CHANGES IN THE 1955 ATOMIC CONSTANTS OCCASIONED BY REVISION OF μ_e/μ_0*

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An error has been found in the theoretical calculation by Karplus and Kroll[1] of the "anomaly" ratio, μ_e/μ_0 (of the magnetic moment of the electron, μ_e, to the Bohr magneton, μ_0). The calculation has been independently repeated by three different authors, Kroll,[2] Petermann,[3] and Sommerfield,[4] all of whom are now in agreement as to the corrected value of the numerical coefficient, 0.328, in the quantum electrodynamic correction term in α^2/π^2. The formula should therefore read

$$\mu_e/\mu_0 = (1+\alpha/2\pi - 0.328\,\alpha^2/\pi^2), \qquad (1)$$

and if we put $\alpha^{-1}=137.039$ we find for μ_e/μ_0 the value

$$\mu_e/\mu_0 = 1.0011596130.$$

Clearly μ_e/μ_0 is very insensitive to small changes in α^{-1}. A change of one unit in the third decimal place of α^{-1} changes μ_e/μ_0 by only 0.83 unit in its eighth decimal place. Since there is now very little doubt indeed of the value of α^{-1} to 3 decimals, as given above, this value of μ_e/μ_0 seems quite secure to the eighth decimal place. The theoretical value of μ_e/μ_0 has, as a result of this correction, been increased by 14.3 parts per million (ppm) relative to the value given by the older (incorrect) theoretical formula, in which the numerical coefficient of the last term was -2.973.

μ_e/μ_0 was an important input datum (appearing as one of the auxiliary constants) in the 1955 least-squares adjustment of Cohen, DuMond, Layton, and Rollett.[5] The 14.3-ppm change affects three of the input equations of that adjustment (in Table II p. 366 of reference 5) as follows: the numeric 4.0 in the third equation changes to 2.6, the numeric -2.3 in the fourth equation changes to -3.7, and the numeric 13.5 in the eighth equation changes to 14.9. (It should further be recalled that, as a result of the 1955 analysis, four of the eleven equations of aforesaid Table II were eliminated from the final adjustment, namely the sixth, the seventh, the ninth, and the tenth, because of evidence indicating systematic errors.)

The purpose of this note is to give the changes, in the values of seven of the more important atomic constants of our 1955 adjustment, which result because of this 14.3-ppm increase in the input datum, μ_e/μ_0. These changes are shown in ppm in Table I along with the resulting revised values of a number of the constants. The Faraday, F, and $\Lambda = \lambda_g/\lambda_s$, the x-unit to milliangstrom-unit conversion factor, are seen to be the quantities least effected by this change. It is worthy of note that the correction of this error in μ_e/μ_0 has restored the least-squares adjusted output value of Λ to much closer agreement with what we believe to be the most probable directly measured value. It should be pointed out, however, that Table I shows only the changes occasioned by the 14.3-ppm change in μ_e/μ_0, all the other input data remaining as they were in the final 1955 adjustment,[6] although several other new sources of information which may occasion changes are now in the making.

Redeterminations are now either under way or in a few cases completed for some five other important input data bearing on the atomic constants as follows: redeterminations of the Faraday by D. A. McInnes at the Rockefeller Institute for Medical Research, using the iodine coulometer, and by D. M. Craig, using a perchlorate silver voltameter at the National Bureau of Standards; redeterminations of λ_g/λ_s by H. A. Kirkpatrick working as a guest in the laboratory of Professor J. Mack at the University of Wisconsin and by J. A. Bearden and A. J. Bearden

Table I. Changes (in ppm) to be expected in seven important output values for a 14.3-ppm change in the electron magnetic moment anomaly ratio, μ_e/μ_0

e	m	h	α	Λ	N	F
-27.0	-12.1	-40.0	-14.0	-7.6	26.3	-1.0

Corrected values after making 14.3-ppm change in μ_e/μ_0

e	=	4.80273×10^{-10} esu
m	=	9.1082×10^{-28} g
h	=	6.62391×10^{-27} erg sec
α	=	7.29719×10^{-3}
α^{-1}	=	137.0391
Λ	=	1.002031
N	=	6.02502×10^{23} (g mole)$^{-1}$ (Physical at. wt.)
F	=	2.89366×10^{14} esu(g mole)$^{-1}$ (Physical at. wt.)
F	=	9652.18 emu(g mole)$^{-1}$ (Physical at. wt.)

