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TWENTY-NINTH ANNUAL REPORT OF THE COMMITTEE ON ATOMIC WEIGHTS

Determinations Published During 1922

BY GREGORY PAUL BAXTER

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Active general interest in this subject is shown by the formation of several national atomic weight commissions. Two reports of the German commission[1] have been published, as well as one each by the Swiss[2] and Spanish[3] commissions.

R. J. Meyer[4] discusses atomic weights from the standpoints of the history, standard methods of determination, accuracy, significance and National commissions, and Richards[5] also discusses the significance of atomic weights, including general methods of determination.

Determinations published during 1922, besides some published earlier but not included in previous reports, are given below.

Hydrogen and Carbon.—Guye and Batuecas,[6] and Batuecas[7] have determined the compressibilities, at 0° and low pressures, and the deviations from Avogadro's law for several gases. These values are combined with earlier density figures for the computation of the atomic weights of hydrogen and carbon.

[1] Bodenstein, Hahn, Hönigschmid, Meyer and Ostwald, *Ber.*, **54A**, 181 (1921); **55A**, 1 (1922).

[2] Bernoulli, Dutoit, Guye and Treadwell, *Helvetica Chim. Acta*, **4**, 449 (1921).

[3] Cabrera, del Campo, Mourelo and Moles, *Anales soc. españ. fís. quím.*, **20**, 25 (1922).

[4] Meyer, *Naturwissenschaften*, **10**, 911 (1922).

[5] Richards, *Bull. soc. chim.*, **31**, 929 (1922).

[6] Guye and Batuecas, *Helvetica Chim. Acta*, **5**, 532 (1922).

[7] Batuecas, *ibid.*, **5**, 544 (1922).

ATOMIC WEIGHTS OF HYDROGEN AND CARBON

	$1 + \lambda = \frac{(PV)_0}{(PV)_1}$	Density	At. wt.
Oxygen	1.00085	1.42891	....
Hydrogen	0.99935	0.089858	H = 1.0077
Carbon dioxide	1.00706	1.97685	C = 11.998
Ethylene	1.00780	1.26401	C = 12.000

Beryllium.—Hönigschmid and Birckenbach[8] purified beryllium material by crystallization of the basic acetate from glacial acetic acid, sublimation of the basic acetate, conversion of the acetate to nitrate, precipitation of the carbonate and solution in ammonium carbonate, reprecipitation of the carbonate, and conversion of the carbonate to oxide by ignition. The chloride was prepared from a mixture of the oxide with carbon by ignition in chlorine, in a quartz apparatus which allowed the collecting of the sublimate in a quartz tube, in which the chloride was again fused in a current of nitrogen and transferred to a weighing bottle. Solution and comparison with silver followed, and the silver chloride was determined. Weights are corrected to vacuum. Cl = 35.457.

ATOMIC WEIGHT OF BERYLLIUM

Wt. of $BeCl_2$ G.	Wt. of Ag G.	Ratio $BeCl_2$: 2 Ag	At. wt. Be	Wt. of AgCl G.	Ratio $BeCl_2$: 2AgCl	At. wt. Be
Preliminary Series						
1.11820	.....	......	...	4.01060	0.278811	9.015
1.71704	.....	......	...	6.15797	0.278832	9.020
1.75631	.....	......	...	6.29918	0.278815	9.015
					Av. 0.278819	9.016
Final Series						
2.24141	6.05027	0.370464	9.017	.....	......	...
2.79454	7.54344	0.370460	9.016	10.02296	0.278813	9.015
2.53396	6.84001	0.370449	9.017	9.08798	0.278825	9.018
2.25154	6.07739	0.370478	9.020	8.07476	0.278837	9.021
2.66893	7.20424	0.370467	9.018	9.57180	0.278832	9.019
1.98998	5.37161	0.370462	9.017	......	......	...
1.95621	5.28047	0.370461	9.017	7.01603	0.278820	9.016
2.82716	7.63133	0.370467	9.018	......	......	...
2.10571	5.68367	0.370484	9.022	......	......	...
1.81164	4.89023	0.370461	9.017	......	......	...
		Av. 0.370465	9.018		Av. 0.278825	9.018

This result is nearly 1% lower than the International value, and is of interest in view of the fact that Aston finds beryllium to be a simple element (see later).

