Bureau International des Poids et Mesures

Consultative Committee for Units (CCU)

Report of the 20th meeting
(14-16 September 2010)
to the International Committee for Weights and Measures

Comité international des poids et mesures

Note:

Following a decision of the International Committee for Weights and Measures at its 92nd meeting (October 2003), reports of meetings of the Consultative Committees are now published only on the BIPM website and in the form presented here.

Full bilingual versions in French and English are no longer published.

A.J. Wallard,
Director BIPM

LIST OF MEMBERS OF THE CONSULTATIVE COMMITTEE FOR UNITS as of 14 September 2010

President

Prof. Ian M. Mills, International Union of Pure and Applied Chemistry [IUPAC], Committee ICTNS, Emeritus Professor of Chemistry, School of Chemistry, Reading University

Executive Secretary

Dr C. Thomas, International Bureau of Weights and Measures [BIPM], Sèvres.

Members

Centro Español de Metrología [CEM], Madrid.

Committee on Data for Science and Technology [CODATA Task group on Fundamental Constants].

International Astronomical Union [IAU].

International Commission on Illumination [CIE].

International Commission on Radiation Units and Measurements [ICRU].

International Electrotechnical Commission [IEC], Technical Committee 25.

International Federation of Clinical Chemistry and Laboratory Medicine [IFCC].

International Organization for Standardization [ISO], Technical Committee 12.

International Organization of Legal Metrology [OIML].

International Union of Pure and Applied Chemistry [IUPAC], Committee ICTNS.

International Union of Pure and Applied Physics [IUPAP], Commission SUNAMCO.

National Institute of Metrology [NIM], Beijing.

National Institute of Standards and Technology [NIST], Gaithersburg.

National Metrology Institute of Japan, National Institute of Advanced Industrial Science and Technology [NMIJ/AIST], Tsukuba.

National Physical Laboratory [NPL], Teddington.

Physikalisch-Technische Bundesanstalt [PTB], Braunschweig.

State Committee of the Russian Federation for Standardization and Metrology, Rostekhregulirovaniye of Russia [VNIIM], Moscow.

Prof. M. Himbert, personal member.

Dr T.J. Quinn CBE FRS, personal member.

Prof. A. Wallard, the Director of the International Bureau of Weights and Measures [BIPM], Sèvres.

1. OPENING OF THE MEETING, APPOINTMENT OF THE *RAPPORTEUR*, APPROVAL OF THE AGENDA

The 20th meeting of the Consultative Committee for Units (CCU) was held at the International Bureau of Weights and Measures (BIPM) headquarters, at Sèvres, from 14 to 16 September 2010.

The following were present: J. Bastie (CIE), C.A. Borghi (IEC/TC 25), N. Capitaine (IAU), J. Flowers (NPL, IUPAP), K. Fujii (NMIJ/AIST), P. Gérôme (ISO), M. Himbert (LNE-INM/Cnam, CCU personal member), M. Kühne (Deputy Director of the BIPM), A. Leitner (OIML), B. Michael (ICRU), I.M. Mills FRS (President of the CCU, IUPAC), M.J.T. Milton (NPL), P.J. Mohr (IUPAP), D.B. Newell (CODATA), J. Obdržálek (IEC), E. Prieto (CEM), T.J. Quinn CBE FRS (Director Emeritus of the BIPM, CCU personal member), J. Stenger (PTB), B.N. Taylor (NIST), A. Thompson (NIST), A. Thor (ISO/TC 12), L. Vitushkin (VNIIM, Rostekhregulirovaniye), A.J. Wallard (Director of the BIPM), B. Wood (CODATA), J. Zhang (NIM), Z. Zhang (NIM).

CIPM members: L. Erard (France), A. Sacconi (Italy)

Invited guests: P. Allisy-Roberts (BIPM), F. Arias (BIPM), W. Bich (INRIM), Ch. Bordé (Académie des Sciences), R.S. Davis (BIPM), J. Fischer (PTB), S. Karshenboim (MPQ, Germany), J. Kovalevsky (Honorary member of the CIPM), A. Picard (BIPM), P. Richard (METAS), L. Robertsson (BIPM), M. Stock (BIPM), R.I. Wielgosz (BIPM).

Also present: J.R. Miles, E. De Mirandés, L. Mussio, C. Planche, R. Sitton, C. Thomas (Executive Secretary of the CCU) from the BIPM.

Excused: G. Férard (IFCC) and J. Buck (IEC).

