Eleventh Report of the Committee on Atomic Weights of the International Union of Chemistry

BY G. P. BAXTER (*Chairman*), M. GUICHARD, O. HÖNIGSCHMID AND R. WHYTLAW-GRAY

The following report of the Committee covers the twelve-month period, September 30, 1939 to September 30, 1940.[1] Only one change in the table of atomic weights has been adopted, in the case of holmium from 163.5 to 164.94.

Carbon and Sulfur.—Moles, Toral and Escribano,[2] have redetermined the limiting densities of oxygen, ethylene, carbon dioxide, sulfur dioxide and hydrogen sulfide using an improved volumeter, in which the globes held more than two liters each. The gases were chemically purified and dried, and finally fractionally distilled or sublimed (carbon dioxide). In the following tables the corrected values of Density/Pressure are given. Adsorption corrections, as determined by Crespi, have been applied.

THURINGIAN GLASS GLOBES

	$P = 1$ atm.	$P = 0.75$ atm.	$P = 0.67$ atm.	$P = 0.50$ atm.	$P = 0.33$ atm.	$P = 0.25$ atm.
			Oxygen			
	1.42895	1.42856	1.42856	1.42829	1.42810	1.42802
	1.42898	1.42860	1.42855	1.42829	1.42802	1.42789
	1.42895	1.42864	1.42840	1.42828	1.42800	1.42802
	1.42894	1.42859	1.42854	1.42830	1.42806	1.42792
	1.42892			1.42826		1.42801
						1.42792
Av.	1.42895	1.42860	1.42851	1.42828	1.42805	1.42796
			Ethylene			
	1.26037	1.25807	1.25732	1.25582	1.25431	1.25341
	1.26035	1.25809	1.25730	1.25572	1.25420	1.25350
	1.26041	1.25810	1.25730	1.25577	1.25425	1.25358
	1.26033	1.25809	1.25732	1.25579	1.25433	1.25346
	1.26033	1.25805	1.25730	1.25571	1.25429	1.25351
	1.26036	1.25804	1.25733	1.25583	1.25430	1.25349
				1.25578		1.25344
				1.25586		1.25363
				1.25574		
Av.	1.26036	1.25807	1.25731	1.25578	1.25428	1.25350
			Sulfur Dioxide			
	2.92658		2.90377	2.89233	2.88090	2.87515
	2.92654		2.90362	2.89226	2.88085	2.87518
	2.92652		2.90357	2.89230	2.88069	2.87513
	2.92654		2.90379	2.89220	2.88070	2.87497
	2.92653		2.90367	2.89223	2.88083	2.87498
	2.92659		2.90374	2.89231	2.88083	2.87522
	2.92653		2.90367	2.89227	2.88084	
					2.88080	
Av.	2.92655		2.90369	2.89227	2.88081	2.87511

JENA GLASS GLOBES

	Oxygen		Carbon Dioxide		Sulfur Dioxide	
	$P = 1$ atm.	$P = 0.5$ atm.	$P = 1$ atm.	$P = 0.5$ atm.	$P = 1$ atm.	$P = 0.5$ atm.
	1.429000	1.42832	1.976896	1.97016	2.92658	2.89229
	1.428937	1.42829	1.97695	1.97011	2.92657	2.89233
	1.428963	1.42828	1.976935	1.97015	2.92654	2.89227
	1.428921	1.42830	1.97694	1.97013	2.92652	2.89234
	1.428952	1.42828	1.97695	1.97011	2.92656	2.89237
	1.428910	1.42828	1.97693	1.97016	2.92654	2.89226
	1.428916	1.42831	1.97694	1.97014	2.92654	2.89230
	1.428943	Av.	1.97693	1.97014	2.92655	2.89231
	1.428954					
Av.	1.428944	1.42829				

Hydrogen sulfide was investigated by Regnault's globe method.