Boron.—Hönigschmid and Birckenbach[9] have analyzed boron trichloride. This substance was prepared from boron and chlorine, and after

[8] Hönigschmid and Birckenbach, *Ber.*, **55B**, 4 (1922).

[9] Hönigschmid and Birckenbach, *Anales soc. españ. fís. quím.*, **20**, 167 (1922).

removal of chlorine with mercury was fractionally distilled in a vacuum. Fractions collected in glass capsules were weighed in air and under water to determine the density. The weight of the glass was found after breaking the capsules under water and collecting the glass fragments on a platinum-sponge crucible. Comparison with silver followed in the customary fashion and the silver chloride was collected and weighed. Samples I and II were prepared and purified by Stock, and Sample III was a commercial specimen purified by Stock. Weights are corrected to vacuum.

Atomic Weight of Boron

Wt. of BCl_3 G.	Wt. of Ag G.	Ratio BCl_3 : 3 Ag	At. wt. of B	Wt. of AgCl G.	Ratio BCl_3 : 3 Ag	At. wt. of B
			Sample I			
1.53349	.....	......	....	5.62574	0.272585	10.843
1.86953	.....	......	....	6.85874	0.272575	10.839
				Av.	0.272580	10.841
			Final Series			
1.58756	4.38365	0.362155	10.837	5.82416	0.272582	10.842
1.56140	4.31122	0.362171	10.842	5.72795	0.272593	10.847
3.02907	8.36399	0.362156	10.837	11.11301	0.272570	10.837
	Av.	0.362161	10.838	Av.	0.272582	10.842
			Sample II			
1.17953	3.25738	0.362110	10.822	4.32825	0.272519	10.815
1.51709	4.18974	0.362096	10.818	5.56682	0.272524	10.817
1.41777	3.91542	0.362099	10.819	5.20227	0.272529	10.819
1.58290	4.37164	0.362084	10.814	5.80824	0.272527	10.818
1.54536	4.26797	0.363083	10.814	5.67047	0.272528	10.819
1.39480	3.85209	0.362089	10.816	5.11857	0.272525	10.818
	Av.	0.362093	10.817	Av.	0.272526	10.818
			Sample III			
1.31626	3.63505	0.362101	10.819	4.82964	0.272538	10.823
1.48670	4.10537	0.362136	10.830	5.45427	0.272575	10.839
1.59888	4.41558	0.362101	10.819	5.86637	0.272550	10.828
1.41893	3.91861	0.362100	10.819	5.20666	0.272522	10.816
	Av.	0.362109	10.822	Av.	0.272546	10.827

The authors prefer the value 10.82 for boron. This agrees very well with the value 10.83 recently obtained by Baxter and Scott.

Monro[10] by titration of borax with hydrochloric acid was unable to find any difference between commercial material and that obtained from the Hanmer Hot Springs, New Zealand.

Nitrogen.—Moles[11] has recalculated the densities of nitrogen found by earlier investigators, and adds four preliminary results of his own obtained by heating weighed quantities of sodium trinitride and collecting the gas in calibrated globes at 0° and at measured pressure.

[10] Monro, *J. Chem. Soc.*, **121**, 986 (1922).

[11] Moles, *J. chim. phys.*, **19**, 283 (1921).

NITROGEN

Wt. of N_2 G.	Vol. at 0°	P	Wt. of normal liter
1.33935	1521.64	534.96	1.25130
1.66114	1521.62	664.48	1.24934
1.59493	1521.63	636.65	1.25200
1.26990	1521.58	507.85	1.24984
			Av. 1.25062

The recalculations give	Wt. of normal liter
Rayleigh	1.25071
Gray	1.25056
Leduc	1.25032

Calculation of the atomic weight of nitrogen using densities of oxygen and nitrogen found by the same experimenters, and 1.00097 and 1.00043 for the values of $1 + \lambda$ for oxygen and nitrogen, yields 14.010 for the atomic weight of nitrogen.

Oxygen.—Moles[12] has published a critical study of modern values for the density of oxygen. Recalculation with the use of the same standards gives ($g\,{}^{0}_{45°}$=980.616 c.g.s.).

