

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

19 June 2010

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The subject meeting was held at the KRISS in Daejeon, Korea. In attendance were the following Task Group members: J. Fischer, K. Fujii, S. G. Karshenboim, P. J. Mohr, D. B. Newell, F. Nez, B. N. Taylor, B. M. Wood (Chair), and Zhang Zhoughua. Also present as observers were N. S. Chung, B. Jeanneret, M Kraft, R. Liu, P. G. Park, Y. S. Song, and, L. Zhengkun.

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. Task group members were requested to provide any corrections to the information on the Task Group member list.
2. The agenda of the meeting was reviewed. There was a request (B. Taylor) to add discussion on the NMIJ natural Silicon lattice spacing measurement ( $d_{220}$  NMIJ-04) and the PTB determination of the quotient  $h/m_n$ .
3. The report of the Task Group meeting on 25 May 2009 at BIPM was reviewed. There was a membership announcement that Werner Martienssen died suddenly on January 29, 2010. On behalf of the Task Group, B. Wood has sent a note of condolences to his family.
4. List of significant new data and theory since May 2009
  - a. By measuring the Lamb shift in muonic hydrogen (Pohl et al., Nature **466** (7303), 213-218 (2010)), the charge radius of the proton has been determined with a factor of 10 lower uncertainty than the CODATA value, however 5 standard deviations from the CODATA value: -34960 (796) ppm with respect to the CODATA value. Either the Rydberg constant has to be shifted by 4.9 standard deviations, or the calculations of the QED effects in atomic hydrogen or muonic hydrogen atoms are insufficient.
  - b. There was a talk by M. O. Distler from Mainz University at the 2010 Precision Physics of Simple Atomic Systems Conference on new results from e-p scattering and a new value of the proton charge radius. The paper should be submitted in 3 months. They are also going to make public a Ph. D. paper by Jan Bernauer in July. The result is in a good agreement with the hydrogen value and disagrees with muonic hydrogen value.
  - c. A 10-times improved measurement of the Hydrogen-Deuterium 1S-2S isotope shift (Parthey et al., Phys. Rev. Lett. 104, 233001 (2010)) allows the calculation of the difference of the mean squared charge radii of deuterium and hydrogen at  $3.82007(65) \text{ fm}^2$ .

- d. There is a new determination of the gravitational constant  $G$  by the HUST group (Luo et al., Phys. Rev. Lett. **102**, 240801 (2009); Tu et al., Phys Rev D **82**, 022001 (2010)) with the results of -118 (27) ppm with respect to the 2006 LSA value.
  - e. A measurement of the  $2^3P_1-2^3P_2$  interval in helium with a 0.15 ppm relative uncertainty combined with corrected QED calculations for Helium fine-structure allows the determination of  $\alpha$  with an accuracy of 31 ppb, consistent with the 2006 LSA value (Pachucki and Yerokhin, Phys. Rev. Lett. **104**, 070403, 4 p. (2010)).
  - f. The uncertainty of the Si molar mass measurement has been investigated by means of a two-isotope model allowing an explicit calibration formula to be given and propagation of error analysis to be made (Mana et al., Int. J. Mass Spectrom. **289**(1), 6-10 (2010)). K. Fujii also reports that G. Mana has found some inconsistencies in the IRMM method in determining the K factors.
  - g. Other publications that will be considered during the 2010 LSA are as follows:
    - i. "Measurement of the 2S hyperfine interval in atomic hydrogen," Kolachevsky et al., Phys. Rev. Lett. **102**, 213002 (2009)
    - ii. "Nonrelativistic contributions of order  $\alpha^5 m_\mu c^2$  to the Lamb shift in muonic hydrogen and deuterium, and in the muonic helium ion," Karshenboim et al., Phys. Rev. A **81**, 060501 (2010)
    - iii. "Second-order corrections to the wave function at the origin in muonic hydrogen and ponium," Ivanov et al., Phys. Rev. D **80**, 027702 (2009)
    - iv. "Optical frequency measurement of the 1S-3S two-photon transition in hydrogen," Arnoult et al., <http://lanl.arxiv.org/pdf/1007.4794>
    - v. "Relativistic, QED, and nuclear mass effects in the magnetic shielding of  $^3\text{He}$ ," Rudzinski et al., J. Chem. Phys. **130**, 244102 (2009).
    - vi. Spin-orbit corrections of order  $m\alpha^6$  to the fine structure of the (37,35) state in the  $^4\text{He}$  p $\bar{p}$  antiprotonic helium atom," Korobov and Zhong, Phys. Rev. A **80**, 042506 (2009)
    - vii. There have been new experimental data on  $e^+e^-$  annihilation into hadrons. For the moment they have been available for the collaboration members. Their release is expected soon which will improve the theoretical mean value of  $g-2$ .
5. J. Fischer gave a general presentation on recent developments of Boltzmann constant experiments (TGFC/10-13). At least five new results are presented with numbers, four of which are already published and another that is expected to be published by December 31, 2010. The five main authors are Pitre, Djerroud, Castrillo, Gavioso and Sutton and their results are -0.65(2.68), 13.7(37.7), -51.0(159.3), -7.53(7.49) and -0.58(3.11) ppm with respect to the 2006 LSA value. Since Moldover's 1988 result has an uncertainty of 1.74 ppm, these results will

have only a minor numerical effect on the 2010 LSA value. It is unlikely to expect any addition publications since the thermometry community (CCT) has recommended that they need till 2012 to complete various Boltzmann determinations.

