JOURNAL OF THE
AMERICAN CHEMICAL SOCIETY

VOLUME 65 AUGUST 9, 1943 NUMBER 8

Report of the Committee on Atomic Weights of the American Chemical Society

BY GREGORY P. BAXTER

Owing to difficulties of communication it has not been possible to publish a report of the International Committee on Atomic Weights since March, 1941. The following report for which the author is solely responsible covers the period since September, 1940. No changes have been made in the International Table of Atomic Weights for 1941, although the new values for samarium and ytterbium appear to be more reliable than those given in the table.

Carbon.—Murphy and Nier[1] have determined with a mass spectrometer the abundance ratio of C^{12} to C^{13} in carbon from different sources to fall between 88.8 and 93.1, corresponding to the values 12.0117 and 12.0112 for the atomic weight of carbon. Both values support the existing chemical evidence that the atomic weight of carbon is very close to 12.01.

Oxygen.—Murphy[2] with a mass spectrometer finds the abundance ratio of O^{16} to that of O^{18} to be 500 ± 15 to 1. This confirms the value of Smythe, 503 ± 10, and the conversion factor 1.000275.

Fluorine.—Hutchison and Johnston[3] have computed the atomic weight of fluorine from density and crystal data of lithium fluoride and calcite, using the equation

$$\mathrm{LiF} = \left[\frac{\mathrm{CaCO_3} \times d_{\mathrm{LiF}}}{d_{\mathrm{calcite}} \times \phi_{\mathrm{calcite}}} \times R^3\right]$$

where ϕ_{calcite} denotes the volume of a calcite cleavage rhombohedron for which the distance between opposite faces is unity and R denotes the ratio between the true grating spaces for lithium fluoride and calcite. The following data (20°)

d_{LiF}	2.64030 g./cc.
d_{calcite}	2.71030 g./cc.
ϕ_{calcite}	1.09594
R	0.663045
Ca	40.075
Li	6.939
C	12.010

yield 18.994 for fluorine. If the atomic weight of calcium found by Hönigschmid and Kempter 40.085, is used, fluorine becomes 18.996.

Zinc.—Hönigschmid and v. Mack[4] have compared zinc chloride with silver. The zinc chloride was prepared by the action of hydrogen chloride on metal which had been purified by distillation in high vacuum and had been found by Gerlach by optical spectroscopy to be free from all metallic impurities. Further purification by two distillations in hydrogen chloride followed. Comparison of weighed quantities of the chloride with equivalent weights of silver was made by the conventional nephelometric method and the resulting silver chloride also was weighed. Weights are corrected to vacuum.

The average of all the experiments, 65.377, confirms the present value in the Table, 65.38, but is 0.05 unit higher than that calculated from mass spectroscopic data, 65.33.

Silver, Bromine and Potassium.—McAlpine and Bird,[5] by quantitative decomposition of potas-

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[1] Murphy and Nier, *Phys. Rev.*, **59**, 771 (1941).

[2] Murphy, *ibid.*, **59**, 320 (1941).

[3] Hutchison and Johnston, THIS JOURNAL, **63**, 1580 (1941).

[4] Hönigschmid and v. Mack, *Z. anorg. allgem. Chem.*, **246**, 363 (1941).

[5] McAlpine and Bird, THIS JOURNAL, **63**, 2960 (1941).

THE ATOMIC WEIGHT OF ZINC

$ZnCl_2$, g.	Ag, g.	$ZnCl_2:2Ag$	At. wt. of Zn	AgCl, g.	$ZnCl_2:2AgCl$	At. wt. of Zn
			Preliminary Series			
2.26845	3.59116	0.631676	65.377	4.77125	0.475411	65.383
2.62763	4.15980	.631672	65.376	5.52705	.475413	65.374
4.62252	7.31790	.631673	65.376	9.72300	.475421	65.377
1.94421	3.07788	.631672	65.376	4.08936	.475431	65.380
3.81948	6.04655	.631679	65.377	8.03341	.475449	65.385
1.78151	2.82023	.631690	65.379	3.74741	.475398	65.370
1.94043	3.07193	.631665	65.374	4.08179	.475387	65.367
2.31880	3.67098	.631657	65.372	4.87719	.475430	65.382
	Average	0.631673	65.376		0.475422	65.377
			Final Series			
2.08378	3.29873	0.631692	65.380	4.38304	0.475419	65.376
2.39497	3.79141	.631684	65.378	5.03743	.475435	65.391
3.25457	5.15229	.631675	65.376			
2.33816	3.70151	.631678	65.377	4.91803	.475426	65.378
2.23578	3.53951	.631664	65.374	4.70270	.475425	65.378
2.54724	4.03245	.631686	65.379	5.35790	.475418	65.376
2.32850	3.68614	.631691	65.380	4.89779	.475418	65.376
2.03634	3.22369	.631680	65.377	4.28307	.475439	65.382
	Average	0.631681	65.378		0.475426	65.378

