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# REPORT OF THE INTERNATIONAL COMMITTEE ON ATOMIC WEIGHTS FOR 1919-20.

Received September 29, 1919.

The last regular report of this committee, apart from an annual recommendation to continue the use of the table of atomic weights then presented, was published in 1916. The interruption in the series of reports was, of course, due to the world war, which created difficulties of a serious kind among all international organizations. Coöperation with Germany became impossible, partly because of the difficulty of correspondence, and partly because of the personal hostilities created by the conduct of the war. There was also an inevitable slackening of scientific activities, and this was well shown by the unusually small number of new researches in the field of atomic weights. Now that peace is in sight, it seems wise to resume the preparation of these reports, even though they may not be for some time quite so truly international as heretofore. The determinations published since the preparation of our last report may now be summarized as follows:

**Hydrogen.**—A very thorough investigation by Burt and Edgar[1] on the volumetric composition of water has given the volume ratio of hydrogen to oxygen as 2.00288 : 1. From this value, taking the normal liter weights of oxygen and hydrogen as 1.42900 and 0.089873 g., respec-

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[1] *Phil. Trans.*, **216A,** 393 (1916). This research was noted in the previous report for 1917. Its review by Guye renders its repetition desirable here.

tively, the atomic weight of hydrogen becomes 1.00772, or, rounded off, 1.0077. Guye,[1] from a discussion of Burt and Edgar's data, accepts this value as lying between the two extremes of 1.00767 and 1.00773. If, however, instead of trusting to the densities of the gases and their physical constants exclusively, we take into account the admirable researches of Morley, Noyes, and others, upon the synthesis and analysis of water,[2] the most probable general mean for the atomic weight of hydrogen becomes 1.0078, which differs from the volumetric value by only 1/10000. That is, the two distinct lines of attack upon the problem agree within the limits of actual uncertainty. For ordinary purposes the approximate value 1.008 is close enough. It must be remembered that the tables prepared by this committee are for the use, not so much for specialists, as for working chemists in general; and too much refinement will only lead to confusion. No determinations of these or any other constants can be absolute and final. All are subject to errors which may be reduced nearly, but not quite, to insignificance, but never eliminated entirely. For example, in the determination of atomic weights from gaseous densities it is not possible to guarantee the *absolute* purity of the gases, or to avoid errors in weighing, in reductions to a vacuum, or in the values given to the physical constants that are used in the final computations. Some of these errors may be so small as to be negligible, and in the aggregate they may tend either to reinforce or to compensate one another, but their extreme magnitude can be estimated with some approach to accuracy, and expressed by means of the usual ± sign. At present an accuracy to within 1/10000 is the best we can expect to obtain.[3]

**Carbon.**—Two investigations on the atomic weight of carbon were reported from the Geneva laboratory in 1918. First, Stahrfoss[4] determined the density of acetylene, ethane, and ethylene. Acetylene proved to be unsatisfactory, because of its tendency to polymerize. From ethane he obtained the value $C = 12.006$, and from ethylene $C = 12.004$. On account of some uncertainties in the reduction, he prefers, provisionally, the value $C = 12.00$.

Secondly, Batuecas[5] determined the density of ethane, and reduced his observations by 3 methods, giving $C = 12.005$, $11.999$, and $11.996$. The last two being concordant he regards as preferable, and their mean, $C = 11.998$, he adopts. It will be remembered that Richards and Hoover, by purely chemical methods, found $C = 12.005$; and a later combination

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[1] *J. chim. phys.*, **15**, 208 (1917).

[2] Computation by F. W. C.

[3] For an elaborate discussion of sources of error in atomic weight determinations, see Guye and his colleagues (M. Germann, Moles and Renard) in *J. chim. phys.*, **14**, 25, 195, 204 (1916); **15**, 60, 360, 405 (1917); **16**, 46 (1918).

[4] *Ibid.*, **16**, 175 (1918).

[5] *Ibid.*, **16**, 322 (1918).

of all determinations published before 1918 gave the chairman of the committee the mean value C = 12.0025. For ordinary purposes the rounded-off value C = 12.00 may be used, and is so given in the table.