6. D. Newell gave a summary of the CCEM WGKg (watt balances) meeting (see document TGFC/10-19). The METAS project has produced a number and promises to have it published in time for the 2010 LSA. The result is  $-0.17(0.42)$  ppm from the 2006 LSA value. The NPL watt balance project published a result in 2007 which was  $0.300(0.066)$  different from the 2006 LSA value. At CPEM 2010, the NPL watt balance project promised to publish a revised uncertainty of their 2007 work. Tentatively the result would be  $0.300(0.174)$  ppm. No other numerical results of watt balance projects are expected to be published before 2011. Concerns were raised about the recent measurement by the NIST watt balance of the 1 kg gold plated copper mass (1000B) from NPL being offset by roughly 0.2 ppm from recent mass calibrations by the NPL and BIPM mass groups. The conclusion of the study was that the 1000B mass was deemed to be unstable and not suitable as a transfer standard.
7. K. Fujii gave an update on the Avogadro project (see presentation TGFC/10-03). The enriched silicon work of  $N_A$  is quickly approaching a numerical. While a number of problems have been encountered, almost all have been solved and an IAC Avogadro publication before December 31, 2010 is promised. The tentative number has an uncertainty of about 0.03 ppm and does not agree with the older natural silicon results. However when considered as a Planck determination it is several sigma from the 2007 NIST watt balance result which has a 0.035 ppm uncertainty. Unfortunately, the natural silicon results of  $N_A$  are more unsettled. It is generally agreed within the community, that the previous molar mass determinations of natural silicon are suspect but for various reasons it is unlikely to expect a definitive publication clarifying this issue by December 31, 2010. K. Fujii is attempting to resolve this matter but this may or may not be possible in the time left. The natural silicon results (used in the 2006 LSA) have a claimed uncertainty of 0.29 ppm but are about 1ppm different than the enriched results. Because the enriched silicon result uncertainty is about 10 times less than that of the natural silicon result it will dominate in the 2010 LSA. This means that numerically the new enriched result will virtually replace the older natural silicon result.
8. Discussion of interactions with CCU and the CIPM in preparation for the proposed changes to the SI:
  - a. Timing and logistics – the CIPM is not going to make a redefinition recommendation this round. The Task Group would like to issue a statement to the CIPM that it will do a LSA for them for the redefinition and if they decide to make a change for the final fixed values, they make it quickly to avoid new data problems. Once the decision is made to go forward with the redefinition, there will need to be two adjustments – one

to determine the fixed values to be used, and a second using the exact fixed values to determine the other fundamental constants. However for the 2010 LSA there will be only one adjustment. The issue of truncation of the exact values was discussed, however it was determined that this is not the Task Group's decision.

- b. How to treat the discrepancies in alpha, Boltzmann,  $h$ , Avogadro, and now the Rydberg will be discussed at the 2010 September CODATA TGFC meeting.

9. Other topics

- a. The NMIJ natural Silicon lattice spacing measurement ( $d_{220}$  NMIJ-04) and the PTB determination of the quotient  $h/m_n$  were discussed and tentatively it was decided to keep as relevant data since there are no official documents to cite to discard the results. The issue will be reviewed at the 2010 September CODATA TGFC meeting.
- b. It was recommended to publish the value for the gyromagnetic ratio of the proton in air since researchers use the value while doing measurements in air. This issue will be discussed at the 2010 September CODATA TGFC meeting.
- c. It was proposed for CODATA to nominate someone for the SUNAMCO medal.

10. Task Group administration – it was noted that the TGFC was not at present a legal task group since the CODATA meeting where the TG was to receive approval for renewal was canceled due to the erupting Eyjafjallajökull volcano. This will be resolved soon.

11. Date and location of the next Task Group meeting

Monday, September 13th 2010 at the BIPM immediately before the 20<sup>th</sup> CCU 2010 meeting, September 14-16.

12. Adjournment

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Members, October 2008**

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# DRAFT AGENDA

## CODATA Task Group on Fundamental Constants

9:30 am Saturday, 19 June 2010

### KRISS

1. Opening of the meeting and introductions
2. Review of the agenda
3. Review of the report of the Task Group meeting on 25 May 2009 at BIPM
4. List of significant new data and theory since May 2009 with a representative reference:
  - a. Gravitational constant - Luo; Phys. Rev. Lett. 102, 240801, 4 p. (2009)
  - b. Alpha  $2^3P_1-2^3P_2$  in helium - Hessels; Phys. Rev. A 79, 060503, 4 p. (2009)  
Helium like theory - Yerokhin; Phys. Rev. Lett. 104, 070403, 4 p. (2010)  
Recoil corrections,  $h/m$  - Karshenboim; Phys. Rev. A 79, 052506, 14 p. (2009)
  - c. Refinements in Rydberg theory - Mohr; Can. J. Phys. 87(7), 757-762 (2009)
  - d.  $V_m(\text{Si})$  uncertainty theory - Mana; Int. J. Mass Spectrom. 289(1), 6-10 (2010)
  - e. Others
5. Recent developments in Boltzmann constant experiments
6. Update on watt balance developments
7. Update on the Avogadro project
8. Discussion of interactions with CCU and the CIPM in preparation for the proposed changes to the SI:
  - f. Timing and logistics
  - g. Discrepancies in alpha, Boltzmann,  $h$ , and Avogadro
9. Other topics
10. Task Group administration
11. Date and location of the next Task Group meeting
12. Adjournment