

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

7 July 2012, Gaylord National Resort, Washington DC USA

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The subject meeting was held at the Gaylord National Resort in Washington DC, USA. In attendance were the following Task Group members: E. de Mirandés, K. Fujii, S. G. Karshenboim, P. J. Mohr, D. B. Newell, F. Nez, K. Pachucki, T. J. Quinn, B. N. Taylor, B. M. Wood (Chair), and Z. Zhang. Present as observers were H. Bettin, Z. Li, T. Mai, E. Massa, L. Pitre, J. Qu, S. Schlamminger, and J. Stenger.

The agenda of the meeting is included as the last page of this report, and the following summary is numbered according to the corresponding agenda item.

1. The meeting opened at 9:30 and introductions were made.
2. The agenda of the meeting was reviewed and accepted.
3. A draft report of the Task Group meeting held on Friday, 17 June 2011 at the BIPM has been posted in the CODATA TGFC working documents for the 2011 June meeting. B. Taylor had minor corrections to be added.
4. Status and discussion of the RMP publication of the 2010 LSA. The paper has been submitted. Proofs should be available 16 July 2012 for review with an optimistic publication date on line of 10 August 2012 (B. Taylor). It was recommended to distribute the proofs to the task group members for comments (K. Pachucki) and it was agreed this will be done (P. Mohr).
5. Update of new or expected results concerning:
  - a. Rydberg and muonic hydrogen. F. Nez gave a presentation on the relevant data in determining the Rydberg constant and the proton charge radius (see document TGFC/12-03). In short, the discrepancy for the proton charge radius is still unresolved. A second transition in muonic hydrogen has been measured ( $2S_{1/2}^{F=0} - 2P_{3/2}^{F=1}$ ) that is consistent with the previous muonic hydrogen transition measurement which are both 0.3 meV discrepant from the prediction using the proton charge radius from CODATA 2010. Preliminary results for muonic deuterium were presented, however the comparison between theory and experiment is limited by the deuteron polarizability contribution to the 2S hyperfine structure. S. Karshenboim stated that the electron-proton scattering data are not convincing and that the new personnel working on the Mainz electron/proton scattering experiment need to comment on the uncertainty on older electron/proton scattering data. K. Pachucki encouraged new experiments involving muonic helium since the transitions are easier to calculate. A possible measurement may take place next year (F. Nez). B. Wood commented that the task group will need to prepare how to analyze the possible discrepant data for the next adjustment if the situation does not change.

- b. Alpha. B. Taylor summarized the new results from Kinoshita's QED calculations. The 8<sup>th</sup> order coefficient is improved by further numerical integrations, but more importantly the 10<sup>th</sup> order coefficient has been calculated and is larger than expected. It shifts the value of alpha by up to 2 standard uncertainties. B. Taylor asked if we should accept the new value's uncertainty or should we increase it. F. Nez commented that the calculations are on going. Other possible new data for the determination of alpha within two years are an improvement in the atom recoil measurement of  $h/m(^{87}\text{Rb})$  by a factor of 2 (Nez) and the BIPM calculable capacitor that is close to achieving a part in 10<sup>8</sup> accuracy. Results from the LNE calculable capacitor will take longer.
- c. *R* and *k*. J. Stenger was to present J. Fischer's presentation, but deferred to L. Pitre (see document TGFC/12-02). The data for *R* and *k* are still highly consistent. The recent, unpublished results from the NIM cylindrical Acoustic gas resonator are very encouraging with an uncertainty of 3 ppm (previous published uncertainty was 7.9 ppm). The NPL AGT has an issue with one of the five Argon gas bottles used in their experiments that shows significantly different impurity and isotopic compositions and is investigating the implications on their published results. While the Boltzmann data are highly consistent, the CCT requirement that there be consistent results from independent methods has not been met. It was speculated that if the Planck constant data was consistent and the Boltzmann data have not changed, the redefinition would most likely occur (T. Quinn).
- d.  $N_A$  and the Planck constant. H. Bettin gave a presentation on the status of the IAC (see document TGFC/12-06). There was discussion on how to redefine the SI by choosing *e* and any another constant that contained the dimension of mass, and on the required uncertainties and agreement of the relevant data to go forward with the redefinition. The discussion was moot because the framework of the new SI has already been established by the CGPM's resolution 1 and it's not the task group's mission to decide on what the requirements are to redefine the SI. It was pointed out that there could be two (highly correlated) values for  $N_A$  due to the two <sup>28</sup>Si spheres instead of one, increasing the available data (H. Bettin). Two other projects were introduced: a EMRP project (SIB03) to reconcile the discrepancies in the relevant data and the Kilogram – 2M project by the PTB to make four more <sup>28</sup>Si spheres. At the end of the IAC presentation the question was asked if the natural silicon data are to be used in future adjustments now that estimates in the isotopic abundances errors have been published (D. Newell). It was stated that the differences in the molar mass for natural silicon varies too much and therefore cannot be used.

