Ninth Report of the Committee on Atomic Weights of the International Union of Chemistry.

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THE following report of the Committee covers the twelve-month period, September 30th, 1937, to September 30th, 1938.* Only one change has been made in the table of atomic weights, in the case of phosphorus from 31·02 to 30·98.

CARBON.—Moles and Escribano (*Compt. rend.*, 1938, **207**, 66) have redetermined the densities of oxygen and carbon dioxide at different pressures :

	Oxygen.		*Carbon Dioxide.*	
	1 Atm.	0·5 Atm.	1 Atm.	0·5 Atm.
	1·42900	1·42832	1·97690	1·97016
	1·42894	1·42829	1·97695	1·97011
	1·42896	1·42828	1·97694	1·97015
	1·42892	1·42830	1·97694	1·97013
	1·42895	1·42828	1·97695	1·97011
	1·42891	1·42828	1·97693	1·97016
	1·42892	1·42831	1·97694	1·97014
	1·42894			
	1·42895			
Average	1·42894	1·42829	1·97693	1·97014

Extrapolation to zero pressure gives the limiting densities 1·42764 and 1·96334. The molecular weight of carbon dioxide is then 44·007 and the atomic weight of carbon 12·007.

NITROGEN.—Moles and Roquero (*Anal. Fís. Quím.*, 1937, **35**, 263) have redetermined the densities of oxygen and ammonia, by an improved volumeter method. Results are referred to $g = 980·665$.

	The Density of Ammonia.	*The Density of Oxygen.*			
	1 Atm.	1 Atm.	0·67 Atm.	0·50 Atm.	0·33 Atm.
	0·771422	1·42895	1·42856	1·42829	1·42810
	0·771397	1·42898	1·42855	1·42829	1·42802
		1·42895	1·42840	1·42828	1·42800
		1·42894	1·42854	1·42830	1·42806
		1·42892		1·42826	
Average	0·771409	1·42895	1·42851	1·42828	1·42805

By the method of least squares $D = 1·42760 + 0·001348p$.

Moles (*ibid.*, p. 134) discusses critically the " limiting density " and " limiting pressure " methods of finding molecular and atomic weights and finds from data obtained earlier the following atomic weights for carbon, nitrogen, and fluorine : C = 12·007; N = 14·008; F = 18·995.

FLUORINE.—Moles and Toral (*Z. anorg. Chem.*, 1938, **236**, 225) have redetermined the densities of silicon fluoride at different pressures. The gas was prepared by (*a*) the pyrolysis of barium silicofluoride, (*b*) the method of Gay-Lussac, and after treatment to remove traces of hydrogen fluoride and moisture was resublimed a number of times. The mean values obtained in two different bulbs are :

	Density.		
	760 mm.	570 mm.	380 mm.
	4·69041	4·67873	4·66708
	4·69049	4·67885	4·66707
	4·69053	4·67875	4·66704
	4·69042	4·67867	4·66699
	4·69054	4·67882	4·66706
	4·69051		4·66708
Mean	4·69049	4·67877	4·66705

* 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.

Extrapolation to zero pressure gives 4·64361 for the limiting density. The molecular weight of silicon fluoride is hence 104·085, from which, with Si = 28·065 (International value), F = 19·005, or, if Si = 28·104 [a mean value from the results of Hönigschmid (*Z. anorg. Chem.*, 1924, **141**, 101) and Weatherill and Brundage (*J. Amer. Chem. Soc.*, 1932, **54**, 3932)], F = 18·995.

PHOSPHORUS.—Hönigschmid and Menn (*Z. anorg. Chem.*, 1937, **235**, 129) have compared phosphorus oxychloride with silver and silver chloride. Commercial oxychloride, after being warmed with phosphoric oxide to remove pentachloride and fractionally crystallised to eliminate trichloride, was subjected to a series of distillations with fractionation columns in exhausted glass systems which provided for removal of head and tail fractions as well as a sample of the main portion in each distillation.

The samples for analysis, which were sealed in glass balls, were weighed in air and water and broken under ammonia in a closed flask. The glass fragments were collected and weighed, and the solution after acidification was compared with silver and silver chloride in the usual way.

The Atomic Weight of Phosphorus.