**Bromine.**—Three sets of determinations of the molecular weight of hydrogen bromide have been made in Guye's laboratory at Geneva, by Moles,[1] Reiman,[2] and Murray.[3] The acid used was prepared by several distinct methods, and all gave concordant results, which may be summarized as follows, when H = 1.0078:

| | Mol. wt. HBr. | At. wt. Br. |
|---|---|---|
| Moles | 80.9332 | 79.9254 |
| Reiman | 80.932 | 79.9242 |
| Murray | 80.930 | 79.9222 |

These values are wonderfully concordant and the variations are far within the allowable limits of experimental error. In a recent combination, by the chairman of this committee, of all the available data relative to the atomic weight of bromine, the value found was Br = 79.9228, in complete harmony with the Geneva determinations. For ordinary purposes the rounded-off figure 79.92 is enough.

**Boron and Fluorine.**—In a very original investigation Smith and Van Haagen[4] have simultaneously redetermined the atomic weights of boron and fluorine. Their starting point was anhydrous borax, $Na_2B_4O_7$, and their chief difficulty was in insuring the complete dehydration of that compound. The salt was then converted, in a series of successive experiments, into sodium sulfate, carbonate, nitrate, chloride and fluoride, which gave 8 independent values for boron ranging from 10.896 to 10.905, in mean, 10.900. This value was computed with Na = 22.997, Cl = 35.457, S = 32.064, N = 14.010, and C = 12.005. The authors finally discuss all previous determinations and show wherein they were affected by errors. The new value 10.900 should be adopted as the most probable.

In this research sodium fluoride was compared not only with borax but also with the sulfate, and the 8 values found ranged from 19.002 to 19.008, in mean 19.005. The rounded-off value F = 19.0 may be retained for all practical purposes.

**Lead.**—Oechsner de Coninck and Gérard[5] have attempted to determine the atomic weight of lead by calcination of the nitrate; and find Pb = 206.98 when $N_2O_5$ = 108. This determination is evidently of no present value. With this exception the other recent researches relative

[1] *J. chim. phys.*, 14, 389 (1916). See review by Guye in the same number, p. 361.

[2] *Ibid.*, 15, 293 (1917).

[3] *Ibid.*, 15, 334 (1917). Reiman and Murray assume H = 1.008; Moles prefers 1.0076.

[4] *Carnegie Inst. Pub.*, 267 (1918).

[5] *Compt. rend.*, 163, 415 (1916).

to this constant have referred to isotopic lead, and the normal element is considered only in comparison with it. Richards and Wadsworth,[1] for instance, find for normal lead Pb = 107.183, and Richards and Hall[2] give Pb = 207.187, values slightly lower than the accepted 207.20 as determined by Baxter and Grover. Similar determinations by A. L. Davis[3] gave discordant results. As for isotopic lead its atomic weight is so variable as to show that it is nearly, if not always, a mixture of isotopes, and not a constant which can as yet be placed in the table. The values found have very great significance, but they are far from final.[4]

**Gallium.**—By the analysis of carefully purified gallium chloride, Richards, Craig, and Sameshima[5] find Ga = 70.09 and 70.11. These determinations, however, are only preliminary, but they justify the provisional adoption of the value 70.10. The original values given by the determinations of Lecoq de Boisbaudran vary from 69.70 to 70.12, the last one being very near the new value.

**Zirconium.**—From the ratio between zirconium chloride and silver, Venable and Bell[6] find Zr = 91.76. Although this determination is regarded as preliminary, the authors, by pointing out sources of error in all previous values, believe the new one to be the most probable. It seems best, however, to await the complete investigation before changing the value heretofore accepted.

**Tin.**—Baxter and Starkweather,[7] by electrolyses of stannic chloride, find Sn = 118.703 when Cl = 35.457. This is in complete agreement with Briscoe's determination, Sn = 118.698. The value 118.70 has already been adopted by the committee.

**Tellurium.**—Staehler and Tesch,[8] from careful syntheses of tellurium dioxide, find Te = 127.51, which is confirmatory of the accepted value 127.5.

**Yttrium.**—Hopkins and Balke,[9] by conversion of $Yt_2O_3$ into $Yt_2Cl_3$ find Yt = 88.9. The ordinary sulfate method is shown to be inaccurate. In a later investigation Kremers and Hopkins[10] determined the ratio between yttrium chloride and silver, and found Yt = 89.33. Since this method

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[1] THIS JOURNAL, **38**, 2613 (1916).

[2] *Ibid.*, **39**, 537 (1917).

[3] *J. Phys. Chem.*, **22**, 631 (1918).

[4] For discussions regarding the atomic weight of isotopic lead see the Presidential address of Richards before the American Association for the Advancement of Science in December, 1918. Also F. W. Clarke, *Proc. Nat. Acad. Sci.*, **4**, 181 (1918).

[5] *Proc. Nat. Acad. Sci.*, **4**, 387 (1918).