The President opened the meeting with words of homage to Jan de Boer, the first President of the CCU from its creation in 1964 until 1994, who passed away in February 2010. He also expressed sympathy to Pierre Giacomo, who was unable to attend the CCU meeting due to health problems.

Dr Stenger was appointed *rapporteur*.

The Draft Agenda dated 1st April 2010 was approved.

2. REPORT OF THE PRESIDENT

Prof. Mills, President of the CCU, reported on the meeting held on 7 August 2009 in Reading, UK, at which the President, Dr Quinn, Prof. Himbert, Dr Davis and Dr Stenger revised the Draft Chapter 2 of the SI Brochure issued from the last CCU meeting in May 2009. The President also reported on his presentation to the CIPM in October 2009 and the summary which was sent to the CIPM members in December 2009, together with the Draft Chapter 2 resulting from the August meeting. He received two comments on Draft Chapter 2 from CIPM members, and the text was subsequently modified. This Draft and a Draft Resolution for presentation to the

24th meeting of the CGPM (2011), which will also be presented to the CIPM, were the central issues at the 20th meeting of the CCU. Prof. Mills stated that the CCU has the task of giving advice and making recommendations to the CIPM on possible revisions to the International System of Units (SI) but does not make any decisions itself.

3. REPORTS ON DEVELOPMENTS SINCE THE 19TH MEETING OF THE CCU

3.1 Report on the watt balance experiments, Avogadro project and CODATA

A meeting of the CODATA Task Group on Fundamental Constants was held on 13 September 2010 and Dr Wood, Chairman of the Task Group, gave a presentation on the situation regarding the adjustment scheduled for early 2011. The adjustment will include results which will be available by 31 December 2010, especially regarding the Planck constant h and the Boltzmann constant k.

Five experimental results from the watt balances of NIST (two results), NPL (two results) and METAS (one result) were considered by the Task Group. Further watt balance experiments are under way but results are not expected in the near future. The Avogadro consortium intends to publish the results of measurements with the enriched ^{28}Si spheres by end of 2010. These results take into account new measurements of the molar mass, because previous measurements were possibly contaminated by natural silicon. It follows that the two main contributors to the estimation of h are the NIST watt balance result of 2007 and preliminary reports of results using the enriched silicon sphere, with uncertainties of 3.6×10^{-8} and 3×10^{-8}, respectively. When considered as determinations of h, they differ by about 15×10^{-8}, so the CODATA uncertainty of the Planck constant may be 30 % higher in the 2010 adjustment than in the 2006 adjustment.

The CODATA Task Group found good consistency in the data for the Boltzmann constant, however the Task Group noted that the acoustic gas thermometry experiments are conceptually quite similar and deliver results which are highly correlated.

Mr Picard gave a summary of the present status of the results from watt balance experiments around the world.

- The current result for the Planck constant from the NPL watt balance (relative standard uncertainty u_r of 174×10^{-9}) exceeds that obtained from the NIST watt balance ($u_r = 36 \times 10^{-9}$) by $308(178) \times 10^{-9}$. This cannot be explained by the different test masses used in the two experiments or by recent technical modifications. This study is in progress. NIST will begin the design and construction of a new watt balance which will eventually serve as the standard of mass for the United States of America. Development of the watt balance will take several years.
- The NPL watt balance was moved into the NRC's newly-built laboratory in February 2010. After major construction work, the NRC has carried out preliminary measurements which already show a repeatability of a few parts in 10^7. They do not expect to have a final value for the Planck constant h before 2011.
- The METAS watt balance has a reproducibility of 5×10^{-8} with a relative standard uncertainty of about 4×10^{-7}. Its Planck constant value differs from the CODATA 2006 value by about 2 parts in 10^7 (results not yet published). METAS is developing a new watt

balance, which will become operational in the next few years, and measurements are scheduled for 2013–2015.

- The LNE watt balance is under construction and it expects to start reporting results after 2011.
- The BIPM watt balance currently achieves a reproducibility of 5×10^{-6} with a deviation from the CODATA 2006 value of h of about 6×10^{-5} ($u_r = 4.9 \times 10^{-5}$). These results have been submitted for publication.
- The NIM joule balance is under construction. Major developments are scheduled for 2011-2015.

It was concluded that significant new results, which may resolve the discrepancies and bring the relative standard uncertainty of the CODATA value of h down to the few parts in 10^8, will need an additional two years at least.

