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Report of the Committee on Atomic Weights of the American Chemical Society[1]

BY G. E. F. LUNDELL, *Chairman*

The following report covers the period since the material was gathered for the publication of the Thirteenth Report of the Committee on Atomic Weights of the International Union of Chemistry.[1b]

No changes in the present International values are recommended, although the recently determined chemical value for beryllium, which lies closer to that determined by mass spectroscopy than does the present International value, will undoubtedly be considered by the International Committee.

Beryllium.—The present International value of the atomic weight of beryllium, 9.02, was based on the work of Hönigschmid and Birckenbach,[2] who prepared $BeCl_2$ and determined the ratios $BeCl_2:2Ag$ and $BeCl_2:2AgCl$.

TABLE I

THE $BeCl_2$:2Ag:2AgCl RATIOS

$BeCl_2$, g.	Ag, g.	$BeCl_2$: 2Ag	Atomic weight of beryllium	AgCl, g.	$BeCl_2$: 2AgCl	Atomic weight of beryllium
2.88408	7.78546	0.370444	9.013	10.34428	0.278809	9.013
2.54076	6.85874	.370441	9.012	9.11319	.278800	9.011
2.53762	6.85032	.370438	9.012	......	......	...
3.80056	10.25930	.370450	9.014	13.63112	.278815	9.015
2.90081	7.83068	.370442	9.013	10.40441	.278806	9.012
2.99139	8.07517	.370443	9.013	10.72931	.278806	9.012
1.17750	3.17854	.370453	9.015	4.22339	.278804	9.012
1.72431	4.65472	.370443	9.013	6.18478	.278799	9.011
2.67073	7.20949	.370446	9.014	9.57924	.278804	9.012
3.14044	8.47762	.370439	9.012	11.26372	.278810	9.014
2.42884	6.55665	.370439	9.012	8.71142	.278811	9.014
	Average	.370443	9.013		.278807	9.013

Hönigschmid and Johannsen[3] redetermined the above ratios and, in addition, determined $BeBr_2:2Ag$ and $BeBr_2:2AgBr$. The preliminary account of this work was published by Johannsen[4] and was included in the Thirteenth Report of the Committee on Atomic Weights of the International Union of Chemistry.

TABLE II

THE $BeBr_2$:2Ag:2AgBr RATIOS

$BeBr_2$, g.	Ag, g.	$BeBr_2$: 2Ag	Atomic weight of beryllium	AgBr, g.	$BeBr_2$: 2AgBr	Atomic weight of beryllium
6.04443	7.72396	0.782556	9.012	13.44565	0.449545	9.014
5.06497	6.47233	.782557	9.013	11.26685	.449546	9.014
5.20475	6.65090	.782563	9.014	11.57790	.449542	9.012
6.76694	8.64730	.782549	9.011	15.05288	.449545	9.013
3.90179	......	......	...	8.67953	.449539	9.011
5.85796	7.48563	.782561	9.013	13.03109	.449537	9.011
6.92159	8.84482	.782559	9.013	15.39705	.449540	9.012
6.88729	8.80098	.782559	9.013	15.32047	.449548	9.015
9.99740	12.77524	.782561	9.013	22.23902	.449543	9.013
6.27960	8.02453	.782551	9.011	13.96881	.449544	9.013
5.36425	6.85471	.782564	9.014	11.93259	.449546	9.014
	Average	.782558	9.013		.449543	9.013

Average of the two series 9.013 ± 0.0004

The full account of the experiments is now available. In computing the atomic weight of beryllium the values for silver, chlorine and bromine taken were 107.880, 35.457 and 79.916, respectively. The weights reported are corrected to the vacuum standard. The final result, 9.013 ± 0.0004, is slightly lower than that found earlier by Hönigschmid and Birckenbach by analysis of the chloride, 9.018, and agrees closely with the value 9.0126 determined by the mass spectrograph.

Copper.—Duckworth and Hogg[5] determined the abundance ratio Cu^{63}/Cu^{65} to be 2.277 ± 0.017, by measurement of 21 mass spectra. Expressed in percentage the isotopic constitution of copper becomes Cu^{63} = 69.48 ± 0.16 and Cu^{65} = 30.52 ± 0.16. In calculating the chemical atomic weight, Duckworth and Hogg assign a value for the packing fraction of $-8.03 \pm 0.10 \times 10^{-4}$ to

(1) (a) Lundell, *Chem. Eng. News*, **26**, 1619 (1948). (b) See also G. P. Baxter, M. Guichard and R. Whytlaw-Gray, THIS JOURNAL, **69**, 731 (1947).