Hydrogen Sulfide

	$P = 1$ atm.		$P = 0.5$ atm.	
	Globe I	Globe II	Globe I	Globe II
	1.53854			1.52948
	1.53836	1.53843	1.52935	1.52941
	1.53833	1.53832	1.52949	1.52936
	1.53834	1.53851	1.52942	1.52934
	1.53837	1.53849	1.52942	1.52944
	1.53843	1.53841		
	1.53846	1.53834		
	1.53843	1.53840		
		1.53848		
	1.53843	1.53850		
	1.53849	1.53848		
Av.	1.53842	1.53844	1.52942	1.52941
	1.53843		1.52941	

The following equations have been derived for Density/Pressure values.

Oxygen	$D/P = 1.427619 + 0.0001326P$
Ethylene	$D/P = 1.251223 + .009134P$
Sulfur dioxide	$D/P = 2.857957 + .068593P$

These and the data for carbon dioxide and hydrogen sulfide give the following molecular and atomic weights.

	Mol. wt.	At. wt. C	At. wt. S
Ethylene	28.046	12.007	
Sulfur dioxide	64.061		32.061
Carbon dioxide	44.008	12.008	
Hydrogen sulfide	34.079		32.063

Phosphorus.—Hönigschmid and Hirschbold-Wittner[3] have compared phosphorus oxybromide with silver. The oxybromide was prepared by refluxing the pentabromide with phosphorus pentoxide. After distillation, in order to remove tribromide the material was again refluxed with

(1) Authors of papers bearing on the subject are requested to send copies to each of the four members of the Committee at the earliest possible moment: Prof. G. P. Baxter, Coolidge Laboratory, Harvard University, Cambridge, Mass., U. S. A.; Prof. M. Guichard, Faculté des Sciences, Sorbonne, Paris, France; Prof. O. Hönigschmid, Sofienstrasse 9/2, Munich, Germany; Prof. R. Whytlaw-Gray, University of Leeds, Leeds, England.

(2) Moles, Toral and Escribano, *Trans. Faraday Soc.*, **35**, 1439 (1939).

(3) Hönigschmid and Hirschbold-Wittner, *Z. anorg. allgem. Chem.*, **243**, 355 (1940).

THE ATOMIC WEIGHT OF PHOSPHORUS

Fraction	$POBr_3$, g.	Ag, g.	$POBr_3$:3Ag	At. wt., P	AgBr, g.	$POBr_3$:3AgBr	At. wt., P
V	5.54550	6.25967	0.885909	30.968	10.89645	0.508927	30.975
	5.16219	5.82671	.885928	30.974			
	5.30583	5.98897	.885934	30.976			
		Average	.885924	30.973		.508927	30.975
H	4.70003	5.30521	.885927	30.974	9.23529	.508921	30.972
H	4.46732	5.04259	.885918	30.971	8.77784	.508932	30.978
H	4.58384	5.17404	.885931	30.975	9.00649	.508949	30.988
		Average	.885925	30.973		.508934	30.979
M	4.64994	5.24880	.885905	30.967	9.13691	.508918	30.970
M	5.20581				10.22916	.508919	30.971
M	5.45761	6.16028	.885935	30.976	10.72369	.508930	30.977
M	5.07426	5.72777	.885905	30.966	9.97123	.508890	30.955
M	6.31287	7.12578	.885920	30.971	12.40460	.508914	30.968
		Average	.885916	30.970		.508914	30.968
M	5.83139	6.58233	.885916	30.970	11.45824	.508925	30.974
M	6.43986	7.26901	.885934	30.976	12.65365	.508933	30.979
M	5.70576	6.44029	.885948	30.980	11.21107	.508940	30.983
M	5.70714	6.44202	.885924	30.972	11.21406	.508927	30.975
M	5.31468	5.99898	.885931	30.975	10.44279	.508933	30.979
		Average	.885931	30.975		.508932	30.978
E	5.07335	5.72633	.885969	30.987	9.96817	.508955	30.991
E	5.05071	5.70099	.885936	30.976	9.92415	.508931	30.978
E	5.95421	6.72069	.885952	30.982	11.69909	.508946	30.986
		Average	.885952	30.982		.508944	30.985
		Average of all	.885929	30.974		.508930	30.976
	Average, omitting Fraction E		.885924	30.973		.508925	30.975

bromine and pentoxide. It was then fractionally distilled many times in an exhausted all-glass system and fractions for analysis were collected in sealed glass bulbs. After six distillations with rejection of substantial light fractions the main portion was divided into light (H), middle (M and M_1) and heavy (E) fractions. The light fractions rejected earlier were combined and fractionated and the heavy fraction (V) was analyzed.