OXYGEN

Jolly	1.42896	Jacquerod and Tourpaïan	1.4289
Lord Rayleigh	1.42894	Bruylants and Bytebier	1.42878
Morley	1.24892	Germann	1.42905
Leduc	1.42880	Scheuer	1.42910
Gray	1.42891	Moles and Batuecas	1.42882
			Av. 1.42892

If g (normal) = 980.665 c.g.s., the average is raised to 1.42897.

Attention is called to the fact that a similar revision for other gases is necessary before making comparisons of molecular weights.

Moles and Gonzalez[13] have redetermined the density of oxygen. The following values are referred to sea level at latitude 45° (g = 980.616 c.g.s.). Apparently these are corrected results which have already been reported.[14]

DENSITY OF OXYGEN

Source of oxygen	Globe I 793.68 cc.	Globe II 619.38 cc.	Globe III 220.26 cc.	Globe 2 647.71 cc.	Globe 3 580.49 cc.	Av.
$KMnO_4$	1.42899	1.46840	1.42918	.....	.....	1.42886
	1.42909	1.42885	1.42957	.....	.....	1.42917
	1.42910	.....	1.42918	.....	.....	1.42914
	.....	.....	1.42817	1.42918	1.42900	1.42878
	1.42855	1.42941	1.42876	.....	.....	1.42891
	.....	1.42964	1.42815	.....	.....	1.42890
	.....	1.42917	1.42819	1.42843	.....	1.42860
						Av. 1.42890

[12] Moles, *J. chim. phys.*, **19**, 100 (1921).

[13] Moles and Gonzalez, *ibid.*, **19**, 310 (1921).

[14] See report for 1921, THIS JOURNAL, **44**, 428 (1922).

$KClO_3$..........	1.42854	1.42823	1.42875	.....	.....	1.42851
	1.42887	1.42908	1.42833	.....	.....	1.42876
					Av.	1.42863
HgO..........	.....	1.42936	1.42924	.....	.....	1.42930
	1.42829	1.42928	1.42968	.....	.....	1.42908
					Av.	1.42917
Ag_2O..........	1.42856	1.42813	1.42942	.....	.....	1.42870
	.....	.....	1.42947	1.42908	1.42921	1.42925
	.....	1.42850	1.42887	1.42932	.....	1.42890
					Av.	1.42895
Electrolysis.....	.....	1.42924	1.42886	1.42856	.....	1.42889
	.....	1.42956	1.42855	1.42922	.....	1.42911
					Av.	1.42900
Av.	1.42875	1.42899	1.42890	1.42896	1.42910	
					General av.	1.42892

If the results of Moles and Batuecas[15] are included, the average becomes 1.42891. Averaged with earlier[12] determinations, 1.42892 is obtained. If g(normal) = 980.665 c.g.s., the density becomes 1.42897.

Moles and Crespi[16] evolved oxygen by heating weighed quantities of potassium permanganate and collected the gas in calibrated globes at 0° and measured pressure.

Density of Oxygen

Wt. of O_2 G.	V	P	Wt. of normal liter corrected to lat. 45°
1.1753	919.63	680.13	1.42894
1.0986	919.63	635.74	1.42895

Sodium.—Moles[17] has converted weighed quantities of sodium trinitride into sodium nitrate and thus obtains the atomic weight of sodium 23.000.

Chlorine.—Magnus and Schmid[18] by a new vapor-density method find the molecular weight of chloroform and benzene at different pressures. Extrapolation to zero pressure yields the value 78.096 for benzene and 119.380 for chloroform.

$$\text{Chlorine} = 119.380 - \frac{78.096}{6} = 35.455.$$

Gleditsch and Samdahl[19] have compared the chlorine occurring in Balme apatite with ordinary chlorine. After extensive purification, sodium chloride was dissolved and a deficiency of silver nitrate added. The silver

[15] Moles and Batuecas, This Journal, **18,** 353 (1920).

[16] Moles and Crespi, *Anales soc. españ. fís. quím.*, **20,** 190 (1922).

[17] Moles, *ibid.*, **19,** 255 (1921).

[18] Magnus and Schmid, *Z. anorg. allgem. Chem.*, **120,** 232 (1922).

[19] Gleditsch and Samdahl, *Compt. rend.*, **174,** 746 (1922).

chloride was dried and weighed, then reduced in hydrogen and the silver was weighed. Expts. I and II were made with chlorine from apatite, Expt. III with ordinary chlorine.