B. Wood gave a presentation updating the status of the NRC watt balance (see TGFC/12-07). They have changed all the hardware involved with the two mass exchange errors and have reduced the uncertainty on the mass exchange errors to below 2 parts in 10<sup>9</sup>. With the modifications, they have made another

- determination of the Planck constant, reproducing the same value as their previous determination with a relative uncertainty of 35 parts in  $10^9$ . While the NRC and NPL results are correlated (to be determined), the mass exchange errors are not constant with time and therefore cannot be extrapolated back to the NPL results. The future efforts will involve a collaborative effort between NRC and NIST to reconcile the discrepancy between the two watt balances. A new vacuum balance is being installed in NRC to help in this effort. S. Schlamminger gave a short update on the NIST3 watt balance. It is currently operating with an overnight resolution of 15 parts in  $10^9$ . Systematic tests of 0.5 kg and 1 kg have been performed showing consistent results. An investigation of the dependence on magnetic field amplitude and polarity is ongoing. E. de Mirandés gave an update presentation on the other balance efforts (see TGFC/12-08). New data may be available from LNE within 2 years and from METAS and MSL within three years. Of note is that both PTB and NMIJ are considering starting watt balance efforts.
- e. Gravitational constant. T. Quinn has re-analyzed his data for two of the three methods for the second generation of the BIPM experiment and has a value that is very close to the old BIPM value with a relative standard uncertainty of around 30 parts in  $10^6$ . There is no official number yet. T. Quinn suggested hosting a special Royal Society meeting on the gravitational constant to encourage researchers to publish detailed papers on their experiments in the hope of uncovering the source of the large scatter among the data.
  - f. Others. The Atomic Mass Data Center is being transferred to the Institute of Modern Physics (IMP), Lanzhou, Peoples Republic of China, with a new set of relative atomic masses to be available soon.
6. TGFC report for the 2013 CCU meeting. It is important for the Task Group to prepare for the possible redefinition of the SI by the 25<sup>th</sup> CGPM in 2014 by having preliminary adjusted values of the constants available for the relevant meetings leading up to the 25<sup>th</sup> CGPM. The timeline (see TGFC/12-09) is that by September 2012 to start generating the next LSA. At the next task group meeting (10 June 2013) the Task Group will adopt a status report for the CCU meeting, 11-12 June 2013. Another LSA may be necessary in February 2014. If the redefinition proceeds, then it is the consensus of the Task Group that the closing date for data to be considered for new fixed values of the constants will be immediately after CPEM 2014. It is also the consensus of the Task Group that the closing date for data for the first adjustment within the new SI to be 31 December, 2014. A possible SI redefinition timeline draft is included at the end of this report.

Data submitted at the last moment will need to be critically reviewed. It was recommended to alert the Consultative Committees to be ready and ask the relevant working groups within the CC's to assist with the review of last minute submissions (T. Quinn).

7. General discussions about

- a. Alternative analysis techniques. A recent publication by Mana et al. from INRIM (Metrologia **49**, (4), 492-500 (2012)) suggests an investigation on the possible application of recognized probabilistic theories to the problem of averaging inconsistent data. F. Cabiati submitted document FCTG/12-04 on additive uncertainty expansions for inconsistent data sets. S. Karshenboim re-iterated that the adjustment method needs to be based on the data. There was concern raised about changing the methodology of the fundamental constants for the most important adjustment facing the Task Group – the assignment of the exact values of  $h$ ,  $e$ ,  $k$ , and  $N_A$  (D. Newell). If a new method is to be used, three conditions must be met (B. Wood): 1) the method must be proposed in detail; 2) the method must have the consensus of the task group; 3) the method must be publicized, accepted, and supported by the relevant outside committees.
- b. Comments about the speed of light. B. Wood highlighted the point that if it were found that neutrinos or other particles traveled faster than the speed of light, then the current definition (and number) for the speed of light within the SI would not change. The speed of light would remain a valuable fundamental constant although perhaps a refined definition might have to be introduced to accommodate the new discovery.