The bulbs were weighed in air and under water, broken under ammonia, and the glass was collected for weighing. After acidification of the solution it was compared with weighed quantities of pure silver by the usual nephelometric process. Finally the silver bromide was collected and weighed. Weights are corrected to vacuum.

Since sample E appears to be slightly different in composition from the others the authors prefer the average obtained with the other four samples, 30.974. This value is slightly lower than that found recently by Hönigschmid and Menn (30.978) by analysis of the oxychloride but the authors feel that the latter value is more reliable.

Potassium.—Baxter and Harrington[4] have compared potassium chloride with silver. Purification of the potassium salt consisted in crystallization of the chlorate, perchlorate and chloride. Fusion in an atmosphere of hydrogen containing hydrogen chloride preceded the weighing of the salt. The comparison with silver followed conventional nephelometric technique. Vacuum weights are given.

THE ATOMIC WEIGHT OF POTASSIUM

KCl, g.	Ag, g.	Ratio KCl:Ag	Atomic weight of K
4.88482	7.06819	0.691099	39.099
4.08265	5.90751	.691094	39.098
8.52040	12.32907	.691082	39.097
8.62997	12.48749	.691089	39.098
8.77749	12.70096	.691089	39.098
	Average	.691085	39.098

Iodine.—Baxter and Kelley[5] by displacement of liquids have found the following values for the specific gravity of iodine pentoxide

	Density I_2O_5 25°/4°
Xylene	4.907
Mesitylene	4.905
Kerosene	4.952
Chlorobenzene	4.980

All of these values are lower than that recently found by Moles and Villan but higher than the older value found by Baxter and Tilley. Of the

(4) Baxter and Harrington, THIS JOURNAL, 62, 1836 (1940).

(5) Baxter and Kelley, *ibid.*, 62, 1824 (1940).

above values that found with chlorobenzene is preferred. By displacement of air the value 4.98 was found.

to silver bromide and weighed before conversion to chloride.

Vacuum weights are given in the following table.

THE ATOMIC WEIGHT OF IODINE

Sample Ag	I_2	AgI, g.	AgCl, g.	Ratio AgI:AgCl	At. wt. of iodine	AgBr, g.	Ratio AgI:AgBr	At. wt. of iodine
B	I	19.29812	11.78127	1.638033	126.911			
B	I	18.56636	11.33416	1.638089	126.919			
B	I	17.61333	10.75259	1.638055	126.914			
B	I	17.28888	10.55452	1.638055	126.914			
A	II	24.77025	15.12167	1.628063	126.915	19.81186	1.250274	126.916
A	II	26.53177	16.19680	1.638087	126.918	21.22030	1.250301	126.922
A	III	27.13226	16.56361	1.638064	126.915			
A	III	26.72367	16.31365	1.638117	126.923			
A	III	23.26211	14.20115	1.638044	126.912			
A	III	24.35477	14.86829	1.638034	126.911			
A	III	23.82804	14.54653	1.638057	126.914			
A	III	23.54677	14.37480	1.638059	126.914			
			Average	1.638062	126.915		1.250288	126.919

THE ATOMIC WEIGHT OF BROMINE

AgBr, g.	AgCl, g.	Ratio AgBr:AgCl	At. wt. of bromine
19.81186	15.12167	1.310163	79.915
21.22030	16.19680	1.310154	79.914

Since with the use of this value no correction for air adsorption (0.001%) is necessary but the vacuum correction is 0.001 smaller, the weights of iodine pentoxide given by Baxter and others in various recent investigations need no correction, in contradiction to the claim of Moles (see Report of this Committee for 1938).