Fractionation.	Fraction.	$POCl_3$, g.	Ag, g.	$POCl_3 : 3Ag$.	At. wt. P.	AgCl, g.	$POCl_3 : 3AgCl$.	At. wt. P.
4	Middle	2·59943	5·48600	0·473830	30·979			
7	Head	3·88813	8·20582	0·473826	30·978			
9	Middle	2·61334	5·51549	0·473819	30·976			
10	Middle	3·05680	6·45125	0·473831	30·980			
11	Head	4·13618	8·72923	0·473831	30·980			
11	Middle	2·83672	5·98674	0·473834	30·981			
11	Tail	2·89397	6·10734	0·473851	30·986	8·11469	0·356634	30·985
14	Head	2·76953	5·84509	0·473822	30·977	7·76609	0·356618	30·979
14	Middle	3·09822	6·53853	0·473840	30·983	8·68750	0·356630	30·984
14	Tail	3·93788	8·31040	0·473850	30·986	11·04238	0·356615	30·977
15	Head	3·91543				10·97914	0·356624	30·981
15	Middle	2·50130				7·01398	0·356616	30·978
15	Tail	1·97687	4·17195	0·473848	30·985	5·54346	0·356613	30·977
18	Head	2·41931	5·10601	0·473816	30·975	6·78422	0·356609	30·975
19	Middle	2·25215	4·75296	0·473842	30·983	6·31508	0·356631	30·984
18	Tail	3·70839	7·82625	0·473840	30·983	10·39849	0·356628	30·983
19	Middle	1·90221	4·01461	0·473822	30·977	5·33387	0·356629	30·983
19	Tail	3·72114				10·43428	0·356626	30·982
			Average	0·473833	30·981		0·356623	30·981

The average value from head fractions is 30·978, that from middle fractions 30·979. Tail fractions gave slightly higher values, diminishing as the fractionation progressed. The authors believe the value 30·978 to represent the best value from their work. This value agrees very closely with that found from the density of phosphine by Ritchie (see Report for 1930). Aston gives the packing fraction of phosphorus as -5×10^{-5}. On the assumption that phosphorus is a simple element with the factor for conversion to the chemical scale 1·00027, the atomic weight is 30·976. It seems to be certain that the International value 31·02 is too high. The atomic weight of phosphorus in the table has therefore been changed to 30·98.

RUBIDIUM.—Brewer (*J. Amer. Chem. Soc.*, 1938, **60**, 691) with a mass spectroscope finds the $^{85}Rb/^{87}Rb$ ratio in natural sources to be 2·61. With the conversion factor 1·00027 and the packing fractions 8·7 and 8·9 the atomic weight of rubidium is 85·456, which is slightly lower than the International value.

RUTHENIUM.—Gleu and Rehm (*Z. anorg. Chem.*, 1937, **235**, 352) in a revision of the atomic weight of ruthenium analysed purpureo-ruthenium chloride, $[Ru(NH_3)_5Cl]Cl_2$, since this salt is stable, and crystallises well without water of crystallisation. Weighed quantities of salt, dried at 110°, were reduced at bright redness in a current of hydrogen and the resulting metal was weighed.

The purpureo-chloride, after being dried at 110° for 4 days, according to the statement of the authors is exceptionally dry and practically undecomposed, although at higher temperatures, *e.g.*, 130°, marked decomposition can be detected.

The authors estimate that uncertainty due to incomplete drying and partial decomposition may amount to 0·1—0·2% of the weight of salt.

$Ru(NH_3)_5Cl_3$, g.	Ru, g.	Ru : $Ru(NH_3)_5Cl_3$.	At. wt. Ru.
0·71170	0·24581	0·34538	101·05
0·66212	0·22872	0·34545	101·08
0·52131	0·18014	0·34555	101·13
0·37477	0·12942	0·34533	101·03
0·74003	0·25567	0·34549	101·10
0·51860	0·17916	0·34547	101·09
0·55504	0·19189	0·34572	101·21
0·57077	0·19707	0·34527	101·00
0·52431	0·18107	0·34535	101·04
0·73077	0·25247	0·34549	101·10
0·67518	0·23317	0·34535	101·04
	Average	0·34544	101·08

The possible uncertainty in the weight of the purpureo-chloride admitted by the authors, 0·2%, corresponds at least to 0·3 unit in the atomic weight of ruthenium. Furthermore, information given by the authors concerning the preparation of the hexammine sulphate, from which the purpureo-chloride is obtained, is meagre. Hence in view of the uncertainty in the mass spectrograph value the Committee feels that it is unwise to alter the value for ruthenium in the Table.

