

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

13 September 2010, BIPM, Sèvres, France

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The subject meeting was held at the BIPM in Sèvres. In attendance were the following Task Group members: J. Fischer, J. Flowers, K. Fujii, S. G. Karshenboim, P. J. Mohr, D. B. Newell, F. Nez, K. Pachucki, T. J. Quinn, B. N. Taylor, C. Thomas, B. M. Wood (Chair), and Z. Zhang. Also present as observers were C. Bordé, R. Davis, G. Genevès, M. Kühne, I. Mills, A. Picard, M. Stock, A. Wallard, and J. Zhang.

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. Krzysztof Pachucki of the Institute of Theoretical Physics, University of Warsaw, joins the Task Group as a new member.
2. The agenda of the meeting was reviewed and accepted.
3. The report of the Task Group meeting on 19 June 2010 at KRISS was reviewed with no comments.
4. Review of data
 - 4.1. B. Wood gave a review of available data related to the Planck constant via watt balances, showing a graph of available data, soon to be published data, and a simple weighted mean with the lowest possible uncertainty. Publications of the NPL and the METAS watt balances are expected before Dec. 2010 with values of 0.30(0.17) ppm and -0.17(0.42) ppm respectively with respect to the 2006 LSA. (Note both the NPL and METAS results has since been changed and been submitted for publication.) There will be no results from the NRC(NPL) watt balance in time for the 2010 adjustment. It was noted that there are five watt balance results that are in reasonable agreement. C. Borde asked about a 0.5 kg problem with the NIST watt balance. While there were inconsistent data for a stainless steel mass, there now have been 0.5 kg silicon and stainless steel mass measurements that are consistent. The similarities between the two NIST results were questioned and when it was observed that covariance between the two is determined through the correlations of the individual uncertainty components, the discussion turned to mass traceability. The CCM wants the results tied back to the IPK and the CIPM will consider the recommendation to take out IPK to determine the relations between masses used in Watt Balance.
 - 4.2. K. Fujii gave a presentation on the IAC status for the determination of the Avogadro constant from enriched silicon. There is a 0.4 ppm discrepancy between the IRMM and PTB results for the molar mass determination, however only the PTB method of isotope dilution mass spectrometry will be use for the

final analysis. The most recent value for the Avogadro constant was - 0.148(0.030) ppm with respect to the 2006 LSA. (Note this result has since been changed and been submitted for publication.) This value has been corrected from the value presented at CPEM 2010 (KRISS) due to is a new surface analysis and will be submitted to Nature or PRL for publication. It was noted that the IRMM has been careful in publishing a new paper. The validity of ignoring the IRMM molar mass value was questioned, however the IRMM involves more steps, making it more susceptible to contamination. NIST has agreed to also perform isotope dilution mass spectrometry on ^{28}Si , but there will be no results available in time for the 2010 adjustment. There was much discussion with no conclusion on what to do with the natural Silicon data from 2004/2005 if there is no official statement from the IAC on known problems.

- 4.3. J. Fischer gave a review of available data related to the Boltzmann constant showing three acoustic gas thermometry (AGT) values in good agreement, however they're correlated through the analysis of the theory where the measured linewidths are larger than the theory. It was noted that the theory needs independent uncertainties associated with it. While not at the 1 ppm level desired by thermometry community, the Boltzmann constant has good, consistent results with possible new results with lower uncertainties by year end. It was noted that it would be desirable to have results from two different methods at the required uncertainty of a few ppm and it would be more convenient for the various efforts to express what is actually being measured (i.e. - Molar gas constant instead of the Boltzmann constant).
- 4.4. D. Newell gave a review of available data related to the gravitational constant. New results from the Huazhong University of Science and Technology, China, and JILA, U.S.A., have values that are -118(27) ppm and -290(21) ppm with respect to the 2006 LSA, respectively. Following established procedures, the weights will most likely need to be expanded. The 1982 Luther and Towler value was reconsidered, however it will not be included without significant input from the authors.
- 4.5. F. Nez gave a review of available data related to the fine structure constant. There is a new value using helium fine structure (M. Smiciklas and D. Shiner, PRL **105**, 123001 (2010)), albeit with a non competitive uncertainty of 20 ppb. It was decided to use the same procedure as the 2006 LSA, with the implication that the fine structure value will be solely defined by the Harvard measurement of g-2 and QED theory.
- 4.6. There was much discussion concerning the new data from the Lamb shift in muonic hydrogen and the impact on the charge radius of the proton and the Rydberg constant. In the end it was decided not to allow the new result to have a significant impact on the Rydberg constant and that there are three values of the proton charge radius. J. Flowers was asked to provide a suggestion on dealing with the discrepant data (see below):

