CODATA Recommended Values of the Fundamental Physical Constants: 2014

Summary

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The compilation of the 2014 self-consistent set of values of the basic constants and conversion factors of physics and chemistry recommended by the Committee on Data for Science and Technology (CODATA) for international use has recently been completed by its Task Group on Fundamental Constants (TGFC). The new values can be found at physics.nist.gov/constants, arXiv and the CODATA Zenodo Collection. They are based on a multi-variant least-squares adjustment that takes into account all data available through 31 December 2014.

As a working principle, the validity of the physical theory underlying the adjustment is assumed. This includes special relativity, quantum mechanics, quantum electrodynamics (QED), the standard model of particle physics, including *CPT* invariance, and the exactness of the relationships between the Josephson and von Klitzing constants K_J and R_K and the Planck constant h and elementary charge e. Although the possible time variation of the constants continues to be an active field of both experimental and theoretical research, to date there has been no confirmed observation of a variation relevant to the data on which the 2014 recommended values are based.

2014 Values: Reduction in Uncertainty

A significant number of new results became available for consideration, both experimental and theoretical, from 1 January 2010, after the closing date of the 2010 adjustment, through 31 December 2014, the closing date of the 2014 adjustment. Overall, the recommended values fundamental constants have become more accurate, i.e., their uncertainties have decreased, due to improved measurements and theoretical calculations of the measurable quantities that depend on the constants. For example, compared to the CODATA 2010 recommended values,

- The 2014 value of the relative mass of the electron $A_r(e)$ has a relative uncertainty of 2.9×10^{-11}, a reduction in uncertainty by a factor of 14.
- The 2014 value of the fine-structure constant α has a relative uncertainty of 2.3×10^{-10}, a reduction by a factor of 1.4.
- The 2014 value of the Newtonian constant of gravitation G has a relative uncertainty of 4.7×10^{-5}, a reduction by a factor of 4.7.
- The 2014 value of the Planck constant h has a relative uncertainty of 1.2×10^{-8}, a reduction by a factor of 3.7.
- The 2014 value of the Boltzmann constant k has a relative uncertainty of 5.7×10^{-7}, a reduction by a factor of 1.6.

Challenges with Input Data for the Proton RMS Electric Charge Radius r_p

As is the case with all CODATA adjustments of the fundamental physical constants, a major challenge is the treatment of discrepant input data. For the 2014 adjustment the input data for the proton root-mean-square (rms) electric charge radius r_p remained a puzzle. The value of r_p from muonic hydrogen experiments has a smaller uncertainty by more than a factor of 10 than that from a combined value of r_p from electron-proton scattering data and hydrogen (H) and deuterium (D) spectroscopy, yet differs by over a factor of five times the uncertainty of their difference, or "5σ". To address this discrepancy, the TGFC invited the principle investigators and experts involved with the experiments and theory related to muonic hydrogen, electron-proton scattering, and H and D spectroscopy to its 2014 meeting held 3-4 November 2014 at the International Bureau of Weights and Measures (BIPM). Based on the advice of these experts, it was decided not to include the muonic hydrogen results in the 2014 adjustment (for details on the November 2014 meeting, see http://www.bipm.org/cc/TGFC/Allowed/Minutes/CODATA_Minutes_14-BIPM-public.pdf). To help address other input-data issues, CODATA co-organized a workshop 1-6 February 2015 in Eltville, Germany where various issues with the analysis of the electron-proton scattering data as well as with some of the acoustic gas thermometry data were resolved (see https://indico.gsi.de/conferenceDisplay.py?confId=2742).

2018 CODATA Recommended Values and the New SI

CODATA is presently preparing for its major role in a significant revision of the International System of Units (SI) scheduled for adoption in the fourth quarter of 2018. This "New SI" will be based on exact numerical values for h, e , the Boltzmann constant k, and the Avogadro constant N_A (for more information, see: http://www.bipm.org/en/measurement-units/new-si/). In 2011 at its 24th meeting the General Conference on Weights and Measures (CGPM) invited CODATA to continue to provide least-squares adjusted, recommended values of the fundamental constants, h, e, k, and N_A in particular, since these values will be those used for the revised SI. Because of the good progress made in both experiment and theory since the 31 December 2010 closing date of the 2010 CODATA adjustment, the uncertainties of the 2014 recommended values of h, e, k and N_A are already at the level required for the adoption of the revised SI by the 26th CGPM in the fall of 2018. The formal road map to redefinition includes a special CODATA adjustment of the fundamental constants with a closing date for new data of 1 July 2017 in order to determine the exact numerical values of h, e, k, and N_A that will be used to define the New SI. A second CODATA adjustment with a closing date of 1 July 2018 will be carried out so that a complete set of recommended values consistent with the New SI will be available when it is formally adopted by the 26th CGPM. Ordinarily the closing date for the regularly scheduled CODATA adjustment carried out every four years—in this case the 2018 CODATA adjustment—would have been 31 December 2018. However, the normal date has been advanced by six months so that the 2018 set of CODATA recommended values will not only be consistent with the New SI, but ready for all to use at the exact same time the New SI becomes a reality.