8. Other topics

9. Task Group administration. 1 January 2013 marks the end of B. Wood's sixth year as task group Chairman and at that time he will be replaced by D. Newell. To aid continuity B. Wood will serve as task group vice chairman for the following two years at which time a new vice chairman will be appointed by the chairman.

10. Date and location of the next Task Group meeting

- already decided. It will be held on 10 June 2013 at BIPM

11. Adjournment

**Possible SI Redefinition Timeline**  
**Draft of August 22, 2012**

**2012**

7 July **TGFC** meeting  
 Sep 2012-May 2013 **TGFC** begins next LSA calculations and prepares status report for 2013 CCU meeting (new data, analysis explanations,  $h$ ,  $e k$ ,  $N_A$  present values). Discussed by email  
 18-19 October CIPM 2<sup>nd</sup> 2012 meeting

**2013**

4-5 March CIPM Bureau meeting  
 10 June **TGFC** meeting  
 Acceptance of status report to CCU  
 11-13 June CCU meeting  
 Acceptance of TGFC status report. CCU prepares Recommendation on draft CGPM redefinition Resolution for CIPM consideration based on the report but with truncated numbers (X to indicate missing digits)  
 19-21 June CIPM 1<sup>st</sup> 2013 meeting  
 Discussion of CCU Recommendation  
 24-25 October CIPM 2<sup>nd</sup> 2013 meeting  
 CIPM prepares near final CGPM draft redefinition Resolution (in English) for Convocation of 25<sup>th</sup> CGPM in 2014

**2014**

February **TGFC** updates LSA for CCU/CIPM and near final CGPM draft redefinition Resolution for Convocation of 25<sup>th</sup> CGPM if required by new data. Update discussed within TGFC by email  
 March CIPM Bureau meeting\*\*\*  
 CIPM finalizes draft redefinition Resolution for Convocation of 25<sup>th</sup> CGPM  
 April Mailing of Convocation of 25<sup>th</sup> CGPM, including English and French final versions of CGPM draft redefinition Resolution  
 June CIPM 1<sup>st</sup> 2014 meeting\*\*\*  
 29 August **TGFC** closing date for data for final LSA for 25<sup>th</sup> CGPM final redefinition Resolution (last day of CPEM 2014 in Rio)  
 30 August **TGFC** meeting in Rio after CPEM 2014  
 Finalize decisions for final LSA  
 September **TGFC** completes final LSA, prepares report for CCU/CIPM/CGPM with final values of  $h$ ,  $e k$ ,  $N_A$ . Final LSA and report discussed within TGFC by email  
 September CCU meeting\*\*\*  
 October CIPM 2<sup>nd</sup> 2014 meeting\*\*\*  
 November 25<sup>th</sup> CGPM meeting\*\*\*  
 31 December Closing date for **TGFC** normal CODATA 4-year cycle LSA—first CODATA LSA to be based on New SI

\*\*\*Expected meeting dates but not yet finalized

## DRAFT AGENDA

### CODATA Task Group on Fundamental Constants

9:30 am Saturday, 7 July 2012

Gaylord National Resort, Washington DC

1. Opening of the meeting and introductions
2. Review of the agenda
3. Review of the report of the Task Group meeting held on Friday, 17 June 2011 at BIPM
4. Status and discussion of the RMP publication of the 2010 LSA
5. Update of new or expected results concerning
  - a. Rydberg and muonic hydrogen
  - b. Alpha
  - c.  $R$  and  $k$
  - d. Planck constant and  $N_A$
  - e. Gravitational constant
  - f. Others
6. TGFC report for the 2013 CCU meeting
7. General discussions about
  - a. alternative analysis techniques
  - b. comments about the speed of light
8. Other topics
9. Task Group administration
10. Date and location of the next Task Group meeting
  - already decided. It will be held on 10 June 2013 at BIPM
11. Adjournment