[6] THIS JOURNAL, **39**, 1598 (1917).

[7] *Proc. Nat. Acad. Sci.*, **2**, 718 (1916).

[8] *Z. anorg. allgem. Chem.*, **98**, 1 (1916).

[9] THIS JOURNAL, **36**, 2332 (1916).

[10] *Ibid.*. **41**, 718 (1919).

is the most trustworthy the value given by it should be adopted. The other sulfate determinations are questionable.

**Samarium.**—The atomic weight of samarium has been determined by Stewart and James[1] from the ratio between the chloride and silver. The value found is 150.44, which is essentially that given in the table. No change is needed.

**Dysprosium.**—Engle and Balke,[2] by conversion of the oxide into the chloride, found Dy = 164.228. Later, by the same method, Kremers, Hopkins, and Engle[3] found Dy = 163.83. This discordance, like that already shown for yttrium, led the last named chemists to determine the ratio between dysprosium chloride and silver, which gave 162.52. The earlier method is discredited and the last value, rounded to 162.5, seems to be the one best entitled to acceptance.

**Erbium.**—For this element, by the oxide-chloride method, Wichers, Hopkins, and Balke[4] obtained values ranging from Er = 168.00 to 168.84. The method of determination is thus again shown to be untrustworthy.

**Thorium.**—In a long series of concordant analyses of thorium bromide, Hönigschmid[5] finds Th = 232.152 from the silver ratio and 232.150 from the silver bromide ratio when Br = 79.916. The value Th = 232.15 should be adopted for general use. He also studied thoria from uranium ores, which contained ionium. For this mixture he obtained an atomic weight slightly in excess of 231.50. This may approximate to the unknown atomic weight of ionium.

**Uranium.**—The latest series of determinations of the atomic weight of uranium by Hönigschmid and Horovitz[6] was based like their earlier series upon analyses of the tetrabromide. Two sets of analyses were made, one upon a bromide which had been fused in bromine vapor, the other in nitrogen. The value obtained ranged from U = 238.04 to 238.16, the latter being in harmony with their former determinations. The rounded figure 238.2 is given in the table.

**Helium.**—Taylor,[7] using the microbalance for determining the density of helium, finds He = 4.0008. Guye,[8] in a recalculation of the data, finds He = 3.998. The value 4 should be retained.

**Argon.**—From the density and compressibility of argon, Leduc[9] finds A = 39.91. He regards the second decimal as uncertain, and advises the adoption of the rounded value 39.9.

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[1] THIS JOURNAL, **39**, 2605 (1917).

[2] *Ibid.*, **39**, 67 (1917).

[3] *Ibid.*, **40**, 598 (1918).

[4] *Ibid.*, **40**, 1615 (1918).

[5] *Z. Elektrochem.*, **22**, 18 (1916).

[6] *Monatsh.*, **37**, 185 (1916).

[7] *Phys. Rev.*, **10**, 653 (1917).

[8] *J. chim. phys.*, **16**, 46 (1918).

[9] *Compt. rend.*, **167**, 70 (1918).