sium bromate, have found the ratio of potassium bromide to oxygen and by comparison of the resulting potassium bromide with silver have found the ratio of these two substances. The results furnish a direct determination of the molecular weight of potassium bromide and an indirect determination of the atomic weight of silver.

Silver and bromine were purified by methods standard in atomic weight work. Potassium bromate was prepared from high-grade potassium hydroxide and an excess of bromine. After the solution had been boiled to remove excess of bromine and possibly iodine, the bromate was many times recrystallized until essentially free from bromide and sodium.

After prolonged drying in a vacuum the salt was further dried at 85–90° in the special weighed quartz decomposition flask, which was provided with a quartz filter disk to prevent loss of solid material, in a dry air stream, and was weighed. Very gradual decomposition in a dry air stream followed, at gradually increasing temperatures up to 550°, until constant weight was obtained. During the decomposition the outgoing air stream was passed through a weighed phosphorus pentoxide tube to absorb residual water in the potassium bromate. In preliminary experiments it was found that decomposition of the bromate was complete and that the resulting bromide was neutral.

In the following table the weight of potassium bromate has been corrected for the water content as determined in each experiment. Vacuum corrections have been applied.

THE MOLECULAR WEIGHT OF POTASSIUM BROMATE

$KBrO_3$, g.	KBr, g.	Ratio, $KBr:O_3$	Mol. wt. KBr
10.67696	7.60833	2.47939	119.011
7.54279	5.37493	2.47937	119.010
7.44818	5.30753	2.47940	119.011
9.72572	6.93055	2.47947	119.015
9.62010	6.85524	2.47942	119.012
8.50007	6.05711	2.47941	119.012
10.69361	7.62021	2.47941	119.012
10.36524	7.38620	2.47939	119.011
9.76351	6.95738	2.47935	119.009
9.78441*	6.97233	2.47942	119.012
	Average	2.47940	119.011

* Corrected in private communication from the authors.

Further evidence that the potassium bromide resulting from the decomposition was normal and free from moisture was obtained by comparing this bromide with silver in the conventional way by the nephelometric method. Similar experiments were made with potassium bromide prepared from pure bromine and potassium oxalate, and fused in nitrogen. Weights are corrected for air buoyancy.

If the established ratio of bromine to silver, 0.740786, is assumed, the atomic weights of bromine and potassium referred to silver as 107.879 are 79.915 and 39.096, respectively. All three

THE ATOMIC WEIGHT OF SAMARIUM

$SmCl_3$, g.	Ag, g.	$SmCl_3$: 3Ag	At. wt. of Sm	AgCl, g.	$SmCl_3$: 3AgCl	At. wt. of Sm
		$SmCl_3$ fused in HCl				
3.27893	4.13279	0.79339	150.403	5.49102	0.59715	150.408
		$SmCl_3$ dried at 450° in HCl				
3.08886				5.17381	0.59702	150.354
2.96740	3.74054	0.79331	150.375	4.96975	.59709	150.385
3.87834	4.88888	.79330	150.372	6.49574	.59706	150.371
3.37089	4.24914	.79331	150.376	5.64562	.59708	150.380
4.40134	5.54798	.79332	150.380	7.37129	.59709	150.385
	Average	.79331	150.376		.59708	150.375

values are in excellent agreement with those in the Table.