NEODYMIUM.—Hönigschmid and Wittner (*Z. anorg. Chem.*, 1938, **235**, 220) have compared anhydrous neodymium chloride with silver and silver chloride, using two samples of neodymium material purified by Feit (Feit and Przibylla, *ibid.*, 1905, **43**, 202). Examination of the *X*-ray spectra by Noddack revealed not over 0·04% of any rare-earth impurity. Repeated precipitation as oxalate from strongly acid solution served to remove ordinary impurities. The chloride was prepared by solution of the oxide in hydrochloric acid and precipitation with hydrogen chloride at ice temperature.

Slow dehydration at moderate temperatures in a current of dry hydrogen chloride was followed by heating to 450° in some cases, rapid fusion in others.

Comparison with silver and silver chloride followed conventional lines. Vacuum weights are given.

The Atomic Weight of Neodymium.

Sample.	$NdCl_3$, g.	Ag, g.	$NdCl_3$: 3Ag.	At. wt. Nd.	AgCl, g.	$NdCl_3$: 3AgCl.	At. wt. Nd.
			$NdCl_3$ dried at 450°.				
I	2·27815	2·94163	0·77445	144·273	3·90844	0·58288	144·274
I	2·49290	3·21892	0·77445	144·273	4·27688	0·58288	144·273
II	3·18825	4·11686	0·77444	144·268	5·47000	0·58286	144·266
II	3·59299	4·63933	0·77446	144·276	6·16424	0·58288	144·272
		Average	0·77445	144·272		0·58288	144·272
			Fused $NdCl_3$.				
I	3·63095	4·68846	0·77445	144·270	6·22951	0·58286	144·267
II	4·31489	5·57154	0·77445	144·273	7·40277	0·58288	144·272
II	3·95113	5·10171	0·77447	144·279	6·77882	0·58288	144·274
		Average	0·77446	144·274		0·58287	144·271
			Average of all	144·273			

The average of all the experiments agrees with that found in 1911 by Baxter and Chapin, and with the International value.

Aston (*Proc. Roy. Soc.*, 1934, *A*, **146**, 46) from abundance ratios and packing fraction found 143·5. Two additional isotopes have recently been found by Dempster (*Physical Rev.*, 1937, **51**, 289) and Mattauck and Hauck (*Naturwiss.*, 1937, **25**, 781). The latter have revised Aston's abundance ratios and find the atomic weight 144·29.

EUROPIUM.—Baxter and Tuemmler (*J. Amer. Chem. Soc.*, 1938, **60**, 602) have published further details on the analysis of europous chloride (see eighth report of this Committee). Material found spectroscopically, by King, to be pure was crystallised as nitrate, precipitated as oxalate, and crystallised as trichloride. The chloride was converted into dichloride by drying and fusion in hydrogen and hydrogen chloride. After solution and oxidation comparison with silver was carried out. For correction to the vacuum standard the density of the dichloride was determined, 4·87.

The Atomic Weight of Europium.

$EuCl_2$, g.	Ag, g.	$EuCl_2 : 2Ag$.	At. wt. Eu.
2·37130	2·29561	1·032971	151·960
3·08194	2·98354	1·032981	151·962
2·81858	2·72847	1·033026	151·972
4·88934	4·73340	1·032945	151·954
4·71094	4·56053	1·032981	151·962
4·76278	4·61057	1·033013	151·969
4·18924	4·05537	1·033011	151·968
2·96223	2·86766	1·032978	151·961
	Average	1·032988	151·963

Kapfenberger (*Z. anorg. Chem.*, 1938, **238**, 273) also has analysed europous chloride. From a rare-earth fraction consisting chiefly of samarium and gadolinium salts with about 1% of europium, the europium was precipitated as europous sulphate by electrolysis, and this process was many times repeated until examination of the *X*-ray spectrum (Noddack) showed only 0·03—0·04% of gadolinium and 0·02—0·03% of samarium. Further purification involved precipitation with oxalic acid and crystallisation of europic chloride. Anhydrous chloride was prepared in some experiments by gradual heating of the trichloride in dry hydrogen and hydrogen chloride below the melting point of the trichloride; in others by final fusion in the same atmosphere. Analysis by comparison with silver was carried out as described by Baxter and Tuemmler except that Kapfenberger determined the silver chloride also. Weights are corrected to vacuum.