(2) O. Hönigschmid and L. Birckenbach, *Ber.*, **55B**, 4 (1922).

(3) O. Hönigschmid and Theodor Johannsen, *Z. Naturforschung*, **1**, 650 (1946); *Z. anorg. Chem.*, **253**, 228 (1947).

(4) T. Johannsen, *Naturwissenschaften*, **31**, 592 (1943).

(5) H. E. Duckworth and B. J. Hogg, *Phys. Rev.*, **71**, 212 (1947).

ATOMIC WEIGHTS
1948

	Symbol	Atomic number	Atomic weight		Symbol	Atomic number	Atomic weight
Aluminum	Al	13	26.97	Molybdenum	Mo	42	95.95
Antimony	Sb	51	121.76	Neodymium	Nd	60	144.27
Argon	A	18	39.944	Neon	Ne	10	20.183
Arsenic	As	33	74.91	Nickel	Ni	28	58.69
Barium	Ba	56	137.36	Nitrogen	N	7	14.008
Beryllium	Be	4	9.02	Osmium	Os	76	190.2
Bismuth	Bi	83	209.00	Oxygen	O	8	16.0000
Boron	B	5	10.82	Palladium	Pd	46	106.7
Bromine	Br	35	79.916	Phosphorus	P	15	30.98
Cadmium	Cd	48	112.41	Platinum	Pt	78	195.23
Calcium	Ca	20	40.08	Potassium	K	19	39.096
Carbon	C	6	12.010	Praseodymium	Pr	59	140.92
Cerium	Ce	58	140.13	Protactinium	Pa	91	231
Cesium	Cs	55	132.91	Radium	Ra	88	226.05
Chlorine	Cl	17	35.457	Radon	Rn	86	222
Chromium	Cr	24	52.01	Rhenium	Re	75	186.31
Cobalt	Co	27	58.94	Rhodium	Rh	45	102.91
Columbium	Cb	41	92.91	Rubidium	Rb	37	85.48
Copper	Cu	29	63.54	Ruthenium	Ru	44	101.7
Dysprosium	Dy	66	162.46	Samarium	Sm	62	150.43
Erbium	Er	68	167.2	Scandium	Sc	21	45.10
Europium	Eu	63	152.0	Selenium	Se	34	78.96
Fluorine	F	9	19.00	Silicon	Si	14	28.06
Gadolinium	Gd	64	156.9	Silver	Ag	47	107.880
Gallium	Ga	31	69.72	Sodium	Na	11	22.997
Germanium	Ge	32	72.60	Strontium	Sr	38	87.63
Gold	Au	79	197.2	Sulfur	S	16	32.066
Hafnium	Hf	72	178.6	Tantalum	Ta	73	180.88
Helium	He	2	4.003	Tellurium	Te	52	127.61
Holmium	Ho	67	164.94	Terbium	Tb	65	159.2
Hydrogen	H	1	1.0080	Thallium	Tl	81	204.39
Indium	In	49	114.76	Thorium	Th	90	232.12
Iodine	I	53	126.92	Thulium	Tm	69	169.4
Iridium	Ir	77	193.1	Tin	Sn	50	118.70
Iron	Fe	26	55.85	Titanium	Ti	22	47.90
Krypton	Kr	36	83.7	Tungsten	W	74	183.92
Lanthanum	La	57	138.92	Uranium	U	92	238.07
Lead	Pb	82	207.21	Vanadium	V	23	50.95
Lithium	Li	3	6.940	Xenon	Xe	54	131.3
Lutecium	Lu	71	174.99	Ytterbium	Yb	70	173.04
Magnesium	Mg	12	24.32	Yttrium	Y	39	88.92
Manganese	Mn	25	54.93	Zinc	Zn	30	65.38
Mercury	Hg	80	200.61	Zirconium	Zr	40	91.22

both copper isotopes, and, with the conversion factor 1.000275, obtain 63.542 ± 0.006.

This value is in excellent agreement with the recently determined chemical value, 63.542, reported by Hönigschmid and Johannsen.[6]

The long-standing value of 63.57 was changed to 63.54 in the Thirteenth Report of the Committee on Atomic Weights of the International Union of Chemistry.