THE ATOMIC WEIGHT OF SILVER, KBr = 119.011

KBr, g.	Ag, g.	Ratio, KBr: Ag	At. wt. of Ag*
	KBr from $KBrO_3$		
5.37498	4.87217	1.103200	107.878
5.30758	4.81110	1.103195	107.878
6.93122	6.28281	1.103204	107.878
6.85536	6.21410	1.103194	107.879
6.05813	5.49155	1.103173	107.881
7.62092	6.90813	1.103181	107.880
7.38622	6.69531	1.103193	107.879
6.95738	6.30663	1.103185	107.879
6.97265	6.32040	1.103197	107.878
	Average	1.103191	107.879

* Recalculated from authors' data.

KBr, g.	Ag, g.	Ratio, KBr: Ag	At. wt. of Ag*
	KBr from $K_2C_2O_4$		
5.08563	4.60984	1.103212	107.877
4.94988	4.48694	1.103175	107.880
5.64545	5.11714	1.103243*	107.874
5.38516	4.88142	1.103195	107.878
5.92139	5.36755	1.103183	107.880
4.62504	4.19245	1.103183	107.880
5.30793	4.81142	1.103194	107.879
4.50218	4.08093	1.103224	107.876
4.34549	3.93902	1.103191	107.879
5.25160	4.76034	1.103199	107.878
5.06778	4.59372	1.103197	107.878
	Average	1.103200	107.878

* 1.103200 in the authors' paper.

Incidental to the investigation three syntheses of silver chloride from silver were made.

THE RATIO OF SILVER TO SILVER CHLORIDE

Ag, g.	AgCl, g.	Ag: AgCl
6.95254	9.23774	0.752623
7.03045	9.34116	.752631
6.63263	8.81249	.752640
	Average	.752631

The previously established value of this ratio is 0.752632.

Samarium.—Hönigschmid and Hirschbold-Wittner[6] have analyzed anhydrous samarium trichloride. The samarium material had been purified by Feit and shown by Noddack by X-ray analysis to be of atomic weight purity. Further purification consisted of double precipitation of the oxalate followed by ignition to oxide in each case and crystallization of the chloride from solution saturated with hydrogen chloride at ice temperature. The chloride was dehydrated by heating in a current of dry hydrogen chloride at gradually increasing temperatures, finally at 450°. Fusion was avoided since it was found experimentally that dissociation occurs at temperatures above the melting point. After being weighed the chloride was dissolved and compared with a nearly equivalent weight of pure silver by the usual nephelometric method and the silver chloride was collected and weighed. Weights are corrected to vacuum.

The average of all determinations, 150.38, is 0.05 unit lower than the present value, 150.43, which depends on analyses of *fused* chloride by Stewart and James[7] and Owens, Balke and Kremers.[8] Although no change in the Table is made at the present time, the new lower value seems to be a more probable one.

Gadolinium.—Wahl[9] finds the isotopic constitution of gadolinium to be as follows:

Mass	152	154	155	156	157	158	160
Per cent.	0.2	2.86	15.61	20.59	16.42	23.45	20.87

These figures lead to the atomic weight 157.18 if the packing fraction -1.5×10^{-4} is employed.

Ytterbium.—Hönigschmid and Hirschbold-Wittner[10] have compared anhydrous ytterbium trichloride with silver. The starting material had been prepared by v. Bruckl by repeated elec-

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(6) Hönigschmid and Hirschbold-Wittner, *Z. physik. Chem.*, **189A**, 38 (1941).

(7) Stewart and James, THIS JOURNAL, **39**, 2605 (1917).

(8) Owens, Balke and Kremers, *ibid.*, **42**, 515 (1920).

(9) Wahl, *Soc. Sci. Fennica, Commentationes Phys.-Math.*, **11**, 3. 1 (1941).

(10) Hönigschmid and Hirschbold-Wittner, *Z. anorg. allgem. Chem.*, **248**, 72 (1941).

