CCEM/19-04.3

CCEM 2019 Report from CODATA Task Group for Fundamental Constants

Barry Wood

BIPM March 28 2019

Outline

NRC·CNRC

- CODATA TGFC
- TGFC's Role in SI Redefinition
- The 2017 special LSA
- Final Values of Planck, Avogadro & Boltzmann constants
- Is the TGFC out of a job?
- Comments about the Fine structure & Rydberg constants
- The 2018 LSA.

ICSU & CODATA

There is a group that has been setting these values for over 50 years!

CODATA Task Group on Fundamental Constants - established in 1969 - “to periodically provide the scientific and technological communities with a self-consistent set of internationally recommended values of the basic constants and conversion factors of physics and chemistry based on all of the relevant data available at a given point in time.”

The Task Group sanctions the data selection and methodology of the adjustment of the recommended values of the constants.

CODATA

- Committee on Data for Science and Technology (CODATA) – was established in 1966 - is an interdisciplinary Scientific Committee of the International Council for Science (ICSU), which works to improve the quality, reliability, management, and accessibility of data of importance to all fields of science and technology.

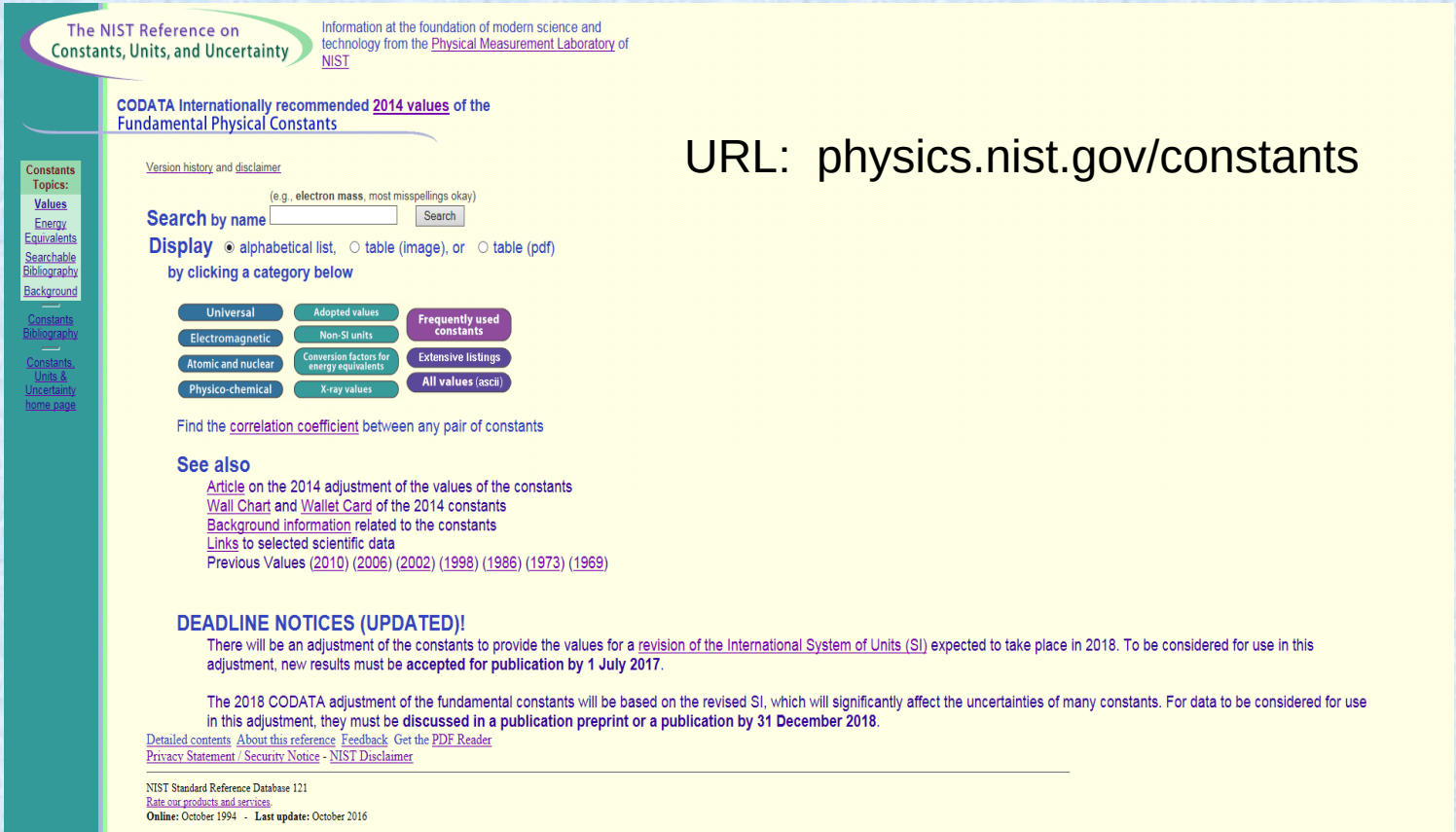
- CODATA Task Group on Fundamental Constants - established in 1969 - “to periodically provide the scientific and technological communities with a self-consistent set of internationally recommended values of the basic constants and conversion factors of physics and chemistry based on all of the relevant data available at a given point in time.”

