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# Adjustment of the Fundamental Constants by the CODATA TGFC

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# Summary and Outline

- Memorandum of Understanding between CODATA/TGFC and the BIPM is in last stages of being approved.
- Impact of a redefinition of the second on the determination of the constants
- Highlights of the 2018 adjustments of fundamental constants.
- Some latest developments, since the previous deadline 31 Dec 2018.
- Deadline for data for the next adjustment is 31 December 2022.

# Redefinition of the second

- D. Newell, member of our TGFC is the External Contributor to the CCTF Task Force group B for redefining the second.
- The TGFC is formulating a formal statement on the impact of redefining the second

## In brief

- ✓ At this time, we do not anticipate any impact on the work of the task group.
- ✓ The relative uncertainties of the fundamental constants are significantly larger than that of the current time standard based on the atomic cesium clock.
- ✓ Caveat: This statement does not necessarily hold for the most accurate experimental data that enters the adjustment of the constants.

# Highlights of the 2018 adjustment

- We are in the new regime where $c$, $\hbar$, $e$, and $k$ are exact in SI.

- Electro Magnetic constants $\mu_0$ and $\varepsilon_0$ are no longer exact. In fact,

$$\mu_0 = 4\pi\ 10^{-7}\ \text{x}\ 1.000\ 000\ 000\ 55(15)$$

- The molar mass of 12-Carbon is no longer exact. In fact,

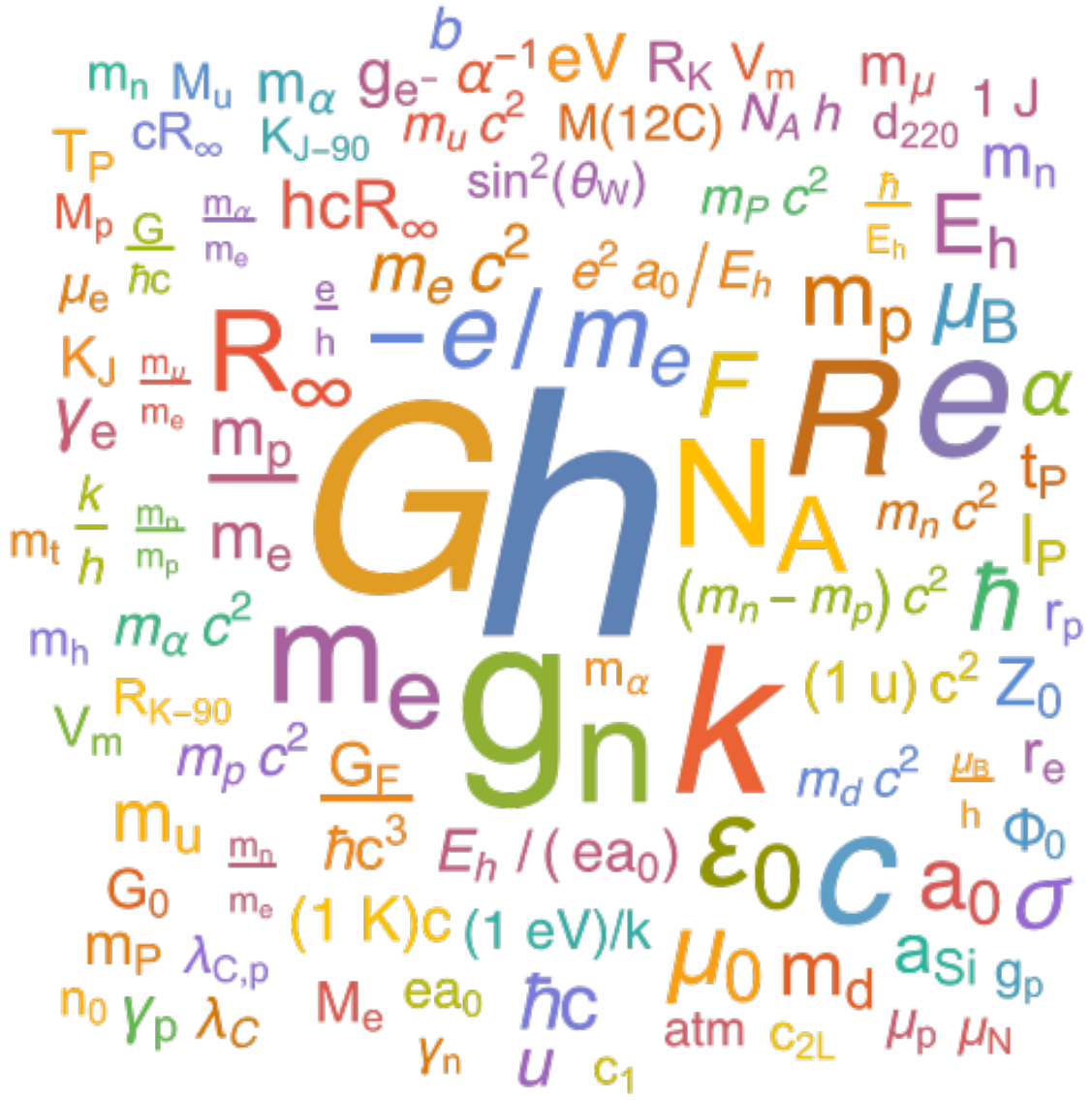
$$\mathrm{M}(^{12}\mathrm{C}) = 12 \times \left(1 - 3.5(3.0) \times 10^{-10}\right)\ \mathrm{g\,mol^{-1}}$$

- We observe no ``problems'' after three years since their introduction.