A further piece of work along this line is that of Brown and Inghram,[7] who determined the abundance ratios of the copper isotopes in terrestrial copper as 2.236 and 2.234, and in meteoric copper as 2.244. Using the above assigned value for the packing fraction, -8.03×10^{-4}, the calculated atomic weights turn out to be 63.55, a value which agrees more closely with that of Duckworth and Hogg and with that of Hönigschmid and Johannsen than with the former International value.

Iron.—Valley and Anderson[8] determined the abundance ratios of the isotopes of iron of both terrestrial and meteoric origin. No certain differences were found in composition either among the different samples of each of the two

(6) O. Hönigschmid and T. Johanssen, *Naturwissenschaften*, **31**, 548 (1943); *Z. anorg. Chem.*, **252**, 364 (1944).

(7) H. Brown and M. G. Inghram, *Phys. Rev.*, **72**, 347 (1947).

(8) G. E. Valley and H. H. Anderson, THIS JOURNAL, **69**, 1871 (1947).

varieties of material or between the two varieties themselves.

The mass numbers 54, 56, 57 and 58 were found to be in the proportion of 6.33:100.00:2.34:0.32. Expressed in percentage the values are 5.81, 91.75, 2.15 and 0.29. These give a mean mass number of 55.911 for iron. By means of the packing fraction -7.15×10^{-4} and the conversion factor 1.000275, the calculated chemical atomic weight is 55.856. From Nier's[9] isotopic percentages the value 55.851 is obtained.

The International value, 55.85, is based on the chemical analysis of ferric oxide,[10] ferric chloride,[11] and ferrous bromide.[12] These individual values are 55.847, 55.853 and 55.850.

Krypton and Xenon.—Lounsbury, Epstein and Thode[13] determined the isotopic composition of normal krypton and of normal xenon.

TABLE III

ISOTOPIC COMPOSITION OF NORMAL KRYPTON

Mass number	Percentage abundance
78	0.342
80	2.228
82	11.500
83	11.480
84	57.020
86	17.430

TABLE IV

ISOTOPIC COMPOSITION OF NORMAL XENON

Mass number	Percentage abundance
124	0.095
126	0.088
128	1.917
129	26.240
130	4.053
131	21.240
132	26.930
134	10.520
136	8.930

Using a value of -7.2×10^{-4} for the average packing fraction and the conversion factor 1.000275, one can calculate the chemical atomic weight as 83.81. The International value is 83.7.

With an average value of -4.1×10^{-4} for the packing fraction and the convertor 1.000275, one can calculate the chemical atomic weight as 131.31, a value in excellent agreement with the International value of 131.3 (Table IV).

Nitrogen.—Hönigschmid and Johannsen-Gröhling[14] prepared ammonium chloride and ammonium bromide and determined the ratios NH_4Cl:Ag, NH_4Cl:AgCl, NH_4Br:Ag and NH_4Br:AgBr.

In computing the atomic weight of nitrogen the values for silver, chlorine and bromine taken were 107.880, 35.457 and 79.916, respectively. The weights reported are corrected to the vacuum standard. The final value obtained, 14.008, is identical with the present International value.

TABLE V

THE NH_4Cl:Ag:AgCl RATIOS

NH_4Cl, g.	Ag, g.	NH_4Cl: Ag	Atomic weight of nitrogen	AgCl, g.	NH_4Cl: AgCl	Atomic weight of nitrogen
2.43720	4.91484	0.495886	14.007	6.53011	0.373225	14.008
1.59424	3.21502	.495873	14.006	4.27169	.373211	14.006
4.79894	9.67737	.495893	14.008	12.85798	.373227	14.008
2.09251	4.21963	.495899	14.009	5.60635	.373239	14.010
2.40566	4.85111	.495899	14.009	6.44562	.373224	14.008
2.49172	5.02469	.495895	14.008	6.67603	.373234	14.009
	Average	.495891	14.008		.373227	14.008