Dealing with the Proton Size Discrepancy in CODATA 2010

Jeff Flowers, NPL

September 30, 2010

Three different groups of data provide input to the evaluation of the bound state nuclear rms proton charge radius R_p . The elastic electron proton scattering, the hydrogen spectroscopic data, and the Lamb shift in muonic hydrogen. In the CODATA 2006 adjustment only the first two of these were available. R_p was treated as a variable in the adjustment. Although the effect of deleting the scattering data for R_p and the deuteron radius R_d was evaluated (Table XLV of P. J. Mohr et al., RMP, vol. 80, pp. 633-98, 2008), the final result included both spectroscopic and electron scattering data and was $R_p = 0.8768(69) \times 10^{-15}$ m, ($u_r = 7.8 \times 10^{-3}$).

Close to the closing date for data in the 2010 adjustment the Lamb shift data in muonic hydrogen became available. This gives an independent determination of the proton size with significantly reduced uncertainty. However the value obtained $R_p = 0.84184(67) \times 10^{-15}$ m, ($u_r = 7.9 \times 10^{-4}$) is strongly discrepant with the earlier value which is mainly derived from hydrogen spectroscopy. The source of this discrepancy is still under active investigation.

To deal with this in the 2010 adjustment we will assume that the more likely source of the discrepancy is theory and not the hydrogen spectroscopy data which comes from multiple sources. So we will evaluate the Rydberg constant R_∞ based on all the available atomic transition frequencies in hydrogen, deuterium and antiprotonic helium but excluding the R_p and R_d data as a source, these then become outputs of this evaluation. The values of R_p and R_d thus produced are separately compared with those obtained from elastic electron proton or deuteron scattering and from the Lamb shift in muonic hydrogen, to produce recommended values of R_p and R_d .

The uncertainty of R_p is expanded due to the inconsistency in the data introduced by the muonic hydrogen Lamb shift data but by this choice of grouping the evaluation the uncertainty of the Rydberg constant is not increased.

5. Other topics

- 5.1. In general it was decided that data would not be excluded without written request by the researchers. K. Fujii is to send a letter to B. Wood to exclude the d_{220} NMIJ-04 value. P. Becker offered a possible explanation for the discrepant PTB h/m_n value due to the surface contamination in a email to B. Taylor, however he was not an author on the publication.
- 5.2. It was decided to report the gyromagnetic ratio of the proton both in air and in vacuum.
- 5.3. Recommendations and nominations for the SUNAMCO medal should be submitted to the Task Group chair and he or she will forward them to SUNAMCO.

6. If requested by the CCU and/or CIPM to provide a special adjustment for changes to the SI, the Task Group will oblige to provide guidance on the uncertainties, however the Task Group will continue with its four year adjustment cycle. There was a request to make the LSA available online, especially for reviewing the drafts of the 2010 adjustment. It was also recommended to have a workshop on the CODATA Task Group or a subset of a larger workshop to provide more transparency.
7. The Task Group is now official for another year, receiving a reduced budget of \$4,000 down from \$5,000.
8. The date and location of the next Task Group meeting was not decided but will be settled after the LSA is finalized.
9. Adjournment

DRAFT AGENDA

CODATA Task Group on Fundamental Constants

9:30 am Monday, 13 September 2010

BIPM

1. Opening of the meeting and introductions
2. Review of the agenda
3. Review of the report of the Task Group meeting on 19 June 2010 at KRISS
4. Review of Data
 - 4.1. Review of data related to the Planck constant via watt balances (Wood)
 - 4.2. Review of data related to the Avogadro constant and the Planck constant via XRCD (Fujii)
 - 4.3. Review of data related to the Boltzmann constant (Fischer)
 - 4.4. Review of data related to the gravitational constant (Newell)
 - 4.5. Review of data related to the fine structure constant (Nez)
 - 4.6. Review of data related to H and D transition frequencies and the charge radius of the proton
5. Other topics
 - 5.1. The NMIJ natural Silicon lattice spacing measurement (d_{220} NMIJ-04) and the PTB determination of the quotient h/m_n
 - 5.2. Gyromagnetic ratio of the proton
 - 5.3. It was proposed for CODATA to nominate someone for the SUNAMCO medal.
6. Discussion of interactions with CCU and the CIPM in preparation for the proposed changes to the SI
7. Task Group administration
8. Date and location of the next Task Group meeting
9. Adjournment