

Report on the Meeting of the CODATA Task Group on Fundamental Constants

9:00 am Saturday, 30 Aug 2014

Brazil

Prepared by B. Wood, National Research Council

The meeting was held just after the CPEM 2014 conference in the Imperial Room of the Windsor Barra Hotel, Rio de Janeiro, Brazil. In attendance were the following members of the Task Group on Fundamental Constants (TGFC): David Newell (chair), Barry Wood (vice chair), Kenichi Fujii and Peter Mohr.

The following sent their regrets: Franco Cabiati, Joachim Fischer, Savely Karshenboim, Estefania de Mirandés, François Nez, Krzysztof Pachucki, Terry Quinn, Barry Taylor, Zhang Zhonghua and Claudine Thomas (BIPM Liaison).

Present as observers were: Nick Fletcher of BIPM, Stephan Schlaminger of NIST and Bernd Fellmuth of PTB.

The agenda of the meeting (TGFC/14-01) is included as the last page of this report, and the following summary is numbered according to the corresponding agenda item.

1. The meeting was opened and introductions were made by all attendees. A moment of silence was held in memory of Jeff Flowers, a TGFC member, who died since the last meeting. He will be missed.
2. The agenda was reviewed and approved.
3. The Minutes of the Task Group meeting held Monday, 10 June 2013 at BIPM were considered. Since there were so many TGFC members absent from this meeting it was agreed to reconsider this item at the next meeting to be held on Nov. 3 at BIPM. At that time approval of the minutes could be made by a larger number of TGFC members.
4. Update of new or expected results concerning
 - a. Stephan Schlaminger showed the present status of the most significant Planck constant determinations, see document TGFC/14-02. This included the NIST-07 and NIST 14 watt balance results both performed on the NIST-3 apparatus but which are mutually discrepant. It also included the METAS-11 and NRC-14 watt balance results and the IAC-11 Avogadro result. During the CPEM conference a number of people have commented that they feel that the NIST-14, NRC-14, METAS-11 and IAC-11 results are in reasonable agreement and in their opinion fulfilled the numerical conditions of the recent CCM recommendation.

Schlaminger also reviewed the present status of possible Planck constant or XRCD results that would be available by the next LSA cut-off date of 12/31/2014. The IAC is still anticipating a new result of N_A to be published in time. NRC may have a new watt balance result but Wood has indicated that this is becoming increasingly unlikely. NIST is not expecting a new result but does commit to providing a guidance document on how to deal with their 2007 and 2013 results. METAS, BIPM and NZ do not plan to have new watt balance results nor does the NIM joule balance project. The LNE watt balance project indicated that they may have a result but that it would have a large uncertainty. There was little new information concerning the watt balance project from KRISS.

- b. Kenichi Fujii then discussed document TGFC/14-03 entitled Present Status of the Avogadro Project. It detailed a number of issues.

He reviewed the most recent molar mass results from PTB, NRC, NIST and NMIJ. He also indicated that the chemistry/mass spectrometry experts are planning to publish an explanation for the discrepant NRC value. However, most agreed that this discrepancy while important does not have a major impact on the h and or N_A result.

He then explained recent advances in lattice parameter measurements at INRIM and PTB, as well as lattice homogeneity measurements at NMIJ. Of particular note is that the recent d_{220} results from INRIM that are smaller by 80% of the 2011 uncertainty.

He continued describing work on the volume measurements of the ^{28}Si enriched spheres, their mass measurements and surface evaluations.

He described the IAC schedule including a new data submission (revised N_A): in November or December of 2014.

Finally Fujii compared the NIST-14, IAC-11 and NRC-14 results with their weighted mean and concluded that from a Chi squared perspective they were consistent. He went on to outline work needed to achieve a 2018 redefinition of the SI.

- c. Bernd Fullmuth introduced document TGFC/14-04 entitled 'Current status of the redefinition of the kelvin (CCT meeting May 2014)'. It summarizes the recent work on R and k .

Fellmuth began by summarizing acoustic gas thermometry (AGT). The NPL group has achieved a result with the lowest relative uncertainty of 0.712 ppm but it is in disagreement with the LNE-11 result by 2.8 ppm. Moldover's 1988 result sits comfortably in the middle of this debate.

Work continues at LNE examining smaller and larger quasi-spheres of BeCu.

Acoustic and microwave modelling studies of at LNE, the gas molar mass studies at INRiM and consistency between double cylindrical resonators at NIM-NIST are all contributing to establish the range, applicability and confidence in the modelling.

Fellmuth described the dielectric constant gas thermometry (DCGT) work at PTB. The aim of this work is to achieve 3 ppm and has already published a 4.3 ppm result in 2013.

Noise thermometry at NIST and NIM was described. While there has been significant progress in extraneous noise rejection and frequency extension there were not any new results. Both groups hope to achieve about 6 ppm in 2014.

The Doppler Broadening Thermometry (DBT) work at LPL+LNE+CNAM and UniNA+INRiM continues. A 2013 result achieved 24 ppm and both groups are hoping for ~10 ppm.

A more detailed list and a graph of these results are contained in Doc TGFC/14-04 pages 24-25. The CCT-WGSI believes that the present data supports a new value for k with relative uncertainty of $\approx 5 \times 10^{-7}$. However there is also the concern that the TGFC 1% self-consistency policy somehow excludes the DCGT result from being used as an alternative method. This has resulted in a modification of the CCT recommended requirements for redefinition of the SI.