### INTERNATIONAL ATOMIC WEIGHTS, 1920.

| | Symbol | Atomic weight. |
|---|---|---|
| Aluminum | Al | 27.1 |
| Antimony | Sb | 120.2 |
| Argon | A | 39.9 |
| Arsenic | As | 74.96 |
| Barium | Ba | 137.37 |
| Bismuth | Bi | 208.0 |
| Boron | B | 10.9 |
| Bromine | Br | 79.92 |
| Cadmium | Cd | 112.40 |
| Caesium | Cs | 132.81 |
| Calcium | Ca | 40.07 |
| Carbon | C | 12.005 |
| Cerium | Ce | 140.25 |
| Chlorine | Cl | 35.46 |
| Chromium | Cr | 52.0 |
| Cobalt | Co | 58.97 |
| Columbium | Cb | 93.1 |
| Copper | Cu | 63.57 |
| Dysprosium | Dy | 162.5 |
| Erbium | Er | 167.7 |
| Europium | Eu | 152.0 |
| Fluorine | F | 19.0 |
| Gadolinium | Gd | 157.3 |
| Gallium | Ga | 70.1 |
| Germanium | Ge | 72.5 |
| Glucinum | Gl | 9.1 |
| Gold | Au | 197.2 |
| Helium | He | 4.00 |
| Holmium | Ho | 163.5 |
| Hydrogen | H | 1.008 |
| Indium | In | 114.8 |
| Iodine | I | 126.92 |
| Iridium | Ir | 193.1 |
| Iron | Fe | 55.84 |
| Krypton | Kr | 82.92 |
| Lanthanum | La | 139.0 |
| Lead | Pb | 207.20 |
| Lithium | Li | 6.94 |
| Lutecium | Lu | 175.0 |
| Magnesium | Mg | 24.32 |
| Manganese | Mn | 54.93 |
| Mercury | Hg | 200.6 |
| Molybdenum | Mo | 96.0 |
| Neodymium | Nd | 144.3 |
| Neon | Ne | 20.2 |
| Nickel | Ni | 58.68 |
| Niton (radium emanation) | Nt | 222.4 |
| Nitrogen | N | 14.008 |
| Osmium | Os | 190.9 |
| Oxygen | O | 16.00 |
| Palladium | Pd | 106.7 |
| Phosphorus | P | 31.04 |
| Platinum | Pt | 195.2 |
| Potassium | K | 39.10 |
| Praseodymium | Pr | 140.9 |
| Radium | Ra | 226.0 |
| Rhodium | Rh | 102.9 |
| Rubidium | Rb | 85.45 |
| Ruthenium | Ru | 101.7 |
| Samarium | Sa | 150.4 |
| Scandium | Sc | 44.1 |
| Selenium | Se | 79.2 |
| Silicon | Si | 28.3 |
| Silver | Ag | 107.88 |
| Sodium | Na | 23.00 |
| Strontium | Sr | 87.63 |
| Sulfur | S | 32.06 |
| Tantalum | Ta | 181.5 |
| Tellurium | Te | 127.5 |
| Terbium | Tb | 159.2 |
| Thallium | Tl | 204.0 |
| Thorium | Th | 232.15 |
| Thulium | Tm | 168.5 |
| Tin | Sn | 118.7 |
| Titanium | Ti | 48.1 |
| Tungsten | W | 184.0 |
| Uranium | U | 238.2 |
| Vanadium | V | 51.0 |
| Xenon | Xe | 130.2 |
| Ytterbium (Neoytterbium) | Yb | 173.5 |
| Yttrium | Yt | 89.33 |
| Zinc | Zn | 65.37 |
| Zirconium | Zr | 90.6 |

In the above table of atomic weights proposed for 1920, few changes have been made from the values given in the last preceding table. The new values are A = 39.9; B = 10.9; Ga = 70.1; Th = 232.15; and Yt = 89.33. In addition to these the atomic weight of nitrogen should be changed from 14.01 to the more precise value 14.008. The latter figure represents all the best determinations, and is probably correct to within 1 in the third decimal place. For so small a value the change is insignificant.

Signed, F. W. Clarke,
T. E. Thorpe,
G. Urbain.

[Contribution from the Electrochemical Laboratories of the University of Manchester.]

# THE OCCLUSION OF HYDROGEN AND OXYGEN BY METAL ELECTRODES.

## Criticism of the Paper by Harding and Smith.[1]

By Edgar Newbery.

Received May 26, 1919.

The very careful work and ingenious apparatus of Harding and Smith call for some remarks of appreciation; and at the same time the theory of conducting hydrogen as developed by them appears to be open to doubt. The following comments are not offered in any spirit of carping criticism, but rather with the thought of friendly collaboration and interchange of views, and the object of reaching the real truth underlying some very interesting phenomena.

When a current is first passed through an electrolytic cell containing a palladium cathode in dilute acid, hydrogen ions are discharged upon the cathode surface and the monatomic hydrogen thus formed is at once absorbed by the metal, being kept in the monatomic form by the dissociating action of the solvent metal. This hydrogen will gradually diffuse to the interior of the metal, and, since the solution has a lower conductivity than the pure metal, the electric resistance of the metal will rise.

After a comparatively short time the external layers of metal will become saturated with hydrogen and the single potential of the metal solid solution will be that of a hydrogen electrode. Hydrogen ions, on discharging, will now no longer disappear into the metal but will tend more and more to stick on the outer surface, being held there by electrostatic forces, thus insulating the outlying parts of the electrode. New ions must therefore penetrate farther and farther into the surface before they can discharge. These ions are again followed by others which arrive faster than the discharged ions can collect together to form molecules, and consequently "blocks" will occur in the large crevices (large compared with an ion) in the metal surface. Since these latest arrivals carry electric charges opposite in sign to the charge on the electrode and are separated from the electrode only by the diameters of two or three atoms or molecules, inconceivably great pressures are set up which may easily attain a

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[1] This Journal, 40, 1508 (1918).