ATOMIC WEIGHTS

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	Symbol	Atomic Number	Atomic Weight
Aluminum	Al	13	26.97
Antimony	Sb	51	121.76
Argon	A	18	39.944
Arsenic	As	33	74.91
Barium	Ba	56	137.36
Beryllium	Be	4	9.02
Bismuth	Bi	83	209.00
Boron	B	5	10.82
Bromine	Br	35	79.916
Cadmium	Cd	48	112.41
Calcium	Ca	20	40.08
Carbon	C	6	12.010
Cerium	Ce	58	140.13
Cesium	Cs	55	132.91
Chlorine	Cl	17	35.457
Chromium	Cr	24	52.01
Cobalt	Co	27	58.94
Columbium	Cb	41	92.91
Copper	Cu	29	63.57
Dysprosium	Dy	66	162.46
Erbium	Er	68	167.2
Europium	Eu	63	152.0
Fluorine	F	9	19.00
Gadolinium	Gd	64	156.9
Gallium	Ga	31	69.72
Germanium	Ge	32	72.60
Gold	Au	79	197.2
Hafnium	Hf	72	178.6
Helium	He	2	4.003
Holmium	Ho	67	164.94
Hydrogen	H	1	1.0080
Indium	In	49	114.76
Iodine	I	53	126.92
Iridium	Ir	77	193.1
Iron	Fe	26	55.85
Krypton	Kr	36	83.7
Lanthanum	La	57	138.92
Lead	Pb	82	207.21
Lithium	Li	3	6.940
Lutecium	Lu	71	174.99
Magnesium	Mg	12	24.32
Manganese	Mn	25	54.93
Mercury	Hg	80	200.61
Molybdenum	Mo	42	95.95
Neodymium	Nd	60	144.27
Neon	Ne	10	20.183
Nickel	Ni	28	58.69
Nitrogen	N	7	14.008
Osmium	Os	76	190.2
Oxygen	O	8	16.0000
Palladium	Pd	46	106.7
Phosphorus	P	15	30.98
Platinum	Pt	78	195.23
Potassium	K	19	39.096
Praseodymium	Pr	59	140.92
Protactinium	Pa	91	231
Radium	Ra	88	226.05
Radon	Rn	86	222
Rhenium	Re	75	186.31
Rhodium	Rh	45	102.91
Rubidium	Rb	37	85.48
Ruthenium	Ru	44	101.7
Samarium	Sm	62	150.43
Scandium	Sc	21	45.10
Selenium	Se	34	78.96
Silicon	Si	14	28.06
Silver	Ag	47	107.880
Sodium	Na	11	22.997
Strontium	Sr	38	87.63
Sulfur	S	16	32.06
Tantalum	Ta	73	180.88
Tellurium	Te	52	127.61
Terbium	Tb	65	159.2
Thallium	Tl	81	204.39
Thorium	Th	90	232.12
Thulium	Tm	69	169.4
Tin	Sn	50	118.70
Titanium	Ti	22	47.90
Tungsten	W	74	183.92
Uranium	U	92	238.07
Vanadium	V	23	50.95
Xenon	Xe	54	131.3
Ytterbium	Yb	70	173.04
Yttrium	Y	39	88.92
Zinc	Zn	30	65.38
Zirconium	Zr	40	91.22

trolytic reduction and when subjected to X-ray analysis by Noddack was found to contain no other rare earths except lutecium, and this element only to the extent of 0.04%. The effect of this impurity would be to raise the atomic weight by only 0.001 unit. After repeated precipitation as hydroxide and oxalate, with intermediate ignition to oxide, the chloride was prepared and crystallized from a solution saturated with hydrogen chloride at 0°. Dehydration in preparation for weighing was effected by heating in a current of dry hydrogen chloride at gradually increasing temperatures up to 450°. Fusion was avoided since Hönigschmid had already found dissociation of the salt to occur above the melting point. Comparison with silver was effected in the usual way with the help of a nephelometer and the resulting silver chloride was collected and weighed. Weights are corrected to vacuum.

The average, 173.10, is 0.06 unit higher than that found by Hönigschmid and Striebel[11] with less pure material isolated by Prandtl. The new

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(11) Hönigschmid and Striebel, *Z. anorg. allgem. Chem.*, **212**, 385 (1933).