- The Task Group sanctions the data selection and methodology of the adjustment of the recommended values of the constants.

TGFC Members

- K. Pachucki, University of Warsaw. Poland (Chair)
- D. B. Newell, NIST, USA (CoChair)
- F. Cabiati, Istituto Nazionale di Ricerca Metrologica, Italy
- E. de Mirandés, BIPM, France
- A. Surzhykov, PTB, Germany
- K. Fujii, National Metrology Institute of Japan, Japan
- S. G. Karshenboim, D. I. Mendeleyev Institute of Metrology, Russia
- H. Margolis, NPL, UK
- P. J. Mohr, NIST, USA
- E. Tiesinga, NIST, USA
- F. Nez, Laboratoire Kastler-Brossel, France
- M. Wang, IMP, China
- B. M. Wood, National Research Council, Canada
- J. Qu, National Institute of Metrology, China
- T. J. Quinn, CBE FRS, France (Emeritus)
- B. N. Taylor, NIST, USA (Emeritus)

How to get the values



URL: physics.nist.gov/constants

SI Redefinition

In essence, the change involves *exactly fixing the values* of 7 constants that set the scale of the SI units :

- c – speed of light — $E = m c^2$
- $\Delta\nu$ – ground state hyperfine splitting frequency of ^{133}Cs
- h – Planck constant — $E = h\upsilon$
- e – the elementary charge — *charge on a proton*
- k – Boltzmann constant — $E = k T$
- N_A – Avogadro constant — *number of entities in a mole*
- K_{cd} – luminous efficacy of 540×10^{12} Hz radiation

c, h, e, k, N_A are fundamental physical constants

CODATA TGFC's Role

CODATA TGFC has been recommending self-consistent values of the fundamental constants since 1973.

The CCU decided that the TGFC would prepare the values for redefinition. The CCU and CIPM approved those numbers.

The task group prepared a Special LSA for the SI redefinition.

This will be followed by a full LSA using the revised SI and its uncertainties

Metrologia

SHORT COMMUNICATION • OPEN ACCESS

The CODATA 2017 values of *h*, *e*, *k*, and N_A for the revision of the SI

D B Newell[1], F Cabiati, J Fischer, K Fujii, S G Karshenboim, H S Margolis, E de Mirandés, P J Mohr, F Nez, K Pachucki + Show full author list

Published 29 January 2018 • © 2018 BIPM & IOP Publishing Ltd
Metrologia, Volume 55, Number 1

Article PDF

Figures References

+ Article information

Abstract

Sufficient progress towards redefining the International System of Units (SI) in terms of exact values of fundamental constants has been achieved. Exact values of the Planck constant *h*, elementary charge *e*, Boltzmann constant *k*, and Avogadro constant N_A from the CODATA 2017 Special Adjustment of the Fundamental Constants are presented here. These values are recommended to the 26th General Conference on Weights and Measures to form the foundation of the revised SI

CGPM 2011: Resolution A
- now with final numbers

- **takes note** of the *intention* of the International Committee for Weights and Measures to propose a *revision to the SI* as follows:
- the *International System of Units*, the SI, will be the system of units in which:

  - the ground state hyperfine splitting frequency of the caesium 133 atom $\Delta\nu(^{133}Cs)_{hfs}$ is exactly 9 192 631 770 hertz
  - the speed of light in vacuum c is exactly 299 792 458 metre per second,
  - the Planck constant h is exactly $6.626\,070\,15 \times 10^{-34}$ joule second,
  - the elementary charge e is exactly $1.602\,176\,634 \times 10^{-19}$ coulomb,
  - the Boltzmann constant k is exactly $1.380\,649 \times 10^{-23}$ joule per kelvin,
  - the Avogadro constant N_A is exactly $6.022\,140\,76 \times 10^{23}$ reciprocal mole,
  - the luminous efficacy K_{cd} of monochromatic radiation of frequency 540×10^{12} Hz is exactly 683 lumen per watt,

And the Resulting Value for *h*

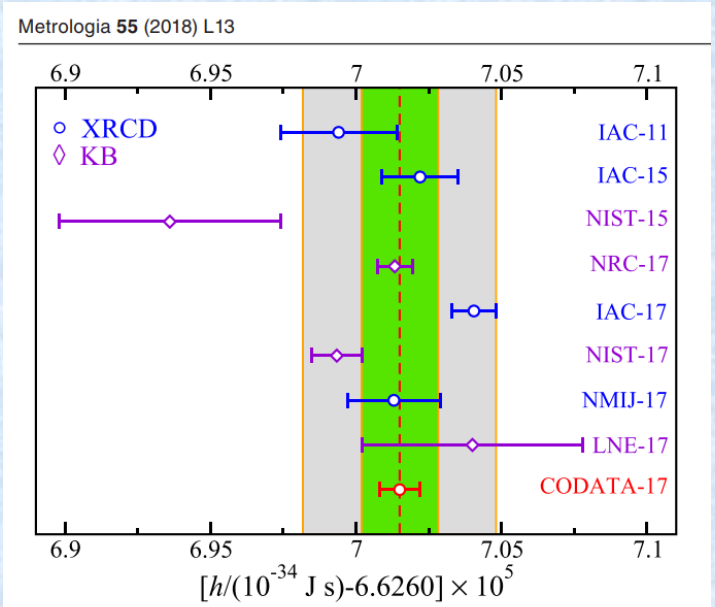


Figure 1. Values of the Planck constant h inferred from the input data in table 1 and the CODATA 2017 value in chronological order from top to bottom. The inner green band is ±20 parts in 10^9 and the outer grey band is ±50 parts in 10^9. KB: Kibble balance; XRCD: x-ray-crystal-density.