Baxter and Titus[6] have redetermined the ratio of silver iodide to silver chloride by heating the former substance in chlorine in a special quartz weighing tube. Silver was purified by (A) crystallization of silver nitrate, reduction, and fusion on lime and (B) precipitation as chloride and as metal, electrolytic transport, and fusion. Iodine was purified (I and II) by distillation from potassium iodide and sublimation in air over hot platinum, (III) by crystallization as iodic acid, decomposition and sublimation. To prepare silver iodide, a solution of the silver in nitric acid was added to a solution of hydriodic acid made by dissolving iodine in distilled hydrazine. The silver iodide was prepared for weighing by heating to fusion in the quartz reaction tube in a stream of air laden with iodine and then in pure air. After being weighed the salt was heated, at first gently, later more strongly until fused in a current of chlorine, and then in air to displace the chlorine. Prolonged heating of silver iodide in air was found to induce slight decomposition. In two experiments the silver iodide was converted

(6) Baxter and Titus, THIS JOURNAL, 62, 1826 (1940).

Baxter and Lundstedt[7] have determined the ratio of silver to silver iodide and of silver iodide to silver chloride. Silver was purified by (A) three electrolyses with a dissolving anode, (B) an additional electrolysis of A and (C) an additional electrolysis of B. Spectroscopically these three specimens appeared identical although the residual electrolytes proved to contain small but diminishing proportions of impurities. Sample D was purified by crystallization of silver nitrate, reduction with formate and one electrolytic transport; Sample E by precipitation as chloride, reduction with formate and one electrolytic transport. All five samples were finally fused in hydrogen on a pure lime support. Quantitative synthesis of silver chloride much as with the iodide gave the following results (vacuum weights).

THE ATOMIC WEIGHT OF CHLORINE

Sample of Ag	Ag, g.	AgCl, g.	Ag:AgCl	Atomic wt. of Cl
A	9.00350	11.96264	0.752635	35.457
B	10.40823	13.82954	.752609	35.461
D	8.99809	11.95549	.752632	35.457

Iodine was purified as follows: Sample I, three distillations from aqueous potassium iodide, made from a portion of the partially purified material in each case, and distillation in a current of oxygen over red hot platinum; Sample II, decomposition of sodium iodate, made from recrystallized iodic acid, and distillation with steam.

(7) Baxter and Lundstedt, *ibid.*, 62, 1829 (1940).

Weighed quantities of silver were dissolved in nitric acid and precipitated with an excess of iodide made by reduction of iodine with hydrazine. The precipitate was washed with dilute nitric acid, and collected on a weighed platinum sponge crucible. After being weighed it was transferred to a special quartz weighing vessel and the change in weight on fusion in iodine was found. The filtrate and washings were evaporated and the dissolved silver iodide recovered. Weights are corrected to the vacuum standard.

THE ATOMIC WEIGHT OF IODINE

Sample of Ag	Sample of I	Ag, g.	AgI, g.	Ratio I:Ag	Atomic wt. of I
A	I	9.11927	19.84738	1.176422	126.9124
A	I	10.48742	22.82508	1.176425	126.9127
A	II	10.14331	22.07589	1.176399	126.9099
A	II	9.00775	19.60483	1.176440	126.9143
D	II	9.53995	20.76333	1.176461	126.9166
D	I	9.78621	21.29919	1.176449	126.9153
B	II	9.04011	19.67510	1.176423	126.9125
B	I	9.99801	21.76008	1.176441	126.9144
A	II	9.14163	19.89601	1.176418	126.9120
B	II	10.00740	21.78024	1.176413	126.9114
D	I	10.47710	22.80288	1.176450	126.9154
B	I	9.52800	20.73713	1.176441	126.9144
C	I	9.89577	21.53744	1.176429	126.9132
C	I	10.47841	22.80542	1.176420	126.9122
C	I	10.44012	22.72226	1.176437	126.9140
E	I	8.47813	18.45227	1.176455	126.9160
			Average	1.176433	126.9135

The weighed silver iodide obtained in many of the experiments was converted to silver chloride as in the foregoing experiments of Baxter and Titus.

