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

25 May 2009, 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: F. Cabiati, J. Fischer, J. Flowers, K. Fujii, S. G. Karshenboim, I. Lindgren, W. Martienssen, P. J. Mohr, D. B. Newell, F. Nez, T. J. Quinn, B. N. Taylor, C. Thomas, and B. M. Wood (Chair). Also present as observers were R. Davis, M. Kühne, V. Korobov, Z. Lu, A. Picard, I. Mills, F. Piquemal, and P. Richard.

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 10:00, and introductions were made. Z. Zhonghua was unable to attend and sent his regrets. Z. Lu attended in his place as an observer. 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 and accepted.

3. A potential reduction in the Task Group funding from CODATA has been avoided and is back to nominal levels. There has been a change in the Task Group membership with J. Fisher becoming a new member and I. Lindgren retiring.

4. The report of the Task Group meeting on 14 June 2008 at the Broomfield, CO, U.S.A. was reviewed. B. Taylor reported that Audi is now working on transferring the Atomic Mass Data Center (AMDC) to China, however an Atomic Mass Evaluation (AME) will probably not be performed by 2010 in time for LSA2010. T. Quinn and P. Mohr stated that the AME has minimal impact on the next LSA.

5. B. Wood and D. Newell will represent CODATA at the 2009 Consultative Committee for Units (CCU) meeting.

6. C. Thomas has established the BIPM website portal for the Task Group. We will use this extensively for future quick decisions on adjustments associated with the SI redefinition efforts. No emails are posted on the general site. Task Group member are encouraged to look at their contact information and inform C. Thomas of any changes. B. Wood would like to receive all other requests and suggestions for modifications to website, such as a short description for the general public (done). S. Karshenboim would like to put links to other "constants communities." J. Fischer would like to see a one page description on how the 2006 LSA was done, as suggested at the 2008 meeting. B. Taylor would like to

post the 1998 and 2002 LSA on open access. T. Quinn envisions a list of new papers that are significant, relevant and most impactful; however P. Mohr suggests a better way of doing this by using the NIST fundamental constant database.

7. D. Newell gave a presentation (TGFC/09-01) on the list of significant new data since June 2008. The most noticeable are the preliminary results for natural and highly enriched Silicon, as presented by K Fujii (see agenda item 9). Other are a universality test of the quantum Hall effect using graphene; the eighth order mass-independent coefficient in QED theory finalized with a paper in preprint, a 10 ppm correction on the UC Irvine gravitational constant still with asymmetric uncertainties; an improved value and uncertainty of $h/m(^{87}\mathrm{Rb})$; and new consistent results with lower uncertainties for the d_{220} values of MO* and WASA4.2a.

8. J. Fischer gave a presentation (TGFC/09-07) on the recent development in Boltzmann constant experiments and recommendations of the CCT WG4 Task Group (TG-SI). There could be four new competitive Acoustic Gas Thermometry (AGT) results by next year from LNE-INM/CNAM, INRIM, NPL, and CEM. LNE-INM/CNAM currently has a less than 3 ppm uncertainty (no value given), NPL has a 7.7 ppm difference from the CODATA value (no uncertainty budget yet), and INRIM has a 5 ppm uncertainty (no value given). There are also four other methods for determining the Boltzmann constant with possible competitive results by 2010: Refractive Index Gas Thermometry (RIGT) (2010 possible uncertainty of 5 ppm), Doppler Broadening Technique (DBT) (2010 possible uncertainty of 10 ppm), Dielectric Constant Gas Thermometry (DCGT) (2010 possible uncertainty of 2 ppm), and Johnson Noise Thermometry (JNT) (2010 possible uncertainty of 6 ppm).

   W. Martienssen inquired if the product of kT is still applicable at very low temperatures. While this issue can be problematic the general consensus was that it was still applicable. R. Davis mentioned that atom cooling uses Doppler broadening (kT), however this method may not be applicable at extremely high temperatures.