TABLE VI

THE NH_4Br:Ag:AgBr RATIOS

NH_4Br, g.	Ag, g.	NH_4Br: Ag	Atomic weight of nitrogen	AgCl, g.	NH_4Br: AgCl	Atomic weight of nitrogen
3.10208	3.41637	0.908005	14.008	5.94697	0.521624	14.010
3.14787	3.46681	.908002	14.007	6.03482	.521618	14.010
5.97099	6.57593	.908007	14.008	11.44747	.521599	14.006
8.43856	9.29345	.908012	14.008	16.17833	.521596	14.006
5.66031	6.23378	.908006	14.008	10.85184	.521599	14.006
6.01066	6.61954	.908018	14.009	11.52321	.521613	14.009
6.16085	6.78486	.908029	14.010	11.81130	.521606	14.008
8.70527	9.58719	.908011	14.008	16.68933	.521607	14.008
7.32292	8.06480	.908010	14.008	14.03929	.521602	14.007
5.55243	6.11491	.908015	14.009	10.64485	.521607	14.008
	Average	.908012	14.008		.521606	14.008

Selenium.—The complete account has appeared of the determination of the ratios $SeOCl_2$:2Ag and $SeOCl_2$:2AgCl by Hönigschmid and Görnhardt,[15] which had been briefly reported[16] earlier and included in the Thirteenth Report of the Committee on Atomic Weights of the International Union of Chemistry.

The authors prepared selenyl chloride. In computing the atomic weight of selenium the value for Ag taken was 107.880, and that for Cl, 35.457. The weights reported are corrected to the vacuum standard. The authors consider the value, 78.961, derived from the titrimetric series as being more exact than the value, 78.962, derived from the gravimetric series. The value obtained in these experiments is in good agreement with the value, 78.962, obtained earlier by Hönigschmid and Kapfenberger[17] in the analysis of silver selenide, upon which the present International value

(9) A. O. Nier, *Phys. Rev.*, **55**, 1143 (1939).

(10) G. P. Baxter and C. R. Hoover, THIS JOURNAL, **34**, 1657 (1912).

(11) O. Hönigschmid, L. Birckenbach and R. Zeiss, *Ber.*, **56B**, 1473 (1923).

(12) O. Hönigschmid and Shu Chuan Liang, *Z. anorg. allgem. Chem.*, **241**, 361 (1939).

(13) M. Lounsbury, S. Epstein and H. G. Thode, *Phys. Rev.*, **72**, 517 (1947).

(14) O. Hönigschmid and L. Johannsen-Gröhling, *Z. Naturforschung*, **1**, 656 (1946).

(15) O. Hönigschmid and Luitgard Görnhardt, *Z. Naturforschung*, **1**, 661 (1946).

(16) O. Hönigschmid and L. Görnhardt, *Naturwissenschaften*, **32**, 68 (1944).

(17) O. Hönigschmid and W. Kapfenberger, *Z. anorg. allgem. Chem.*, **212**, 198 (1932).

of 78.96 rests. Mattauch and Flügge[18] report the value from mass spectroscopy as 78.95, and later,[19] in the English edition of "Nuclear Physics," as 78.94.

TABLE VII

THE $SeOCl_2$:2Ag:2AgCl RATIOS

	Titrimetric			Gravimetric		
$SeOCl_2$, g.	Ag, g.	$SeOCl_2$: 2Ag	Atomic weight of selenium	AgCl, g.	$SeOCl_2$: 2AgCl	Atomic weight of selenium
3.88093	.....	......	....	6.70714	0.578627	78.963
3.91475	5.09206	0.768795	78.961	6.76573	.578615	78.960
3.63360	4.72643	.768783	78.959	6.27987	.578611	78.959
3.81769	4.96600	.768766	78.955	6.59818	.578598	78.955
3.46312	4.50439	.768832	78.969	5.98480	.578653	78.971
3.19867	4.16051	.768820	78.967	5.52788	.578645	78.969
4.15394	5.40331	.768777	78.957	7.17916	.578611	78.959
4.46080	5.80239	.768787	78.960	7.70920	.578633	78.965
6.00116	7.80602	.768786	78.959	10.37136	.578628	78.964
5.39786	7.02111	.768804	78.963	9.32870	.578629	78.964
4.05741	5.27781	.768768	78.955	7.01231	.578613	78.959
4.65053	6.04910	.768797	78.962	8.03731	.578618	78.961
4.53967	5.90490	.768797	78.962	7.84567	.578621	78.962
4.59714	5.97953	.768813	78.965	7.94479	.578636	78.966
2.27775	2.96277	.768791	78.960	3.93648	.578626	78.963
	Average	.768794	78.961		.578624	78.962

Tungsten, Silicon and Boron.—Inghram[20] determined the isotopic constitution of tungsten, of silicon and of boron. Five isotopes of tungsten were observed at masses 180, 182, 183, 184 and 186, with abundances of 0.122, 25.77, 14.24, 30.68 and 29.17%, respectively. Using Dempster's[21] value of $+1.8 \times 10^{-4}$ for the packing fraction of tungsten and the conversion factor 1.000275, the calculated chemical atomic weight is 183.89, which compares favorably with the chemically determined value of 183.92.