Atomic Weight of Chlorine

	Wt. of AgCl G.	Wt. of Cl G.	At. wt. Cl
I	0.9220	0.2282	35.49
II	0.8870	0.2194	35.45
III	0.9024	0.2232	35.46

The differences are within the experimental error.

Gallium.—Richards[5] with W. M. Craig, synthesized gallium chloride from the constituent elements and purified the salt by fractional sublimation in a vacuum. Sealed glass bulbs containing the salt were weighed and the salt was dissolved and compared with silver. Weights are corrected to a vacuum. Cl = 35.458.

Atomic Weight of Gallium

Wt. of $GaCl_3$	Wt. of Ag	At. wt. Ga
3.40649	6.26079	69.718
4.56208	8.38446	69.722
2.55769	4.70108	69.707
3.27922	6.02688	69.718
		Av. 69.716

Selenium.—Bruylants and Dondeyne[20] have determined the density of hydrogen selenide prepared by the action of water on aluminum selenide. All the usual precautions were taken and customary corrections applied. The following figures refer to 0° and 760 mm. at Louvain ($g = 981.128$ c.g.s.).

Density of Hydrogen Selenide

Globe 1 761.592 cc.	Globe 2 312.950 cc.	Globe 3 206.967 cc.
3.67125	3.67287	3.67139
3.67193	3.67138	3.67203
3.67324	3.67316	3.67153
3.67234	3.67127	3.67260
.....	.....	3.67235
Av. 3.67219	3.67217	3.67198

The average value 3.67210 becomes 3.6702 when corrected to latitude 45°.

The compressibility and limiting density were found by determining the density at $^2/_3$ and $^1/_3$ atmosphere. The following two tables contain these results multiplied by $^3/_2$ and 3, respectively, and are not corrected to latitude 45°.

By the limiting density method of Guye, $1 + \lambda = \frac{(PV)_0}{(PV)_1}$ is found to be 1.01095. Using the density for oxygen 1.4289 and $1 + \lambda$ for oxygen

[20] Bruylants and Dondeyne, *Bull. acad. Belg.*, **7**, 387 (1922).

1.00097, the molecular weight of hydrogen selenide is 81.382, and the atomic weight of selenium 79.37.

DENSITY OF HYDROGEN SELENIDE

	Globe 2 312.950 cc.	Globe 3 206.967 cc.	Globe 4 324.340 cc.
	3.65811	3.65669	3.65549
	3.65741	3.65822	3.65647
	3.65670	3.65829	3.65779
	3.65771	3.65768	3.65755
Av.	3.65743	3.65772	3.65681
		General av. 3.65732	
	3.64468	3.64484	3.63904
	3.64781	3.64394	3.64343
	3.64794	3.63913	3.64071
	3.64289	3.64739	3.64690
Av.	3.64583	3.64382	3.64252
		General av. 3.64407	

Bromine.—Moles[21] corrects errors in the computation of $1 + \lambda$ for hydrogen bromide and using the densities 1.42891 and 1.42905 for oxygen finds the values 79.939 and 79.927, respectively, for the atomic weight of bromine.

Baxter[22] discusses the computation of molecular weights from gas densities by Guye's method of limiting densities with special reference to hydrogen bromide.

Yttrium.—Fogg and James[23] purified yttrium material by crystallization of the bromate, precipitation of basic nitrate by sodium hydroxide and by sodium nitrite, precipitation of the ferricyanide and precipitation of the cacodylate. Six final fractions were converted to chloride and after careful drying the chloride was compared with silver. Vacuum weights are given.

ATOMIC WEIGHT OF YTTRIUM

Fraction	Wt. of YCl_3 G.	Wt. of Ag G.	At. wt. Y	
1	2.45615	4.06741	89.06	
1	1.53281	2.53937	88.98	Av. 89.02
2	2.32881	3.85660	89.06	
2	2.99852	4.96557	89.06	
2	2.60321	4.31174	89.03	
2	2.05579	3.40596	88.98	
2	2.19335	3.63357	88.99	
2	2.17992	3.61115	89.00	Av. 89.02
3	2.62838	4.35335	89.03	
3	3.13897	5.19903	89.03	
3	2.86276	4.74036	89.08	
3	2.70410	4.47765	89.08	Av. 89.05

[21] Moles, *J. chim. phys.*, **19**, 135 (1921).

