Urbain's material for samarium, gadolinium and europium was exceedingly good, if not absolutely free from ad-

¹ Ber. 38, 826.

² Ibid. 38, 1444.

³ J. chim. phys. 3, 617.

⁴ Chem. News, 91, 193; 92, 251; Ber. 38, 3371. See also Sackur: Ber. 38, 1756.

⁵ Compt. rend. 40, 583.

⁶ Z. anorg. Chem. 45, 375.

mixtures. Bettendorff's samarium preparation contained other earths.

For gadolinium, Urbain's data are as follows, calculated with $H = 1.007$ and $S = 32.06$.

Fraction.	Weight $Gd_2(SO_4)_3 \cdot 8H_2O$.	Weight Gd_2O_3 .	Atomic weight.
18	1.9256	0.9350	157.35
19	1.9749	0.9589	157.35
19	1.9975	0.9698	157.32
20	2.1083	1.0231	157.15
20	1.8993	0.9214	157.04
21	2.2065	1.0707	157.13
21	1.9535	0.9479	157.12
22	2.2008	1.0685	157.32
22	2.2482	1.0914	157.28
23	2.1932	1.0646	157.25
35	2.0551	0.9974	157.19
36	2.1555	1.0469	157.45
37	2.2277	1.0807	157.04
38	2.2559	1.0946	157.11
39	2.2523	1.0939	157.45

Mean, 157.24

The value adopted by Urbain, from fractions 18 to 23, is $Gd = 157.23$.

The paper by Brill¹ describes an attempt to determine atomic weights on very small quantities of material, by means of the microbalance invented by Nernst. In each case a few milligrams of a sulphate, previously heated to 480° , was ignited to oxide. At 480° acid sulphates were destroyed, and the normal salts were stable. The results obtained may be summarized as follows:

Yt.	Er.	Yb.	La.	Sa.	Nd.
89.7	165.6	173.2	139.5	151.2	141.8
89.5	167.5	172.2	139.8	150.5	143.0

These figures, of course, are only approximations; but they indicate the convenience of the method for the ordinary rough determinations which are needed in the identification of the earths.

Feit and Przibylla,² in an investigation of the monazite earths, made several determinations of atomic weights by a volumetric method. The weighed oxides were dissolved in a known quantity

¹ Z. anorg. Chem. 47, 464.

² Ibid. 43, 202.

of standard sulphuric acid, and the excess of the latter was ascertained by titration, with methyl or ethyl orange as indicator. For lanthanum, in a single experiment, the value 139.0 was found.

For neodymium and samarium the following results were obtained:

Nd.	Sa.
144.51	151.20
144.48	151.25
144.53	151.13

Mean, 144.5

Mean, 151.2

Matignon¹ has found that samarium sulphate, heated to about 1000°, is converted into a stable basic salt, Sm_2SO_6 . He proposes to use this transformation as a means of determining the atomic weight of samarium. In one experiment, 0.7325 gram of $\text{Sm}_2(\text{SO}_4)_3$, calcined, at a dull red heat, gave 0.5335 of the basic compound. Hence $\text{Sm} = 150.6$.

According to Urbain,² in a communication to the Chemical Society of Paris, the following atomic weights are approximately true. Terbium, 159.5; dysprosium, 162-163; holmium, 140. In a later paper³ he assigns the value 159.2 to terbium. For an impure terbium preparation Feit⁴ found the value 158.6. Emma Potratz,⁵ from a preparation of terbium sulphate, found $\text{Tb} = 153.9$, and from another sample 154.2. From the formate she obtained the figure 154, and from the acetate, 153.1. No details are given, but another report is promised in the future.

MISCELLANEOUS NOTES.

From the density and critical constants of sulphur dioxide, Guye⁶ has computed its true molecular weight. $\text{SO}_2 = 64.065$, and therefore $\text{S} = 32.065$. The molecular weight of argon, determined in the same way, is 39.866. Jaquerod and Scheuer,⁷ from the compressibility and density of SO_2 , determine its molecular weight as 64.036, whence $\text{S} = 32.036$. Guthe,⁸ in a paper upon the silver coulometer, has discussed the electrochemical

¹ Compt. rend. 141, 1230.

² Bull. soc. chim. [3] 33, 403.

³ Compt. rend. 141, 521.

⁴ Z. anorg. Chem. 43, 280.

⁵ Chem. News, 92, 3.

⁶ Compt. rend. 140, 1247.

⁷ Ibid. 140, 1384.

⁸ Bull. U. S. Bureau Standards, 1, 349.

equivalent of silver. There is also a memoir by Reuterdahl¹ on electrochemical equivalents and atomic weights.

Makower² has attempted to determine, from their rates of diffusion, the molecular weights of the radium and thorium emanations. For the radium emanation he finds the values 85.5, 97, and 99, assuming the substance to be monatomic. The thorium emanation is but slightly different. Makower suggests that the emanation may fill the vacant place in the periodic table between molybdenum and ruthenium. The atomic weight of radium itself has been discussed by Jones,³ who, from a critical examination of all the evidence, is inclined to favor the higher of the two rival values, namely, $Ra = 258$.

On the calculation of atomic weights, there is an interesting paper by J. Meyer.⁴ An important suggestion by Luther⁵ is to refer combining weights, through the aid of Faraday's law, to the C. G. S. system of units. In this way the question of standards might be settled, and a rational table devised.

FURTHER STUDIES ON THE HYDRATES OF SODIUM THIOSULPHATE.

BY S. W. YOUNG AND W. E. BURKE.

Received December 30, 1905.

INTRODUCTION.

IN A previous paper⁶ we gave an account of some investigations upon the solubility and composition of some of the hydrates of sodium thiosulphate. Since that time we have completed the study of the hydrates there mentioned, and also have discovered and investigated a number of new hydrates. This paper contains the results of this work, as well as a considerable number of observations upon the supercooling, superheating, and transitions of the various substances.

THE VARIOUS HYDRATES, THEIR PREPARATION AND COMPOSITION.

Following is a list of the hydrates of sodium thiosulphate, together with descriptions of the methods of their preparation,

¹ Trans. Amer. Electrochem. Soc. 7, 187.

² Phil. Mag. [9] 9, 56.

³ Am. Ch. J. 34, 467.

⁴ Z. anorg. Chem. 43, 242.

⁵ Z. Elektrochem. 11, 273.

⁶ This Journal, 26, 1413.