THE ATOMIC WEIGHT OF YTTERBIUM

$YbCl_3$, g.	Ag, g.	$YbCl_3:3Ag$	At. wt. of Yb	AgCl, g.	$YbCl_3:3AgCl$	At. wt. of Yb
3.87107				5.94071	0.649934	173.108
3.82762				5.88965	.649889	173.089
4.12899	4.78127	0.863576	173.117	6.35269	.649959	173.119
2.58325	2.99157	.863510	173.095	3.97473	.649918	173.101
2.66672	3.08799	.863578	173.117	4.10299	.649946	173.113
2.58988	2.99916	.863535	173.104	3.98478	.649943	173.112
2.06819	2.39519	.863476	173.085			
2.42097	2.80349	.863556	173.100	3.72495	.649934	173.108
2.08411	2.41356	.863500	173.092	3.20680	.649904	173.095
1.72464	1.99732	.863477	173.085	2.65378	.649881	173.085
3.12912	3.62361	.863537	173.089	4.81490	.649883	173.086
3.92599	4.54636	.863546	173.107	6.04062	.649932	173.107
4.98554	5.77369	.863493	173.090	7.67151	.649877	173.083
	Average	.863526	173.098		.649916	173.100

higher value is evidently to be preferred although Wahl[12] by determination of isotopic abundances obtains the lower figure.

Mass	168	170	171	172	173	174	176
Per cent.	0.06	4.21	14.26	21.49	17.02	29.58	13.38

Lead.—Permyakov[13] finds the atomic weight of lead from Khito-Ostrov uraninite to be 206.12 and that from Sadon galena to be 207.20.

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(12) Wahl, *Naturwiss.*, **29**, 536 (1941).

(13) Permyakov, *Bull. acad. sci. U. R. S. S., Classe sci. chim.*, 581 (1941).

RECEIVED JULY 1, 1943

[CONTRIBUTION FROM THE CENTRAL EXPERIMENT STATION, BUREAU OF MINES]

Mechanism of the Steam–Carbon Reaction[1]

BY B. R. WARNER[2]

It has been generally accepted that when steam is passed over carbon, the oxide of carbon first formed is principally carbon monoxide, and that carbon dioxide is formed mainly in subsequent catalytic reactions tending to establish the water–gas equilibrium

$$CO + H_2O \underset{\longleftarrow}{\overset{\longrightarrow}{\text{catalyst}}} CO_2 + H_2 \qquad (1)$$

Most experimenters[3] base this conclusion on the observation that in all cases where steam velocity is so high that the equilibrium is not established, the experimental equilibrium constant, $p_{CO}p_{H_2O}/p_{CO_2}p_{H_2}$,[4] exceeds the true constant; that is, it appears that the equilibrium is approached from the left. This conclusion assumes that at high steam velocities (*i. e.*, short contact times) the gases leave the interstices of the carbon bed (where close contact with catalytic surfaces attains) before reaction (1) can proceed to equilibrium. Alternatively at high steam velocities steam may be channeled past the coal bed (such channels may exist or be formed during the reaction by erosion of the coke surface) without sufficient participation in the reaction. In this case it would be possible that equilibrium is established in the interstices, but the values of the experimental constant are high because the exit gas is diluted with steam. But if this were true, it would also follow that the ratio of CO_2/CO should remain constant with increasing steam velocities, if the reaction products were simply diluted with steam. However, in experiments with high steam velocities the ratio of CO_2/CO is found not to be constant but actually to decrease with increase in steam velocity. Thus the channeling effect is ruled out as the sole cause of the high values of the experimental equilibrium constant,

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(2) Associate Physical Chemist, Central Experiment Station, Bureau of Mines, Pittsburgh, Pa.

(3) Clement and Adams, *Bureau of Mines Bull.*, **7**, 50 (1911); Gwosdz, *Z. angew. Chem.*, **31**, 137 (1918); Taylor and Neville, THIS JOURNAL, **43**, 2055 (1921); Pexton and Cobb, *Gas J.*, **163**, 160 (1923); Dolch, *Gas u. Wasserfach.*, **175**, 807 (1932); Terres and co-workers, *ibid.*, **77**, 703 (1934); Mayers, THIS JOURNAL, **56**, 1879 (1934).

(4) This formulation of the equilibrium constant follows the convention of writing the exothermic reaction equation, $CO + H_2O \rightarrow CO + H_2 + 9646$ calories and dividing the products of the concentrations on the left by the products of the concentrations on the right. By this convention the equilibrium constant of any reaction increases with temperature.