[22] Baxter, THIS JOURNAL, **44**, 595 (1922).

[23] Fogg and James, *ibid.*, **44**, 307 (1922).

Atomic Weight of Yttrium (*Continued*)

Fraction	Wt. of YCl_3 G.	Wt. of Ag G.	At. wt. Y	
4	2.42924	4.02481	88.97	
4	3.22857	5.34787	89.01	
4	2.80721	4.64965	89.03	Av. 89.00
5	2.70726	4.48289	89.08	
5	4.20721	6.96662	89.08	
5	2.86866	4.75281	88.97	
5	2.79189	4.62545	88.98	Av. 89.02
6	2.57431	4.26298	89.07	
6	2.10381	3.48514	89.00	Av. 89.04
			Av. 89.03	

This value is considerably lower than the one given in the most recent table of the International Committee.

Silver.—Baxter and Parsons[24] show that contrary to the suggestion of Guye, the purest silver and iodine prepared by customary processes for purposes of atomic weight comparison are free from important quantities of gaseous impurities, and Baxter[25] by spectroscopic examination of similar silver was able to detect only the merest traces of calcium, except in one specimen which also contained a trace of silicon. The proportion of calcium was found by wet analysis to be of the order of 0.00004%.

Antimony.—Winkler[26] oxidized weighed amounts of metallic antimony with nitric acid and weighed the tetroxide after ignition to 800°.

Atomic Weight of Antimony

Wt. of Sb	Wt. of Sb_2O_4	At. wt. Sb
5.01799	6.34004	121.460
4.97948	6.29170	121.430
5.00038	6.31796	121.444
5.00512	6.32390	121.448
		Av. 121.445

Lanthanum.—Hopkins and Driggs[27] have analyzed lanthanum chloride prepared from lanthanum material which had been fractionally crystallized as double magnesium nitrate and double ammonium nitrate. Spectroscopic examination by the United States Bureau of Standards showed the material to be "of a high degree of purity, no lines being found thus far which can be attributed to any of the related elements." Comparison of the carefully dried chloride with silver yielded the following results. Weights are corrected to vacuum. Cl = 35.457.

This result agrees very well with the value recently obtained by Baxter, Tani and Chapin,[28] 138.91.

[24] Baxter and Parsons, This Journal, **44**, 577 (1922).
[25] Baxter, *ibid.*, **44**, 591 (1922).
[26] F. Winkler, Doctoral *Dissertation*, Technische Hochschule, Munich, **1917.**
[27] Hopkins and Driggs, This Journal, **44**, 1927 (1922).
[28] Baxter, Tani and Chapin, *ibid.*, **43**, 1080 (1921); **44**, 328 (1922).

ATOMIC WEIGHT OF LANTHANUM

Wt. of $LaCl_3$	Wt. of Ag	Ratio $LaCl_3$: 3 Ag	At. wt. La
0.60680	0.80078	0.75776	138.87
0.73504	0.96987	0.75787	138.91
1.02450	1.35189	0.75783	138.89
0.92965	1.22654	0.75794	138.93
1.84436	2.43317	0.75807	138.97
0.72863	0.96164	0.75769	138.85
0.59234	0.78180	0.75766	138.84
0.98017	1.29330	0.75788	138.91
1.02852	1.35729	0.75778	138.88
0.85193	1.12428	0.75775	138.87
		Av. 0.75782	138.89

Thallium.—Hönigschmid, Birckenbach and Kothe[29] prepared thallous chloride from recrystallized thallous sulfate, and recrystallized the product in platinum vessels. The chloride was further purified by distillation in quartz apparatus in a current of air or nitrogen and was collected in a quartz tube for weighing, without exposure to moisture. Solution and comparison with silver followed and the silver chloride was collected and weighed. Weights are corrected to vacuum.