The Atomic Weight of Europium.

$EuCl_2$, g.	Ag, g.	$EuCl_2 : 2Ag$.	At. wt. Eu.	AgCl, g.	$EuCl_2 : 2AgCl$.	At. wt. Eu.
1·60119	1·55044	1·032733	151·908	2·06015	0·777220	151·895
2·15842	2·09010	1·032687	151·899	2·77705	0·777235	151·900
2·59610	2·51389	1·032702	151·902	3·34016	0·777238	151·900
2·94429	2·85104	1·032707	151·903	3·78795	0·777278	151·911
2·52095	2·44115	1·032690	151·899	3·24349	0·777234	151·899
2·29944	2·22660	1·032713	151·904	2·95844	0·777251	151·904
	Average	1·032705	151·902		0·777243	151·901

The discrepancy between the two determinations by Baxter and Tuemmler and by Kapfenberger is far beyond the experimental error and presumably is to be explained on the basis of impurity in one or both samples. The mass spectroscopic value apparently lies between the two. Aston estimates the abundances of the two europium isotopes as ^{151}Eu, 50·6%; ^{153}Eu, 49·4% and the packing fraction as -4×10^{-4}. Dempster (*Physical Rev.*, 1938, **53**, 64) has recently found Aston's packing fractions to be about 2/10,000 too large.* With the above abundances, the packing fraction -2×10^{-4}, and the conversion factor 1·00027 the atomic weight of europium is 151·917. Because of these discrepancies no change in the atomic weight of europium is made in the Table.

LUTECIUM.—Hönigschmid and Wittner (*Naturwiss.*, 1937, **25**, 748) find the atomic weight of a specimen of lutecium (Welsbach) to be 174·96 by analysis of the chloride. Noddack was unable to find appreciable impurity except 1·18% of ytterbium. The atomic weight corrected for ytterbium is 174·98. The mass spectrographic value is uncertain, for though Aston found lutecium to be a simple element, Gollnow reports 1·5—2·5% of either ^{173}Lu or ^{177}Lu.

LEAD.—Baxter and Kelley (*J. Amer. Chem. Soc.*, 1938, **60**, 62) have compared lead from St. Joachimsthal pitchblende with that from cerussite (Wallace, Idaho). Purification of both samples included crystallisation of the nitrate and the chloride and distillation in quartz in hydrogen chloride. Comparison of lead chloride with silver followed the conventional method. Weights are corrected to vacuum.

Isotopic analysis of the St. Joachimsthal lead by Nier is as follows: ^{208}Pb, 21·56%; ^{207}Pb, 11·74%; ^{206}Pb, 66·12%; ^{204}Pb, 0·58%. With the packing fraction $+1·5 \times 10^{-5}$

* See also Aston, *Nature*, 1938, **141**, 1096.

(Nier, *J. Amer. Chem. Soc.*, 1938, **60**, 1571) and the conversion factor 1·00027 the atomic weight of this specimen is found to be almost identical with the above chemical value, 206·51.

The Atomic Weight of Lead.

$PbCl_2$, g.	Ag, g.	$PbCl_2$: 2Ag.	At. wt. Pb.
	Cerussite.		
4·81912	3·73859	1·28902	207·205
2·45187	1·90209	1·28904	207·209
1·55822	1·20877	1·28910	207·222
	Average	1·28905	207·212

$PbCl_2$, g.	Ag, g.	$PbCl_2$: 2Ag.	At. wt. Pb.
	St. Joachimsthal.		
1·59548	1·24121	1·28542	206·428
2·75039	2·13878	1·28596	206·545
3·77378	2·93499	1·28579	206·506
2·70109	2·10070	1·28580	206·510
4·40976	3·42962	1·28579	206·507
		1·28575	206·500

Nier (*J. Amer. Chem. Soc.*, 1938, **60**, 1571) by mass spectrographic analysis has found the isotopic composition of common leads to vary over a considerable range, although the atomic weight computed from isotopic abundances diverges appreciably from the International value 207·21 only in one case out of ten, that of lead from Joplin, Mo., U.S.A.