3.2 Report on the position of the CCM

Dr Richard, Chairman of the CCM Working Group on Changes to the SI kilogram (WGSI-kg) and of the CCM Working Group on Mass Standards (WGM), reported on the 12th meeting of the CCM in March 2010, on a workshop organized by the CCM WGSI-kg, and on the activities of Task Groups 1 and 2 of the WGM.

In the CCM Recommendation G 1 (2010) on “Considerations on a new definition of the kilogram” the CCM requested three experimental results for the determination of h based on at least two different methods, and consistent within a few parts in 10^8, before it is possible to implement the redefinition of the kilogram.

The CCM has discussed technical aspects of the *mise en pratique* for the definition of the kilogram after the redefinition, such as comparisons and sorption effects, possible relative drifts of prototypes and possible tools associated with the establishment of a pool of artefacts. The text of the *mise en pratique* will be drafted for presentation to the 13th meeting of the CCM in May 2011, with a view to final approval by the CCM at its 14th meeting, possibly in 2012.

The CCU discussed the implications for legal metrology of the redefinition of the kilogram. An option for practical dissemination, with less severe implications than introducing an additional uncertainty to prototypes, would be to refer all measurements to the future pool of standards, thus eliminating the common uncertainty. Dr Leitner stated that the *mise en pratique* should be agreed and to ensure consistency, the same methods of traceability should apply to both legal metrology and Calibration and Measurement Capabilities (CMCs). The CCM stated that when traceability is taken from a common source no additional uncertainty from the redefinition would affect the CMC claims, as is presently the case for CMCs related to electrical measurements.

3.3 Status of experiments to measure the Boltzmann constant and the position of the CCT

Dr Fischer, Chairman of the CCT Task Group on the SI, reported on the experiments to measure the Boltzmann constant k using acoustic gas thermometry, Doppler broadening thermometry, and dielectric-constant gas thermometry.

At present, the acoustic gas thermometry experiments achieve relative standard uncertainties of 3×10^{-6} with the uncertainties of the other methods being considerably higher. CODATA 2006 lists an uncertainty of 1.7×10^{-6} for k. The CCT expressed in Recommendation T 2 (2010) “Considerations for a new definition of the kelvin” that it expects the experiments will allow a determination of k with a relative standard uncertainty of 1×10^{-6} based on a variety of experiments possibly in 2012. Thus, the uncertainty associated with the temperature of the triple point of water would be 0.25 mK immediately after the redefinition of the kelvin.

The CCT agrees with the proposed explicit-constant formulation of the definition of the kelvin.

3.4 Position of the CCQM

Dr Milton, Chairman of the CCQM Working Group on the SI, reported on the CCQM Recommendation Q 1 (2009) “On the possible redefinition of the mole and the kilogram”. The Working Group supports the redefinition of the mole based on a fixed value of the Avogadro constant when the discrepancy between results from the watt balance and the x-ray crystal density/molar mass measurements has been resolved and when agreement is demonstrated between N_A values derived from independent measurements of the isotope amount ratios of silicon on samples of both natural and enriched isotopic composition. The CCQM also recommends increasing the efforts to raise awareness of the proposals within various scientific, industrial, and professional organizations. The *mise en pratique* for the definition of the mole still needs to be formulated and agreed.

3.5 Reports from other Consultative Committees

Dr Wood, Chairman of the CCEM Working Group on Proposed Modifications to the SI, presented a document on the CCEM’s perspective on the redefinition of the SI, requesting that the delay between fixing the values of the constants and the implementation of the redefinition of the SI be minimized. He also considered that a delay in implementing the new definition of the ampere past 2015 would be undesirable and may be problematic for the electrical community. The meeting stated that the first problem to solve is to have at disposal estimates of the values of the fundamental constants with sufficiently small uncertainties, each based on a sufficient number of sound experimental results.

Dr Arias reported that the CCTF supports the proposed rewording of the definition of the second, but that the specification of the caesium 133 atom “at rest and at a temperature of 0 K” must be added to the formal definition. The CCTF discussed a possible redefinition of the second on the basis of an optical atomic reference transition but does not expect a decision on this issue in the next few years.

Dr Stock gave a report on the position of the CCPR, and discussed the relationship between radiant intensity and photon intensity, according to a proposal of the CCPR in 2009 to include the photon intensity in the explanatory note following the definition of the candela. The CCU did not agree with this proposal, and was supported in its decision by Mr Bastie.

Dr Allisy-Roberts pointed out that the field of ionizing radiation is not affected by the proposed redefinition and thus the CCRI does not have a recommendation on this subject.