# Usage of the CODATA/TGFC fundamental constant website

- Usage data of fundamental constants at
  http://physics.nist.gov/constants

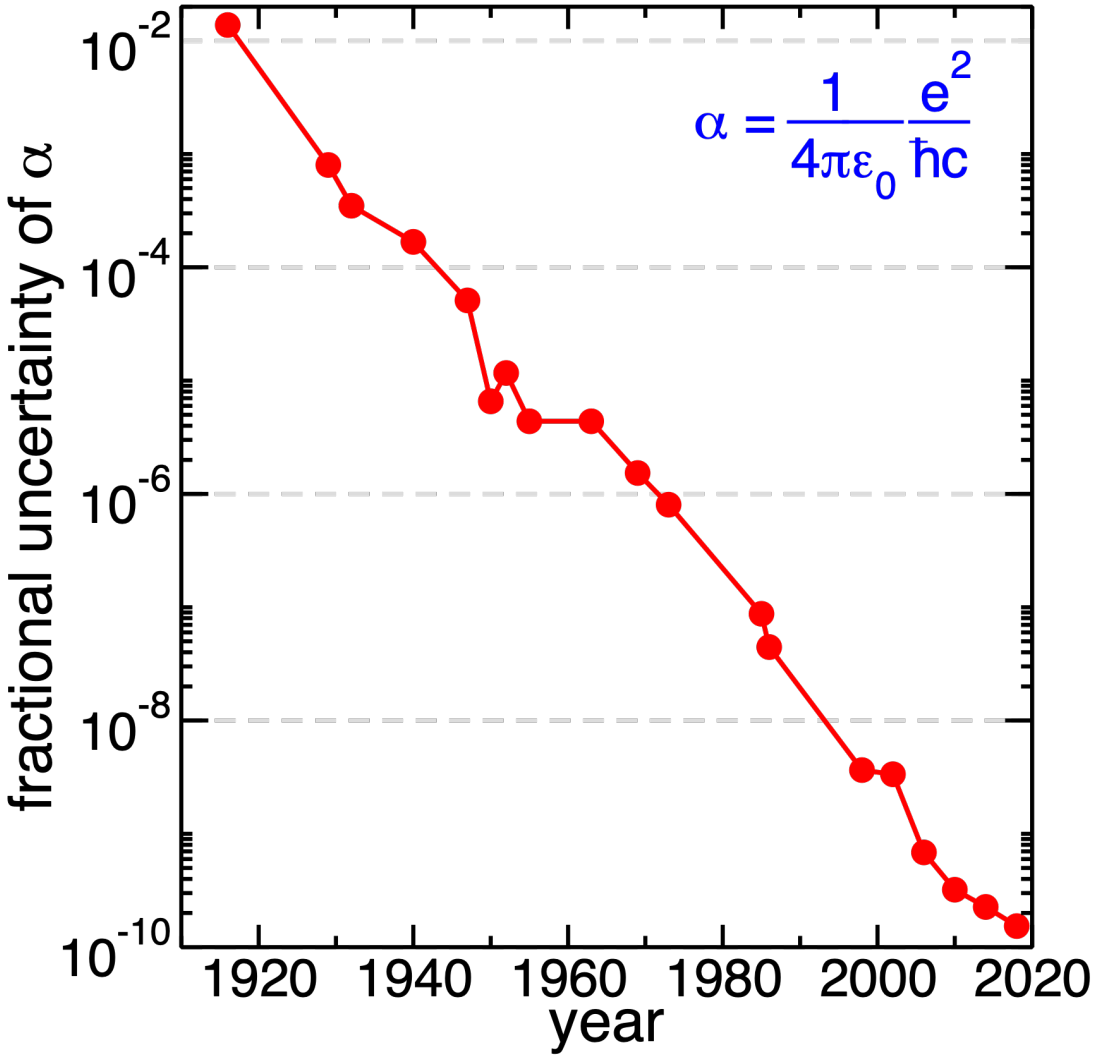
✓ A larger symbol implies more requests




$g_n$ is earth's gravitational acceleration

# Relevance for science

- The latest value of the fine-structure constant $\alpha$ [LKB, 2020] has a fractional unc. of $81 \times 10^{-12}$
  - ✓ $\alpha$ reflects the strength of the Coulomb potential in natural units
- Value has improved exponentially over time.
- True for most constants. This indicates the liveliness of the field of fundamental constants and its relevance.



# Persistent and marginal inconsistencies

- Newton's Gravitational constant

  Uncontrolled systematic uncertainties among experiments

- Fine-structure constant determinations differ by more than 2 sigma

- Data on mass of the proton is inconsistent by far more than 2 sigma

- The theoretical and experimental value for the g-factor of the muon are so inconsistent that we do not use the theory.

  ✓ In 2018 only one experiment was available.

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# Recent developments

- A new measurement of the *muon* magnetic moment became available
  - ✓ It has similar uncertainty as the old experiment and is consistent with it.
- Four values for the proton and deuteron mass have been reported
  - ✓ Two are based on a novel method: spectroscopy of molecular $HD^+$
- Two measurements of hydrogen and deuterium transition frequencies have been published.
- The theory for the hydrogen energy levels and that for the g-factor of the bound electron keep improving.
- The task group plans to add “new” constants to its purview in order to keep up with the newest research directions.
  - ✓ That is, all electromagnetic moments of the lightest nuclei.

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# Finally,

- The deadline for data for the next adjustment is 31 December 2022.