Brief Overview of the CODATA 2010 Adjustment of the Values of the Constants

The principal responsibility of the Committee on Data for Science and Technology (CODATA) Task Group on Fundamental Constants (TGFC) is periodically to provide the world-wide scientific and technological communities with a self-consistent set of internationally recommended values of the basic constants and conversion factors of physics and chemistry.

The 2010 set of recommended values is the result of applying the same procedures as in previous adjustments and is based on a least-squares adjustment with, in this case, $N = 183$ items of *input data*, $M = 87$ variables or "unknowns," also called *directly adjusted constants* (or simply *adjusted constants*), and degrees of freedom $\nu = N - M = 96$. The statistic "chi-squared" for the adjustment is $\chi^2 = 76.8$ with probability $p(\chi^2|\nu) = 0.925$ and Birge ratio $R_B = (\chi^2/\nu)^{1/2} = 0.894$.

A significant number of new results became available for consideration, both experimental and theoretical, between the 31 December 2010 closing date of the 2010 adjustment and the 31 December 2006 closing date of the 2006 adjustment, its immediate predecessor. However, those affecting the determination of the fine-structure constant α, Planck constant h, molar gas constant R, Newtonian constant of gravitation G, Rydberg constant R_∞, and rms proton charge radius r_p are deserving of special mention in this brief overview, because of the inherent importance of these constants and, in the case of α, h, and R, their impact on the determination of the values of many other constants. (Recall that constants that are not among the directly adjusted constants are calculated from appropriate combinations of those that are directly adjusted.)

Fine-structure constant α. An improved measurement of the electron magnetic moment anomaly a_e, the discovery and correction of an error in its theoretical expression, and an improved measurement of the quotient $h/m(^{87}\mathrm{Rb})$ have led to a new 2010 value of α with a relative standard uncertainty $u_r = 3.2 \times 10^{-10}$ compared to $u_r = 6.8 \times 10^{-10}$ of the 2006 value. Perhaps more significant, because of the correction of the error in the theory, the 2010 value of α shifted significantly and now exceeds the 2006 value by 6.4 times the u_r of that value. This change has rather profound consequences, because many constants depend on α.

Planck constant h. A new value of the Avogadro constant N_A with $u_r = 3.0 \times 10^{-8}$ obtained from highly enriched silicon with amount of substance fraction $x(^{28}\mathrm{Si}) \approx 0.99985$ and which replaces the 2006 value based on natural silicon provides an inferred value of h with essentially the same uncertainty. This uncertainty is somewhat smaller than $u_r = 3.6 \times 10^{-8}$ of the most accurate directly measured watt-balance value of h. Because the two values disagree, their a priori assigned uncertainties were increased by a factor of two to reduce the insistency to an acceptable level; hence u_r of the recommended values of h and N_A are 4.4×10^{-8}, only slightly smaller than $u_r = 5.0 \times 10^{-8}$ of the corresponding 2006 values. The 2010 value of h exceeds the 2006 value by the fractional amount 9.2×10^{-8} while the 2010 value of N_A is smaller than the 2006 value by the fractional amount 8.3×10^{-8}. As for α, a number of constants

depend on h and consequently the 2010 recommended values of these constants reflect the change in h.

Molar gas constant R. Five consistent new values of the molar gas constant together with the two previous consistent values, with which the new values also agree, have led to a new 2010 recommended value of R with $u_r = 9.1 \times 10^{-7}$ compared to $u_r = 1.7 \times 10^{-6}$ of the 2006 value. The 2010 value is smaller than the 2006 value by the fractional amount 1.2×10^{-6} and u_r of the 2010 value is a little over half that of the 2006 value. This shift in value and reduction in uncertainty is reflected in a number of constants that depend on R.

Newtonian constant of gravitation G. Two new values of G resulting from two new experiments, each with comparatively small uncertainties but in disagreement with each other and with earlier measurements with comparable uncertainties, led to an expansion of the a priori assigned uncertainties of the G data by a factor of 14 compared to a factor of 10 in 2006. In both cases the expansion was necessary to reduce the inconsistencies to an acceptable level. This increase has resulted in a 20 % increase in u_r of the 2010 recommended value of G compared to that of the 2006 value: 12×10^{-5} vs. 10×10^{-5}. Furthermore, the 2010 recommended value of G is smaller than the 2006 value by the fractional amount 6.6×10^{-5}.

Rydberg constant R_∞ and proton radius r_p. New experimental and theoretical results that have become available in the last four years have led to the reduction in uncertainty of the recommended value of the Rydberg constant R_∞ from $u_r = 6.6 \times 10^{-12}$ to 5.0×10^{-12}, and the reduction in uncertainty from 0.0069 fm to 0.0051 fm of the proton rms charge radius r_p based on spectroscopic and scattering data but not muonic hydrogen data. Data from muonic hydrogen are so inconsistent with the other data that they have not been included in the determination of r_p and thus do not have an influence on R_∞. The 2010 value of R_∞ exceeds the 2006 value by only the fractional amount 1.1×10^{-12} and the 2010 value of r_p exceeds the 2006 value by only 0.0007 fm.

Timing of detailed report. It is expected that a preprint of the article that describes in detail the 2010 adjustment of the values of the constants will be completed, posted on this Web site, and submitted for publication by the end of 2011 or early in 2012.