3.6 Reports from the Unions

Dr Capitaine does not envisage any implications for IAU from the rewording of the definition of the second. She noted that the IAU welcomes with great interest the development of optical clocks.

Dr Quinn reminded the CCU that the need to introduce leap seconds is mostly due to the 1967 definition of the second being based on the length of the day in the early 19th century, and that since then the rotation of the Earth has slowed down. He suggested that the general redefinition of the base units represented an opportunity to redefine the second with a step change of about 3 parts in 10^8 in order to synchronize it better with today's earth rotation rate, and in this way reduce the need for leap seconds. Dr Arias did not consider leap seconds to be a major problem. Modern applications such as satellite navigation make use of TAI rather than UTC and thus avoid the complication of leap seconds.

Prof. Borghi reported on the agreement of the IEC on the proposed redefinition of the SI.

Dr Bastie reported on the considerations of the CIE on the $V(\lambda)$ curves to better address mesotopic vision, which may be considered by the CCPR for future inclusion in the *mise en pratique* of the definition of the candela. This, however, has no impact on the definition of the candela itself.

Dr Michael did not envisage any implications from the redefinition of the SI on the ICRU.

There was no report from ISO.

Dr Leitner summarized the discussion within the OIML. Legal mass metrology will be affected by the redefinition of the kilogram, which will introduce an extra uncertainty to any primary realization, corresponding to the uncertainty of the Planck constant immediately before the redefinition. Dr Leitner preferred an alternative proposal, in which the whole system of legal metrology would be traceable to the pool of mass standards to be kept at the BIPM rather than to a primary realization. This would avoid the extra uncertainty. The Calibration and Measurement Capabilities (CMCs) claimed under the CIPM MRA must also have the same source of traceability, since legal metrology is ultimately traceable to National Metrology Institutes which have published CMCs. Dr Leitner added that the uncertainty requirement of the E1 weights, as laid down in the OIML document R111, is drawn up with respect to the present definition without referring to any possible drift of the prototype. He commented that the new definition of the kilogram will be more honest with respect to fundamental physics, but it will require a careful revision of the *mise en pratique* for the kilogram in order to satisfy the requirement for E1 mass standards in R111. In a later discussion on the needs of the OIML and future uncertainties of mass metrology, it was made clear that the contacts already exist between the CCM and the relevant OIML Technical Committee. Dr Richard recalled the schedule for the *mise en pratique* of the new definition of the kilogram.

Prof. Mills reported on the IUPAC General Assembly in August 2009. IUPAC supports the proposed redefinitions through a Resolution of the Interdivisional Committee on Terminology, Nomenclature and Symbols (ICTNS) adopted by the IUPAC Executive Committee in October 2009. Dr Wielgosz noted that this Resolution also recommends that the name "amount of substance" should be changed on the occasion of the redefinition. He said that at this stage the CCQM does not support any change in the name "amount of substance" and will have a look at the communication process inside ICTNS. The word "stoffmenge" was suggested as an alternative to amount of substance but it is not the responsibility of the CCU to recommend a new name for a quantity.

4. DISCUSSION OF OTHER MATTERS CONCERNING REVISIONS TO THE SI

4.1 Revised wording of definitions for all SI base units: Draft Chapter 2 of the SI Brochure

Prof. Mills initiated a discussion on the general structure of Draft Chapter 2 of the SI Brochure.

The scaling of the entire system of units by fixing the numerical values of the seven chosen invariants of nature (fundamental physical constants or properties of atoms) is a new feature of the presentation of the SI. The discussion concluded that this method of presentation was elegant, that it worked, and that it was easy to understand and teach.

The list of the invariants of nature whose numerical values will be fixed to scale the system will be as follows:

1. the ground state hyperfine splitting frequency of the caesium 133 atom,
2. the speed of light in vacuum,
3. the Planck constant,
4. the elementary charge,
5. the Boltzmann constant,
6. the Avogadro constant,
7. the luminous efficacy of monochromatic radiation of frequency 540×10^{12} Hz.

While acknowledging that this list is sufficient in itself to define the entire system of units, the CCU affirmed the importance of maintaining the historical structure of the SI with its set of defined base units, and coherent derived units obtained as products of powers of base units without numerical factors. The CCU considered that this historical structure was more convenient and understandable for the general user. For this reason the traditional set of base units will be retained, but they will be listed in a new order reflecting the list of the invariants of nature used to scale the whole system:

1. second,
2. metre,
3. kilogram,
4. ampere,
5. kelvin,
6. mole,
7. candela.