TABLE I.

No.	Source of lead, locality.	Geological age, years $\times 10^{-6}$.	Isotope abundances. 204.	206.	207.	208.	Mean mass number.	Atomic weight. Physical.	Chemical.
1	Galena, Great Bear Lake	1300	1·000	15·93	15·30	35·3	207·243	207·218	207·206
2	Galena, Broken Hill, N.S.W.	950	1·000	16·07	15·40	35·5	207·242	207·217	
3	Cerussite, Broken Hill, N.S.W.	950	1·000	15·92	15·30	35·3	207·242	207·217	207·21
			1·000	15·93	15·28	35·2	207·241	207·216	
4	Galena, Yancey Co., N.C.	600	1·000	18·43	15·61	38·2	207·229	207·204	207·209
5	Galena, Nassau, Germany	240	1·000	18·10	15·57	37·85	207·231	207·206	207·21
6	Cerussite, Eifel, Germany	240	1·000	18·20	15·46	37·7	207·228	207·203	207·20
7	Galena I, Joplin, Mo.	230	1·000	21·65	15·88	40·8	207·203	207·178	207·22
8	Galena II, Joplin, Mo.	230	1·000	21·60	15·73	40·3	207·200	207·175	
			1·000	21·65	15·75	40·45	207·200	207·175	
9	Galena, Metalline Falls, Wash.	80	1·000	19·30	15·73	39·5	207·228	207·203	207·21
10	Cerussite, Wallace, Idaho	80	1·000	15·98	15·08	35·07	207·239	207·214	207·21
			1·000	16·10	15·13	35·45	207·242	207·217	
11	Wulfenite and vanadinite, Tuscon Mts., Arizona	25	1·000	18·40	15·53	38·1	207·229	207·204	207·22
12	Galena, Saxony, Germany		1·000	17·34	15·47	37·45	207·240	207·215	
			1·000	17·38	15·44	37·3	207·238	207·213	

The value 207·21 is retained for the table, although in the future it is apparent that the geological occurrence of common lead must be taken into account so far as its atomic weight is concerned.

INTERNATIONAL ATOMIC WEIGHTS, 1939.

	Symbol.	At. No.	At. wt.		Symbol.	At. No.	At. wt.
Aluminium	Al	13	26·97	Neon	Ne	10	20·183
Antimony	Sb	51	121·76	Nickel	Ni	28	58·69
Argon	A	18	39·944	Niobium (Columbium)	Nb (Cb)	41	92·91
Arsenic	As	33	74·91	Nitrogen	N	7	14·008
Barium	Ba	56	137·36	Osmium	Os	76	190·2
Beryllium	Be	4	9·02	Oxygen	O	8	16·0000
Bismuth	Bi	83	209·00	Palladium	Pd	46	106·7
Boron	B	5	10·82	Phosphorus	P	15	30·98
Bromine	Br	35	79·916	Platinum	Pt	78	195·23
Cadmium	Cd	48	112·41	Potassium	K	19	39·096
Cæsium	Cs	55	132·91	Praseodymium	Pr	59	140·92
Calcium	Ca	20	40·08	Protoactinium	Pa	91	231
Carbon	C	6	12·010	Radium	Ra	88	226·05
Cerium	Ce	58	140·13	Radon	Rn	86	222
Chlorine	Cl	17	35·457	Rhenium	Re	75	186·31
Chromium	Cr	24	52·01	Rhodium	Rh	45	102·91
Cobalt	Co	27	58·94	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	Sulphur	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	163·5	Terbium	Tb	65	159·2
Hydrogen	H	1	1·0081	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	55·84	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	175·0	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
Molybdenum	Mo	42	95·95				
Neodymium	Nd	60	144·27				