   The TG-SI recommends an explicit constant redefinition of the SI, however C. Thomas pointed out that it is not an official CCT recommendation. F. Cabiati observed that the explicit-unit definition wording should require a body for a change in thermodynamic energy. Specifying a specific body in the definition would be difficult – another reason why the TG-SI prefers the explicit-constant definition. I. Mills also commented that the words of the explicit-unit definitions are the ones he prefers, since it's preferable to discuss thermal energy, instead internal energy.

   The TG-SI also recommended having at least three different methods giving consistent results with a final (total) uncertainty expected to be around 1 ppm.

This would require individual measurements to have uncertainties on the order of 2 ppm.

9. A. Picard gave a presentation (TGFC/09-08), giving an update on the status of watt balance developments. Although somewhat off topic he reported that the shift of the new natural Silicon values as presented (Avogadro 2003 – Avogadro 2009) was 1.2 ppm towards the CODATA value (see agenda item 9). The test mass comparison between the NPL watt balance and the BIPM, of a gold plated copper 1 kg artifact does not explained the 0.3 ppm discrepancy between the NIST and NPL watt balance results. However the extrapolated drift from two sets of data separated by 4.5 months, as measured by the NPL watt balance, was -0.64 µg/day. The test mass comparison between the NPL watt balance and the BIPM of a Silicon 500 g artifact (C4) does not explained the 0.05 ppm discrepancy between C4 and the 1 kg data set B as given in *Metrologia*, **44** (2007), pp. 247-440. The NPL watt balance results have shown no significant changes over time and a new publication is planned for late 2009. The project has been shut down and is being transferred to NRC. The preliminary NIST measurement of the 500 g Silicon mass C4 is consistent with the 2007 NIST published value, alluding to a problem with the NIST 500 g gold mass. The METAS watt balance has a standard deviation in air of 0.4 ppm and there are plans of a publication towards the end of 2009. The LNE watt balance is at an integration of components stage, but will have no results before 2010. The BIPM watt balance is starting a feasibility study on the cryogenic system, but will not have any results in the next 2 to 3 years. The NIM Joule balance has a 1 ppm determination of the mutual inductance and 100 ppm for mass determination and is aiming for an ultimate uncertainty of 0.1 ppm by 2010. MSL is in the feasibility-study stage of its pressure watt balance. LNE is piloting the IMERAplus Joint Research Project, e-MASS, which involves five members: LNE, INRIM, METAS, LNE-INM, and LNE-SYRTE. W. Martienssen asked if it would be difficult to achieve results due to the number of members or the complexity of the scientific work packages – the response was that both would be challenges.

   At this point of the meeting, the discussion turned to scheduling of various CC meetings and of possible adjustments (see also agenda item 11a). P. Richard reported that two CCM Task Groups have been established, one on Mass metrology under vacuum for a *mise-en-partique* (TG 1) and another on the Uncertainty components due to traceability to the international prototype of the kilogram (TG 2). Both TGs will meet at the next CCM (March, 2010) to collect results. There were no fundamental changes at the 11th CCM meeting in 2008 to the CCM recommendations and requirements since 2005. There needs to be clarification to the number of independent practical realizations needed for redefinition, the creation of an international pool of artifacts to ensure long term traceability to the SI after redefinition, and how to proceed after the redefinition. R. Davis commented that the CCM meeting in March, 2010 is unique and should have something less vague after the meeting. B. Wood reported that the CCEM

has re-endorsed recommendation E1, its position hasn't changed, and the CCEM is ready to go ahead with the redefinition. J. Fischer reported that the CCT will meet in May, 2010, and consider the CCT WG4 Task Group's recommendations. Various questions were raised concerning; how much time the CCM needs to implement the new definition, what's the implied uncertainty of the IPK, whether a *mise en pratique* already exists in current mass dissemination, and what role the watt balances will play in the future.

B. Wood suggested there could be three adjustments needed in the near future: the official 2010 adjustment, an unofficial adjustment in time for the CCU meeting to be held from 13 to 15 of September, 2010, and a final one with the exact values to be used in the redefinition.