This revised order ensures that no base unit is defined in terms of one of the other base units later in the list.

The CCU confirmed its previous decision that the wording of the definitions of the seven base units will follow the formulation of the explicit-constant type, that is, a definition in which the unit is defined indirectly by specifying an exact value for a well-recognized fundamental constant. Each definition will be followed by an explanation of the implication of the definition, including explicit-unit definitions and information on the nature of the science involved.

The CCU stated that the Draft Chapter 2 must be complemented by *mises en pratique* for the definition of the base units, not integrated in Chapter 2 but kept on the BIPM website as it is at present.

The CCU discussed the detailed wording of Draft Chapter 2. An objection arose about the wording involving the de Broglie-Compton frequency of the kilogram in the paragraph placed just below the definition of the kilogram. Prof. Bordé explained the link between mass and the Planck constant in quantum mechanics, such as expressed by the de Broglie-Compton frequency. Although formally correct, concern was expressed that it may lead to confusion resulting from the unusual concept of associating a bulk mass or a hypothetical particle of mass 1 kg with a frequency analogous to the de Broglie wavelength of an elementary particle. The wording "de Broglie-Compton frequency" was also considered to be unusual. The CCU gave a mandate to Prof. Mills to formulate a new paragraph. This he did over the tea-break, in consultation with colleagues. The revised paragraph was presented to the meeting at its next session but was not discussed further. It is possible that this paragraph may yet be further revised at a later date.

"The value of the Planck constant is a constant of nature, which may be expressed as the product of a number and the unit joule second, where J s = s^{-1} m^2 kg. The effect of this definition, together with those for the second and the metre, which are based on fixed numerical values for the caesium frequency $\Delta\nu(^{133}\mathrm{Cs})_{\mathrm{hfs}}$ and the speed of light c, is to open the way to a definition of the unit of mass through two of the most fundamental equations of physics, namely $E = mc^2$ and $E = h\,\nu$, which relate energy E to mass and to frequency, and which together lead to
$m = h\,\nu\,/c^2$."

The discussion in the meeting about the various suggestions to modify Draft Chapter 2 is summarized as follows:

- The paragraph on the de Broglie-Compton frequency in Section 2.3.3 was deleted and replaced as specified above.
- The expression "fixed numerical value" replaced "fixed value" throughout the document.
- The word "coherent" was added to the expression "derived units" in the introduction of Section 2 and in the sentence of Section 2.2 "Note that the units hertz, joule, coulomb, lumen and watt referred to here are coherent derived units as defined in table 3 in Section 2.5 below.
- The last sentence of the last but one paragraph of Section 2.1 should read "The base units and the derived units obtained from the base units as described in Chapter 1 necessarily form a coherent set".
- In Section 2.2 the sixth bullet point now reads "6.02214X × 10^{23} reciprocal mole" instead of "6.02214X × 10^{23} per mole" in order to avoid a unit-less numerator.
- The expression "at rest at a temperature of 0 K" was added in the definition of the second in Section 2.3.1 and in the side note.
- Four modifications were made to Section 2.3.5 on the kelvin, namely:
    - o "together with" replaced by "and" in the introduction,
    - o "about 2 × 10^{-6}" replaced by "of order 1 × 10^{-6}",

- "1 mK" replaced by "0.25 mK",
- replacement of the sign "=" by a sign "minus" in the equation $t = T - T_0$.

It was agreed that Prof. Mills will produce a new version of Draft Chapter 2 reflecting these changes, which will be posted on the open-access CCU web page at: http://www.bipm.org/en/committees/cc/ccu/ as a PDF file clearly watermarked as a draft document. This will constitute the first step towards ensuring wider public awareness of the proposed changes to the SI.[1]

4.2 Status of the *mises en pratique* for the new definitions

Dr Thomas explained how information on the practical realizations of the definitions of units is presented on the BIPM's website. She showed the progress made in the presentation of the list of recommended values of standard frequencies for the practical realization of the metre and for secondary representations of the second. Dr Thomas also noted that the text on the practical realization of time scales had been recently updated. She stated that the BIPM has an obligation to keep these pages up-to-date, and thanked the Executive Secretaries of the Consultative Committees for their help with this.