Fellmuth also solicited the task group's help applying the correct covariance to the AGT data. The attempt by the community with the 2010 LSA is now believed to be flawed and a better solution is being sought, see documents TGFC14-05, 05a, 05b and 05c. The problem is that many believe that there are strong correlations especially among the Type B uncertainty components. David Newell stated that the task group would consider this issue and approach Mike Moldover for advice on how to 'recompile' the various uncertainty budgets.

- d. Dave Newell presented document TGFC/14-06. The first six slides detailed the status of the Planck, Avogadro and Boltzmann constants which are described in more detail in earlier sections. Slides 7-9 outlined the gravitational constant results. Since 2010 there are three new results. BIPM-13 is a new result using a different method. The result agrees well with the BIPM-01 result. The Flor-14 result uses atomic gravimetry and in its first attempt achieved a relative uncertainty of 150 ppm and a value near the JILA-10 result. Finally, there is the CUI-14 result of Riley

Newman, document TGFC14_07 which is actually three individual results (he leaves it to the TGFC to aggregate them into one result). Although there are three new results the inherent inconsistency of this data set remains.

- e. Newell went on in slide 10 of document TGFC/14-06b to review the fine structure constant. Kinoshita has a new mass independent 10th order QED value which in combination with the Harvard-08 anomalous magnetic moment of the electron yields a new fine structure result. It is 1.49 sigma larger than the CODATA-10 result. These results will also be reconsidered during the next meeting on Nov. 3.
- f. Peter Mohr began the Rydberg discussion and introduced document TGFC/14-08 'Atomic spectroscopy and the muonic hydrogen proton radius'.

The CODATA adjustment of the constants of physics includes precise frequency measurements in hydrogen and deuterium as input data. The theory of the hydrogen frequencies is expressed in terms of various constants, including the Rydberg constant, the radius of the proton, and the radius of the deuteron. The least-squares adjustment of these constants, along with other constants, determines the values that give the best agreement between theory and experimental values for the frequencies. In particular, this yields a value for the proton radius that may be associated with the spectroscopic data and hydrogen theory. The 2010 CODATA value for the proton radius is an average of the values from spectroscopic data and electron scattering experiments.

The charge of the proton is distributed over a radius of about 1 fm. This affects: electron scattering by protons and atomic energy levels. Pohl et al., (Nature, July 2010) made a measurement of the Lamb shift in muonic hydrogen (negative muon + proton) that implied a radius of the proton in 5 σ disagreement with the CODATA 2010 value.

Mohr then showed graphs illustrating the impact of this data on the Rydberg and the fine structure constants, as well as the radius of the proton and the charge and mass of the electron.

This subject will be the focus of the November 4 meeting.

- g. On slide 12 of document TGFC/14-06 there is a graph with the new Mainz-14 result of the proton magnetic moment with an uncertainty reduction of 2.5 times CODATA-10

- h. From Heidelberg there is a new relative mass of the electron determination with a factor of 10 improvement over CODATA-10. Peter Mohr will check but it seems that the previous point is 1.7 sigma from the new one.
 - i. Others – no comments
- 5. The timeline for the 2014 adjustment is preceeding much as expected. The issues will be reconsidered at the November 3 meeting.
- 6. Other topics
 - a. The timeline for possible adoption of the new SI in 2018 was briefly discussed. It was suggested that the cut-off date of the special LSA that is to be used to fix the values should be set as the date when the CIPM requests their LSA. If this is put in the public TGFC minutes it should suffice as public notification.
 - b. Peter Mohr requested that consideration of the additive uncertainty expansion technique be added to the next agenda.
 - c. Concerning radians/seconds and other unitless quantities. It was suggested that the task group should endorse the following statement. *The Task Group on Fundamental Constants recognizes that the unitless quantities will require adaptation for a more consistent and unambiguous use with other SI units.* This will also be discussed at the next meeting.
- 7. David Newell discussed recent Task Group administration matters. The task group's status is under renegotiation with CODATA and it may change its status into a permanent part of CODATA. This could result in a new classification and possibly a new name. These negotiations are at an early stage and more information may be available by the next meeting.
- 8. The next Task Group meeting will be held at BIPM, on the 3 – 4 November, 2014
- 9. The meeting was adjourned.

DRAFT AGENDA

CODATA Task Group on Fundamental Constants

9:00 am Saturday, 30 August 2014

Imperial Room, Windsor Barra Hotel, Rio de Janeiro, Brazil

1. Opening of the meeting and introductions; review of the agenda
2. Review of the agenda
3. Review of the report of the Task Group meeting held Monday, 10 June 2013

BIPM

4. Update of new or expected results concerning
 - a. Planck constant h and N_A
 - b. R and k
 - c. Gravitational constant
 - d. Alpha
 - e. Rydberg constant, muonic hydrogen, proton radius
 - f. Proton magnetic moment
 - g. Others
5. Timeline for 2014 adjustment
6. Other topics
 - a. Timeline for possible adoption of new SI in 2018
7. Task Group administration
8. Date and location of the next Task Group meeting
BIPM, 3 – 4 November, 2014
9. Adjournment