THE ATOMIC WEIGHT OF IODINE

AgI : AgCl

AgI, g.	AgCl, g.	Ratio AgI:AgCl	Atomic wt. of I
21.24430	12.96904	1.638078	126.917
21.70430	13.24993	1.638069	126.916
19.80231	12.08877	1.638075	126.917
21.61515	13.19557	1.638061	126.915
22.69504	13.85480	1.638063	126.915
20.61686	12.58599	1.638080	126.917
21.28690	12.99508	1.638073	126.916
22.65326	13.82927	1.638066	126.915
22.47202	13.71853	1.638078	126.917
18.19991	11.11055	1.638075	126.917
	Average	1.638071	126.916

If the mean of all the silver iodide syntheses, 126.913(5), is combined with the mean of all the above silver iodide–silver chloride conversions, 126.915(6), the average value 126.914 is obtained. With the conversion factor 1.000275 this atomic weight yields the packing fraction -3.9×10^{-4}, while mass spectrograph data seem to indicate a value slightly larger than -4×10^{-4}.

Combination of recent experimental ratios involving iodine pentoxide yields values tending to support the above average.

Assumed		At. wt. I
O = 16.0000	$2Ag/I_2O_5$ = 0.646236 and Ag/I = 0.849904	126.920
O = 16.0000	$6AsCl_3/I_2O_5$ = 3.25818 and $AsCl_3/I_2$ = 0.714191	126.905
Ag = 107.880	$6AsCl_3/I_2O_5$ = 3.25818 and $AsCl_3/3Ag$ = 0.560128	126.915
Ag = 107.880	$AsCl_3/I_2$ = 0.714191 and $AsCl_3/3Ag$ = 0.560128	126.913
Ag = 107.880	I_2O_5/Na_2CO_3 = 3.14950 and $2Ag/Na_2CO_3$ = 2.03556	126.916
	Average	126.914

Cesium.—Baxter and Harrington[8] have compared cesium chloride with silver. Nearly pure cesium nitrate remaining from an earlier investigation (Baxter and Thomas) was fractionally crystallized through twenty series with occasional rejection of the most soluble fraction until rubidium and potassium could not be detected spectroscopically in the most soluble fraction. The three least soluble fractions of the twentieth series were combined and precipitated as perchlorate, and this salt was crystallized three times in platinum vessels. Conversion to chloride by thermal decomposition in platinum followed, and the chloride was crystallized four times in platinum in the presence of a small quantity of hydrazine to prevent attack of the platinum. The purified salt was prepared for weighing by drying and fusion in a platinum boat in an atmosphere of dry hydrogen and hydrogen chloride.

THE ATOMIC WEIGHT OF CESIUM

CsCl, g.	Ag, g.	Ratio CsCl:Ag	Atomic wt. of cesium
15.73190	10.08001	1.560703	132.912
17.98374	11.52285	1.560702	132.912
11.62978	7.45177	1.560674	132.909
18.23097	11.68119	1.560712	132.913
16.45522	10.54340	1.560713	132.913
14.74725	9.44889	1.560739	132.916
17.06711	10.93545	1.560714	132.913
15.19052	9.73300	1.560723	132.914
17.58470	11.26723	1.560694	132.911
18.32957	11.74473	1.560663	132.907
16.59433	10.63256	1.560709	132.912
17.53781	11.23671	1.560760	132.918
	Average	1.560709	132.912(5)

(8) Baxter and Harrington, THIS JOURNAL, 62, 1834 (1940).

After being weighed, the salt was dissolved and compared with weighed quantities of silver in the usual way, with the aid of a nephelometer. Tests showed the fused salt to be neutral and free from hydrazine and ammonia. Weights are corrected to vacuum.

With the conversion factor 1.000275, the packing fraction of cesium is calculated to be -3.79×10^{-4}, which compares favorably with the physical values -3.8×10^{-4} (Dempster), -4.0×10^{-4} (Hahn, Flügge and Mattauch) and -3.8×10^{-4} (Aston).

Holmium.—Hönigschmid and Hirschbold-Wittner[9] have analyzed holmium chloride by comparison with silver. The holmium material had been purified by Feit[10] by fractionation as bromate and as basic nitrate. X-Ray analysis by Noddack showed the following atom per cent. of rare earth impurity: yttrium, 0.013; erbium, 0.04; dysprosium, 0.03; other rare earths, 0.02. After repeated precipitation of the hydroxide and oxalate, the chloride was prepared by solution of the oxide in hydrochloric acid and the chloride was twice precipitated by saturating the aqueous solution with hydrogen chloride. Drying was effected by gradually heating the chloride, ultimately to fusion, in a current of hydrogen chloride. Comparison with silver in the usual way with a nephelometer followed and the silver chloride was collected. Weights are corrected to vacuum.