at Johns Hopkins; completed redeterminations of the velocity of light by K. D. Froome, by E. Bergstrand, and others, under way at the U. S. National Bureau of Standards; a remarkably accurate redetermination of γ, the gyromagnetic ratio of the proton, just completed by Bender and Driscoll[7] at the U. S. National Bureau of Standards; redeterminations of the important transfer constant, g, the acceleration due to gravity, which exerts a frequently overlooked effect on the measurement of many other constants.[8] Two efforts by theoretical physicists[9] to derive the complete correction terms for the effect of the finite extension of the nuclear (proton) charge and magnetic dipole distributions in the expression connecting α with the very accurately measured hyperfine structure shift, $\Delta\nu_H$, in hydrogen still leave the question in an unsatisfactory state because of lack of knowledge of the part played by the virtual meson field in perturbing the electric and magnetic interaction between the electron and the proton in hydrogen.

Because of this array of new information which promises to be forthcoming in the next one or two years we feel it would be premature at present to make a complete new least-squares adjustment accompanied with a long table of derived values of constants and conversion factors. It seems unlikely that any of the values as given in our 1955 tables will be modified seriously outside the error measures (standard deviations) tabulated in that adjustment. The changes will chiefly permit giving the values with increased precision. The information in this letter is discussed in much greater detail in a recent paper,[10] which also gives a complete review of the entire present experimental foundation of our knowledge of the constants.

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[1] M. Karplus and N. M. Kroll, Phys. Rev. 81, 73 (1951).

[2] So far as we know, N. M. Kroll has not publicly announced his verification. We are gratefully indebted for this information to private correspondence with A. Petermann.

[3] A. Petermann, Helv. Phys. Acta 30, 407 (1957).

[4] C. M. Sommerfield, Phys. Rev. 107, 328 (1957).

[5] Cohen, DuMond, Layton, and Rollett, Revs. Modern Phys. 27, 363 (1955).

[6] We deem it preferable to give independently the effects of changes in various input data rather than showing the combined result of a number of these, at least until a complete new least- squares adjustment is prepared. In the following references the evidence for and the result, of changing another input datum, the directly observed value of λ_g/λ_s (the first equation in Table II of reference 5), has already been discussed. How great this change will be can at present only be roughly estimated. J. W. M. DuMond and E. R. Cohen, Phys. Rev. 103, 1583 (1956); J. W. M. DuMond, Suppl. Nuovo cimento 6, 77 (1957); E. R. Cohen and J. W. M. DuMond, Handbuch der Physik (Springer-Verlag, Berlin, 1957), Vol. 35, p. 86; Cohen, Crowe, and DuMond, The Fundamental Constants of Physics (Interscience Publishers, New York, 1957), p. 178.

[7] P. L. Bender and R. L. Driscoll, Minutes of the August 13, 1958, Boulder, Colorado, Conference on Electronic Standards and Measurements, Paper No. 1.3. (Published versions of all papers read at the Boulder Conference mentioned in this and succeeding references are planned to appear in Transactions of the Institute of Radio Engineers under the Professional Group on Instrumentation.)

[8] The role played by g in determinations of other important constants has been ably discussed by R. D. Huntoon and A. G. McNish of the United States National Bureau of Standards in the following two papers: R. D. Huntoon and A. G. McNish, Nuovo cimento, 6, 146 (1957); R. D. Huntoon, Minutes of the August 13, 1958, Boulder, Colorado, Conference on Electronic Standards and Measurements, Paper No. 1.1.

[9] A. M. Sessler and R. L. Mills, Phys. Rev. 110, 1453 (1958). C. K. Iddings and P. M. Platzman, California Institute of Technology (to be published).

[10] Jesse W. M. DuMond, Minutes of the August 13, 1958 Boulder, Colorado, Conference on Electronic Standards and Measurements, Paper No. 1.2.

NUCLEAR SPIN OF 12.6-HOUR IODINE-130†

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The nuclear spin of 12.6-hr I^{130} has been measured by means of an atomic-beam magnetic-resonance experiment and found to be 5. The apparatus used to make this measurement was designed for the observation of the nuclear spins and hyperfine structure of the radioactive halogen isotopes and has been described elsewhere.[1]

The I^{130} was produced in the Berkeley 60-inch cyclotron by bombarding powdered tellurium metal with 12-Mev protons, by the use of the reaction $Te^{130}(p,n)I^{130}$. The radioactive iodine was evaporated from the target material in an electric furnace and collected upon a cooled