Report on the Meeting of the CODATA Task Group on Fundamental Constants
Document TGFC-21-02

12:00 a.m. – 15:30 p.m. (UTC), Monday, 19 October 2020

Virtual Meeting

Prepared by

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1. Opening of the meeting and introductions

The meeting opened at 12:00 AM (UTC) Monday and introductions were made. Members of the Task Group on Fundamental Constants in attendance: Krzysztof Pachucki (chair), Eite Tiesinga (vice-chair), Kenichi Fujii, Savely Karshenboim, Helen Margolis, Peter Mohr, Dawid Newell, François Nez, Randolf Pohl, Jifeng Qu, Andrey Surzhykov, Meng Wang, Barry Wood, Barry Taylor (emeritus member), Franck Bielsa (BIPM liaison), and Toshihiro Ashino (CODATA liaison).

The following members sent their regrets: Richard Hartshorn (CODATA liaison).

Present as observers: Joachim Ullrich (CCU president), Michael Stock (BIPM), Richard Davis (BIPM), Robert Hanisch (NIST), Enrico Massa (INRiM), Nadine de Courtenay (U of Paris).

2. Review of the agenda

The agenda, TGFC/20-01, was reviewed and accepted.

3. Task Group administration

a. membership

Due to the lack of contact, the memberships of Franco Cabiati and Estefania De Mirandes were terminated. As a BIPM representative Estefania De Mirandes has been replaced by Franck Bielsa.

b: membership contact information for posting

Members have been requested to check and update contact information

4. Review of the report of the Task Group meeting held on Monday, 7 October 2019, BIPM, France

The minutes of the last meeting, (TGFC/19-03 and TGFC/20-02), were approved without change and will be posted on the unrestricted website.

5. Status of the publication of the CODATA 2018 Adjustment of the fundamental constants

The publication of the CODATA 2018 Adjustment has been delayed due to the need for thorough checking of the manuscript regarding the changes introduced by the redefinition of the SI. The manuscript has been sent to all members of the CODATA TGFC by Eite Tiesinga during this meeting, with a request to send comments within a month. It will then be submitted to Review of Modern Physics and the Journal of Physical and Chemical Reference Data. S. Karshenboim proposed that E. Tiesinga (the main author) send the manuscript to TGFC members at earlier stages of writing, to avoid excessive delays in the publication. After the meeting, E. Tiesinga received a long list of remarks and corrections from TGFC members, which allowed him to improve the manuscript. The paper was eventually published in June 2021 as Rev. Mod. Phys. **93**, 025010 (2021).

6. Review of relationship among the fine-structure constant, Hartree energy, electron mass, and atomic mass constant

E. Tiesinga initiated a scientific discussion on these relationships by showing Fig. 3 of the RMP manuscript and presenting the motivation for the figure in relation to the revised SI, where both the Planck constant and the speed of light are exact. He pointed out that the Rydberg and Hartree energies are essentially the same. It was followed by a lively discussion by R. Pohl, S. Karshenboim, K. Pachucki, B. Taylor, and E. Tiesinga, about details of the figure contents. Specifically, R. Pohl argued that the Lyman-α transition frequency is not being measured with a sufficient accuracy and the conclusion was to correct the figure by using the expression “other transition frequencies”. After this discussion, E. Tiesinga presented details regarding the least square adjustment with relation to exact physical constants in the revised SI. As a consequence, μ_0 no longer has a fixed value of $4\pi \bullet 10^{-7}$ N A^{-2}.

7. Update of new or expected results concerning:

a: Hydrogen and deuterium energy levels: theory and experiments

and

g: Muonic hydrogen and deuterium Lamb shifts and charge radii

K. Pachucki informed us that there have been several spectroscopic measurements on atomic hydrogen in 2018-2019: The 2S-2P transition by E. Hessels, which leads to a proton charge radius r_p that is in agreement with that derived from muon-based data. Other measurements were those of the 2S-4P transitions by a group in Garching and the 1S-3S transition both in Garching and Paris. F. Nez told us that Paris group is currently talking data on 1S-3S transition in deuterium. Next, R. Pohl presented an overview of the proton radius determination from H/D and μH/μD spectroscopy and mentioned an upcoming direct determination of r_p by electron scattering of a hydrogen target by the PRAD collaboration. Moreover, he then informed us about results of a new Lamb shift measurement in μ-He performed at PSI. Their result for the alpha-particle charge radius was in agreement with the old value, obtained by electron scattering of a He target. K. Pachucki pointed out that this is an important result, because it shows that there is no need for introducing ``new'' physics or violation of lepton universality in muonic-atom spectra. He also mentioned another project for the determination of the nuclear charge radius of the alpha-particle from ^{4}He spectroscopy and accurate calculations of helium energy levels. Moreover, K. Pachucki described two ongoing measurements in Garching and Amsterdam of the 1S-2S transition in He^+, and possibility of a novel accurate determination of the Rydberg constant.

S. Karshenboim pointed out the importance of measuring the isotope shift in the 2S-2P transition for μ-^{4}He and μ-^{3}He. R. Pohl pointed out that the alpha-particle charge radius might be important for the interpretation of precise measurements of transitions in antiprotonic helium.