ATOMIC WEIGHT OF THALLIUM

Wt. of TlCl G.	Wt. of Ag G.	Ratio TlCl : Ag	At. wt. Tl	Wt. of AgCl G.	Ratio TlCl : AgCl	At. wt. Tl
4.54695	2.04516	2.22327	204.39	.....	.....	....
4.87772	2.19400	2.22320	204.38	2.91508	1.67327	204.38
4.44375	1.99880	2.22320	204.38	2.65516	1.67362	204.43
4.73108	2.12806	2.22318	204.38	2.82758	1.67319	204.37
4.70255	2.11521	2.22321	204.38	2.81039	1.67327	204.39
4.81477	2.16565	2.22324	204.39	2.87677	1.67367	204.44
4.75748	2.13955	2.22358	204.42	2.84329	1.67323	204.38
4.76741	2.14415	2.22344	204.41	2.84883	1.67346	204.41
4.64623	2.09013	2.22294	204.35	2.77697	1.67313	204.36
4.95373	2.22829	2.22310	204.37	.....	.....	....
4.07035	1.83075	2.22332	204.40	2.43251	1.67331	204.39
5.43917	2.44658	2.22317	204.38	3.25060	1.67328	204.39
6.36696	.....	.....	....	3.80514	1.67325	204.38
4.94141	.....	.....	....	2.95334	1.67316	204.37
		Av. 2.22324	204.39		Av. 1.67332	204.39

This new value is nearly 0.4 unit higher than the one in common use, which was found by Crookes nearly 50 years ago.

Lead.—Dillon, Clarke and Hinchey[30] claim to have partially separated radioactive lead chloride by treatment with phenylmagnesium bromide.

Mercury.—Brönsted and Hevesy[31] compared the densities of various

[29] Hönigschmid, Birckenbach and Kothe, *Sitzungsb. Bayer. Akad. Wiss.*, **1922**, 179.

[30] Dillon, Clarke and Hinchey, *Sci. Proc. Roy. Dublin, Soc.*, **17**, 53 (1922).

[31] Brönsted and Hevesy, *Z. anorg. allgem. Chem.*, **124**, 22 (1922).

samples of mercury from the following sources: cinnabar from Gölnicz, Hungary; Almaden, Spain; Palatinate, Bavaria; Idria, Dalmatia; California, United States; Santafiore, Italy; Ras el Mah, Tunis; commercial cinnabar; calomel, and mercury oxychloride from Terlingua, Texas, United States. The results agreed within 0.0004–0.0012 unit in the atomic weight.

Since the last report, evidence concerning the isotopic character of the following elements has been published.

ISOTOPES

	Atomic number	Atomic weight	Minimum number of isotopes	Masses of isotopes in order of abundance
Be[32]	4	9.02	1	9
Al[33]	13	26.96	1	27
Ca[34]	20	40.07	(2)	40, (44)
Fe[35]	26	55.84	(1)	56, (54?)
Zn[34]	30	65.37	4	64, 66, 68, 70
Se[33]	34	79.2	6	80, 78, 76, 82, 77, 74
Sn[36]	50	118.70	7 (8)	120, 118, 116, 124, 119, 117, 122 (121)

CAMBRIDGE 38, MASSACHUSETTS

[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF PRINCETON UNIVERSITY]

SOME PROPERTIES OF GRAPHITE

BY R. M. BURNS AND G. A. HULETT

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The determination of the density of a porous solid by the liquid immersion method is affected by the ability of the liquid to penetrate the smaller capillaries of the solid. The speed of this penetration may be slow, measurable, and may result in a "drift," or increase in the weight with time after immersion in the liquid, as has been shown in the case of charcoal with a variety of liquids.[1] The rate of penetration was found to be proportional to the product of surface tension and fluidity of the liquids used. The attainment of a final value for the density which ordinarily might require months may be accomplished in a few hours by the application to the system of an external pressure.[2]

It was with a view to extending the investigation in this field that a study of the density of graphite was undertaken. The work to be described in this paper was done early in 1920.

[32] Thomson, *Phil. Mag.*, **42,** 862 (1921).
[33] Aston, *Nature,* **110,** 664 (1922).
[34] Dempster, *Phys. Rev.*, **19,** 431 (1922).
[35] Aston, *Nature,* **110,** 312 (1922).
[36] Aston, *ibid.*, **109,** 813 (1922).

[1] Cude and Hulett, THIS JOURNAL, **42,** 391 (1920).
[2] Ref. 1, p. 399.