Table 2. The CODATA 2017 adjusted values of h, e, k, and N_A.

Quantity	Value	Rel. stand. uncert u_r
h	$6.626\,070\,150(69) \times 10^{-34}$ J s	1.0×10^{-8}
e	$1.602\,176\,6341(83) \times 10^{-19}$ C	5.2×10^{-9}
k	$1.380\,649\,03(51) \times 10^{-23}$ J K^{-1}	3.7×10^{-7}
N_A	$6.022\,140\,758(62) \times 10^{23}$ mol^{-1}	1.0×10^{-8}

Table 3. The CODATA 2017 values of h, e, k, and N_A for the revision of the SI.

Quantity	Value
h	$6.626\,070\,15 \times 10^{-34}$ J s
e	$1.602\,176\,634 \times 10^{-19}$ C
k	$1.380\,649 \times 10^{-23}$ J K^{-1}
N_A	$6.022\,140\,76 \times 10^{23}$ mol^{-1}

Is TGFC Out of a Job ?

- With Planck, Avogadro, elementary charge and Boltzmann fixed, what is left?

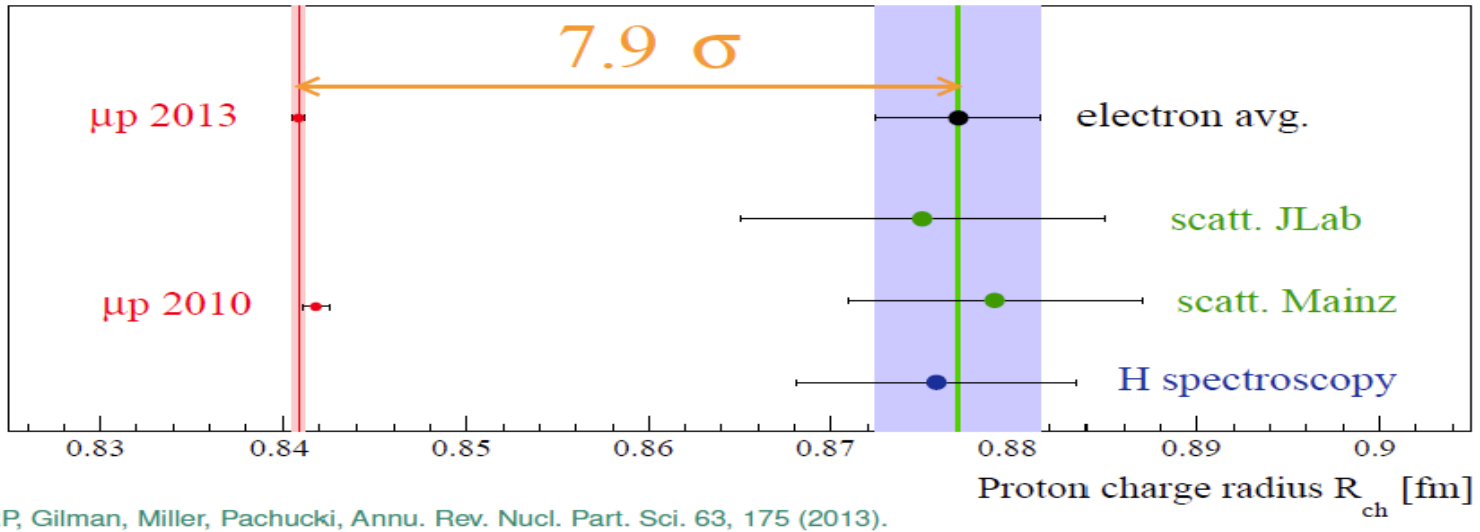
- Rydberg, fine structure constant, Newtonian gravitational constant and many other derived and lesser known constants including μ_0 .

The proton charge radius controversy: a significant correction for the Rydberg

The proton rms charge radius measured with

electrons: 0.8770 ± 0.0045 fm

muons: 0.8409 ± 0.0004 fm



RP, Gilman, Miller, Pachucki, Annu. Rev. Nucl. Part. Sci. 63, 175 (2013).

Timeline

The 2018 Least Squares Adjustment is underway.

Submission of new data is closed and analysis is proceeding.

Both the Rydberg and fine structure constant are expected to change, but not enough to affect electrical measurements ($< 3\times10^{-10}$).

Public release of the 2018 LSA is anticipated around May 20, 2019