S. Karshenboim informed us about his recent improvements in calculating higher-order (two-loop and three-loops) QED effects in H and He^+. K. Pachucki described calculations of additional nuclear polarizability effects in μD, which lead to agreement with 1S-2S isotope shift H/D measurements. Finally, R. Pohl mentioned his plans for improved measurement of the Lamb shift in μH and thus a more accurate determination of the proton charge radius. One, however, needs better estimates of the effect of the proton polarizability on μH energy levels.

b: Electron and muon magnetic moment anomalies:

No new results for the *g*-2 of the electron, but there is promise of an improved measurement by G. Gabrielse. A new value can improve the determination of the fine structure constant. Announcement of a new result for *g*-2 of the muon is planned for late 2020. S. Karshenboim informed us about progress in lattice calculations of the hadronic contribution to the muon *g*-2.

c: Atom recoil measurements for determination of the fine structure constant α:
E. Tiesinga pointed out that the fractional uncertainty of α over the last 100 years has improved exponentially and that the most recent value has a $1.5 \bullet 10^{-10}$fractional uncertainty. A cesium atom-recoil measurement has already been included in the determination of α, while a new measurement with rubidium is ongoing in Paris with the aim to further improve α. [The rubidium results for α by the Paris collaboration has been published in Nature **588**, 61 (2020).]

d: Relative atomic masses
E. Tiesinga raised the point about the importance of Rb and Cs masses in atomic mass units for the alpha determination. Wang Meng informed us about new results for the masses of the light nuclei p, d, t. A new global atomic mass evaluation will be published next year. S. Karshenboim raised a question regarding correlation coefficients for measurements of the masses of d, t and α by a group at the University of Washington, USA. E. Tiesinga mentioned new measurements of proton and deuteron masses by Fink and Myers in Phys. Rev. Lett. **124**, 013001 (2020) (p/d ratio) and Rau *et al*., Nature **585**, 43 (2020). This last measurement is inconsistent with 2018 CODATA. Richard Davies reminded us about the necessity of new measurements of the helion mass.

e: Electron-proton mass ratio from HD+ spectroscopy
E. Tiesinga informed us about a new measurement of e/p and e/d mass ratios from precise molecular spectroscopy in HD^+ by Alighanbari *et al*. in Nature **581**, 152 (2020) and by Patra *et al*. in Science **36**, 1238 (2020). K. Pachucki briefly described the physical ideas behind this new way of mass ratio determinations.

f: Atomic *g*-factors in hydrogenic ions (^{12}C and ^{28}Si)
No new results. A. Surzhykov informed us about plans of a group in Heidelberg, Germany to remeasure the electronic g-factor in the $^{12}C^{5+}$ hydrogenic ion.

h: Electron-proton and electron-deuteron scattering and charge radii

R. Pohl informed us about plans for improved scattering measurements of the proton charge radius by the Jefferson Lab and that of the deuteron (and the proton) in Mainz. Mainz is considering scattering measurements for ^{3}He, ^{4}He, Li, and Be charge radii as well. R. Pohl described planned experiments with muons scattering from protons at PSI and by COMPASS at CERN. R. Pohl asked the question, whether we can gain information about fundamental constants from measurements of the ground-state hyperfine splitting of μH. The consensus answer was that the complexity of the proton polarizability prohibits any accurate determination of fundamental physical constants.

i: Proton magnetic moment in units of nuclear magnetons

The proton magnetic moment is the only nuclear magnetic moment measured directly for the 2018 adjustment. K. Pachucki described an improved determination of the deuteron magnetic moment from the shielding differences in the HD molecule. No new information regarding the magnetic moment of other light nuclei was available, although a Heidelberg group is working on a value for ^{3}He. K. Pachucki also informed us about the possibility to determine of ^{3}He magnetic moment from NMR measurements and the calculation of the shielding factor in ^{3}He.

j: Electron-to-muon mass ratio and muon-to-proton magnetic moment ratio

B. Taylor asked a question about the status of muonium hyperfine-structure measurements in Japan. No progress has been reported.

k: Gravitational constant *G*

According to D. Newell, no new results have been reported since 2018. E. Tiesinga described the status of the determination of G, which is the least-known fundamental constant with many contradicting measurements. An in-depth discussion was devoted to the analysis of G-measurements and the necessity of an expansion of all measurement uncertainties by a factor of 3.9.

l: **New directions: electromagnetic moments of light nuclei**

K. Pachucki pointed out that in the near future we need to include charge radii of all light nuclei, that is of the proton, deuteron, triton, helion and alpha particle, into the adjustment.

Moreover, K. Pachucki suggested there exists a need for including magnetic dipole and electric quadrupole moments of light nuclei in our CODATA adjustments. He raised the problem that tabulated data on such moments for light nuclei are not always correct, as

the data do not necessarily include all physical corrections determining the value of these moments. As an example, K. Pachucki and E. Tiesinga presented the history of the determination of the deuteron electric quadrupole moment. This presentation was followed by an intense discussion between S. Karshenboim, K. Pachucki, and R. Pohl without definite conclusions regarding the need for including these moments in the adjustment. The discussion will be continued during the next CODATA TGFC meeting.

The consensus was that we add the alpha-particle and helion charge radii in the CODATA adjustment.

8: Other topics

a: MOU with the BIPM

M. Stock introduced the topic of a memorandum of understanding (MoU) between the BIPM and collaborating organizations. MoU between CODATA TGFC and BIPM was approved after introducing several corrections and will be signed by representatives of BIPM and CODATA.

b: Upcoming workshops to endorse

S. Karshenboim informed us that the next Workshop on Precision Physics and Fundamental Physical Constant (FCC) is planned for October, 2021 in Slovakia. The workshop has been endorsed by the TGFC. The next International Conference on precision physics of simple atomic systems (PSAS) is preliminary scheduled for May 2022 in Wuhan, China.

9: Date and location of the next Task Group meeting

The next CODATA TGFC meeting due to the continuing COVID-19 pandemic will be virtual and take place a week before CCU meeting. The dates are September 14 and 15, 2021, hours 12:00 - 14:00 (CET). There was a discussion regarding the possibility to organize the hybrid meeting. A decision will be taken in due time, although a virtual meeting was preferred.

10: Adjournment

The meeting was adjourned at 15:30 UTC.