Break for lunch –

10. K. Fujii gave a presentation (TGFC/09-09), giving an update on the status of the IAC project. A reevaluation of the natural Silicon result due to a molar mass calibration error yields a new value for N_A that is 0.20 ppm different from the 2006 CODATA value (was -0.84 ppm) with a relative standard uncertainty of 0.30 ppm. The difference between K. Fujii's correction and previous preliminary corrected values given by P. Becker was that the density distribution throughout NRLM4 has now been taken into consideration. Isotope Dilution Mass Spectrometry (IDMS) needs to be performed at the PTB for confirmation of the molar mass change before the final natural Silicon value is released (IDMS uncertainty should be around 0.03 ppm). Preliminary results for the highly enriched Silicon were also given with the difference from the 2006 CODATA value of N_A of 0.13 ppm with a relative standard uncertainty of 0.052 ppm. With the more consistent Silicon results, the discrepant h/m_n and d_{220}(NR3) values need to be reviewed.

11. Assistance to the CCU and CIPM in preparation for the proposed changes to the SI (official observer Ian Mills):
    a. Timing and logistics
    As mentioned above, B. Wood offered to make an unofficial adjustment of the Sept. 2010 CCU meeting. I. Mill stated that the 2010 LSA would be sufficient and that a full (unofficial) LSA would not be necessary. There probably will be no reliable results before June 2010 for CCT and CCQM to consider, however the 2010 official adjustment is more than just the numbers – it is a document that should clearly specify how CODATA will deal with discrepant data. New results may appear after 2010 that may be rushed for the final adjustment of the exact values and they will require more careful consideration.

    b. Discrepancies in alpha, *h*, and Avogadro
    The funding of the WGAC ends in March 2010, however there is a EURAMET IMERAplus Avogadro project funded to 2011 and a watt

balance project funded to 2016. It was noted that the watt balance and Avogadro project compete financially. The next step for the Avogadro project is to determine what part of the Silicon spheres need to be measured for future dissemination and who owns them. It was suggested that the spheres and crystals be kept at the BIPM (A. Picard).

Finally there was discussion concerning defining mass with respect to h-bar instead of h. While it really is the job of the CCU to decide, some say there is no fundamental difference, others state h-bar is more fundamental, and others state that introducing the radian introduces another unit. It is dutifully noted that a vote was taken: 8 for h and 4 for h-bar (2 abstained).

12. Other topics
    It was noted by that a full paper by T. Kinoshita on the finalized eighth order mass-independent coefficient in QED theory has been accepted for publication.

13. Date and location of the next Task Group meeting
    Saturday, June 19th 2010 in Korea immediately after CPEM 2010, June 13-18.

14. Adjournment

CODATA Task Group on Fundamental Constants
Members, October 2008

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DRAFT AGENDA

CODATA Task Group on Fundamental Constants

10:00 am Monday, 25 May 2009

BIPM

1. Opening of meeting and introductions.
2. Review of agenda.
3. Task Group administration and membership
4. Review of the report of the Task Group meeting on 14 June 2008 at the Broomfield, CO, U.S.A.
5. CODATA and Task Group membership/representation in the Consultative Committee for Units (CCU).
6. BIPM website portal for CODATA TGFC
7. List of significant new data since June 2008
    a. Graphene/GaAs QHR universality
    b. Eighth order mass-independent coefficient in QED theory - finalized
    c. Gravitational constant *G*: UC Irvine - 10 ppm correction; asymmetric uncertainties;
    d. $h/m(^{87}\mathrm{Rb})$
    e. d_{220} – new results for MO* and WASA4.2a
    f. $V_m(\mathrm{Si})$
    g. Others
8. Recent development in Boltzmann constant experiments (Joachmin Fischer)
9. Update on watt balance developments (official observer Alain Picard)
10. Update on Avogadro project (Ken Fujii/Rich Davis/Alain Picard)
11. Assistance to the CCU and CIPM in preparation for the proposed changes to the SI (official observer Ian Mills):
    h. Timing and logistics
    i. Discrepancies in alpha, *h*, and Avogadro
12. Other topics
13. Date and location of the next Task Group meeting
14. Adjournment