Three isotopes of silicon were observed at masses 28, 29 and 30, with abundances of 92.28, 4.67 and 3.05%, respectively. Calculating the chemical atomic weight, using the packing fractions -4.86×10^{-4}, -4.54×10^{-4} and -5.68×10^{-4} for the masses 28, 29 and 30, respectively, as given by Pollard,[22] and the conversion factor 1.000275, the value 28.086 was obtained, which is in good agreement with the chemically determined value of 28.06.

Two isotopes of boron were observed at masses 10 and 11, with abundances of 18.83 and 81.17%, respectively. Using the packing fraction $+16.3 \times 10^{-4}$ for mass 10 and $+11.8 \times 10^{-4}$ for mass 11, as determined by Bainbridge[23] and the conversion factor 1.000275, the calculated value of 10.821 was obtained, which is in good agreement with the chemically determined value of 10.82.

The chairman wishes to acknowledge the valuable aid given by Raleigh Gilchrist in the preparation of this report.

(18) Mattauch and Flügge, *Ber.*, **76**, 1 (1943).

(19) J. Mattauch and S. Flügge, "Nuclear Physics Tables and an Introduction to Nuclear Physics," Interscience Publishers, Inc., New York, N. Y., 1946.

(20) M. G. Inghram, *Phys. Rev.*, **70**, 653 (1946).

(21) A. J. Dempster, *Phys. Rev.*, **53**, 869 (1938).

(22) E. Pollard, *Phys. Rev.*, **57**, 1186 (1940).

(23) K. T. Bainbridge, *Phys. Rev.*, **51**, 385 (1937).

[CONTRIBUTION FROM THE WARTIME METALLURGICAL LABORATORY, UNIVERSITY OF CHICAGO]

The First Isolation of Element 93 in Pure Compounds and a Determination of the Half-life of $_{93}Np^{237}$

BY L. B. MAGNUSSON[1a] AND T. J. LACHAPELLE[1b]

Wahl and Seaborg,[2] who first detected the α-particles from $_{93}Np^{237}$ in April, 1942, found a value of 3×10^6 years, considered to be accurate within a factor of two, for the half-life of the isotope by measuring the ratio of seven-day U^{237} activity to that of its daughter, Np^{237}. The corresponding specific counting rate of 500 α-particle counts minute^{-1} microgram^{-1} in the 50% geometry α-particle counter was used in subsequent determinations of mass by radiometric assay. A more precise and corroborating value for the half-life was desired for accurate standardization of the radiometric method of mass determination and because of the fundamental importance of this constant. The method of direct weighing on the ultramicro scale of a neptunium compound and measurement of its disintegration rate by α-particle emission was first attempted by Cunningham and Werner,[3] and Cunningham[4] who, it now appears, had available such extremely small amounts that isolation of the pure material was not feasible. Cunningham found a value for the half-life of 6×10^6 years. The purity and composition of the materials isolated were unknown. The work reported in this paper culminated in the preparation and identification for the first time of two pure compounds of neptunium in June and July, 1944.

As part of the Manhattan Project program of research, a more accurate and detailed knowledge of the chemistry of neptunium was needed than

(1a) Present address: Department of Chemistry and Radiation Laboratory, University of California, Berkeley, California.

(1b) Present address: Department of Chemistry, University of California, Los Angeles, California.

(2) A. C. Wahl and G. T. Seaborg, *Plutonium Project Record*, Vol. XIVB, No. 1.5 (1948) (to be issued); *Phys. Rev.*, **73**, 940 (1948) (written on April 14, 1942).

(3) B. B. Cunningham and L. B. Werner, Manhattan Project Report CN-556 (March 31, 1943).

(4) B. B. Cunningham, Manhattan Project Report CN-991 (October 9, 1943).