THE ATOMIC WEIGHT OF HOLMIUM

$HoCl_3$, g.	Ag, g.	$HoCl_3$:3Ag	At. wt. Ho	AgCl, g.	$HoCl_3$:3AgCl	At. wt. Ho
2.20620				3.49683	0.63092	164.929
2.16354	2.58091	0.83829	164.932	3.42918	.63092	164.932
2.22679	2.65622	.83833	164.946	3.52933	.63094	164.940
1.44966	1.72930	.83829	164.934	2.29770	.63092	164.931
3.18194	3.79581	.83828	164.929	5.04342	.63091	164.927
4.74923	5.66553	.83827	164.926	7.52767	.63090	164.924
	Average	.83829	164.933		.63092	164.930

Correction for the yttrium content raises the experimental average to 164.94. Since holmium appears to be a simple element the atomic weight may be computed from the mass number with the use of the conversion factor and the packing fraction -0.8×10^{-4}. The physical value 164.94 thus agrees exactly with the above value, and is adopted for the table.

Hartley, Henry and Whytlaw-Gray[11] have measured experimentally the adsorption of certain gases on fused silica surfaces, and find this to be only a small fraction of that on glass surfaces. In the following table are given the values in ml. $\times 10^{-6}$ per cm.^{2} at 760 mm. and 21°.

	ml. $\times 10^{-6}$/sq. cm.	Per cent. monomolecular layer
SO_2	11.0	50
N_2O	1.61	
C_2H_4	1.51	
CO_2	1.44	6
N_2	0.74	
CO	0.44	
A	0.42	
O_2	0.20	0.7

Even with sulfur dioxide the effect upon the measurements with a micro displacement balance with uncompensated bulb of 1.7 ml. is only 1×10^{-5}, and of course disappears if the two arms of the balance expose equal surfaces.

Bloom due to condensed silica vapor during the construction of the silica apparatus was found to increase the quantity of adsorbed gas to many times its value on clean surfaces.

Attention is called to the marked discrepancies between several chemical values in the atomic weight table and the corresponding values based on mass-spectrographic evidence. In most of these cases the element is simple so far as is known so that the atomic weight cannot be far from the mass number. Although it seems unlikely that new physical evidence will alter the mass spectrographic values materially the Committee hesitates to change the values in the table at the present time. The packing fractions used below are taken from the table of Hahn, Flügge and Mattauch (*Ber.*, **73A**, 1 (1940)), while the value 1.000275 is used for the conversion factor.

Scandium.—Simple element, packing fraction -6.9×10^{-4}, physical atomic weight 44.96.

Terbium.—Simple element, packing fraction -1.4×10^{-4}, physical atomic weight 158.93.

(9) Hönigschmid and Hirschbold-Wittner, *Z. anorg. allgem. Chem.*, **244**, 63 (1940).

(10) Feit, *ibid.*, **243**, 276 (1940).

(11) Hartley, Henry and Whytlaw-Gray, *Trans. Faraday Soc.*, **35**, 1452 (1939).

INTERNATIONAL ATOMIC WEIGHTS

1941

	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	63.57	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	32.06
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

Thulium.—Simple element, packing fraction -0.4×10^{-4}, physical atomic weight 168.95.

Iridium.—Abundance ratio $Ir^{191}/Ir^{193} = 38.5/61.5$, packing fraction $+2.1 \times 10^{-4}$, physical atomic weight 192.22. In this case the chemical atomic weight 193.1 appear to be impossible.

Gold.—Simple element, packing fraction $+2.0 \times 10^{-4}$, physical atomic weight 196.99.

Hönigschmid[12] reviews the determinations of atomic weights carried out during the past thirty years in his laboratory at Munich.

(12) Hönigschmid, *Angew. Chem.*, **53**, 177 (1940).