The status of the *mises en pratique* for the new definitions is as follows:

- The CCEM has approved a complete draft *mise en pratique* for the ampere and other electric units.
- The CCM Working Group on Changes to the SI kilogram and the CCT Task Group on the SI are drafting *mises en pratique* for the new definition of the kilogram and the kelvin, respectively. This is at the stage of an outline for the kilogram. In thermometry, ITS-90 has not to be replaced, so most parts of the *mise en pratique* for the kelvin are already available.
- The CCQM will start producing a draft *mise en pratique* for the definition of the mole.

4.3 Conditions to be met before changes are implemented

Prof. Kühne reminded the CCU of Resolution 12 of the 23rd meeting of the CGPM in 2007, which recommended that besides satisfactory data quality for the relevant constants the *mises en pratique* must be prepared and awareness campaigns initiated to alert user communities to the possibility of redefinitions.

The subject of awareness campaigns gave rise to a number of comments. While the Draft Chapter 2 is the main source of information to be widely distributed in order to foster discussion and raise awareness of the redefinitions, at least two other actions should be taken:

- creation of a BIPM website dedicated to the explanation of the "New SI",
- production of a concise SI Brochure for providing a simplified view to governments, teachers, students and other stakeholders.

Prof. Wallard confirmed that the BIPM will purchase the domain "newsi.org" for the creation of a web portal dedicated to awareness of the new SI. The content has yet to be determined, probably in collaboration with National Metrology Institutes and Unions, but the idea is that it will be the primary source of information on the new SI for the entire metrological community.

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[1] The watermark Draft Chapter 2 file was made openly available from the CCU webpage on 29 September 2010.

Prof. Mills stated that a Working Group should be created to prepare a concise document about the redefinition of the SI. This was not urgent but should be considered at the next CCU meeting, after the 24th meeting of the CGPM.

4.4 CCU Recommendation to be offered to the CIPM, in view of proposing a Draft Resolution for the CGPM at its 24th meeting in 2011

The CCU discussed Recommendation U 1 (2010) to be presented to the CIPM: “Proposal to the CIPM on elements for a draft resolution for the CGPM at its 24th meeting on the revision of the International System of Units, the SI”. The French and English texts of the Recommendation are given in the Annexes.

Prof. Mills asked for a formal vote on draft Recommendation U 1, with the understanding that minor editorial modifications may be made after the vote[2]. The CCU approved the text unanimously with all 18 members present voting. Only two representatives of CCU members were absent at the time of the vote (IAU and IFCC).

5. OTHER MATTERS FOR DISCUSSION: DECIMAL MARKER, MULTIPLE- AND SUB-MULTIPLE PREFIXES, CCU ATTITUDE TO NON-SI UNITS

Prof. Mills reported that he and the Director of the BIPM had written a letter to ISO/IEC explaining the policy on the use of the point on the line or the comma on the line as decimal markers, according to Resolution 10 of the 22nd meeting of the CGPM. There has been no reply so far.

The CCU agreed not to adopt any suggestions for expanding the list of SI prefixes for the expression of powers of 10 beyond 10^{24} or 10^{-24}.

Prof. Mills reminded the CCU of his opinion that it is not the responsibility of the bodies of the Metre Convention to forbid the use of non-SI units, but rather to convince the relevant communities of the advantages of using the SI.

6. STATUS REPORT ON PHYSIOLOGICAL QUANTITIES

Prof. Kühne reported on the Workshop on Physiological Quantities and SI Units held at the BIPM headquarters on 16-17 November 2009. The CCPR has started to address THz metrology as a result of this workshop. The CCEM is also considering possible action concerning the effect of magnetic fields on the human body.

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[2] In practice, comments were requested to be sent by email to the President and the Executive Secretary before Tuesday 21 September 2010. They led to minor changes that the President considered while producing the definitive English version finalized by 23 September 2010. The French version was finalized by 6 October 2010.

The idea of creating a joint Working Group of the CCU and the JCGM on this subject was abandoned during the Workshop. It was agreed that it would duplicate existing efforts and would not bring significant benefits in view of the diversity of subjects. Prof. Mills stated that physiological quantities will become increasingly important in the future.

7. ANY OTHER BUSINESS

Prof. Mills drew attention to the document CCU/10-9.year, “Definition of the year in astronomy”, provided by Dr Capitaine, and thanked her for the work on this document.

Dr Quinn informed the CCU about the Discussion Meeting “The new SI: units of measurement based on fundamental constants” to be held at the Royal Society, London, on 24-25 January 2011.

Prof. Mills concluded the meeting by congratulating and offering his best wishes to Dr Davis, who will retire as Director of the Mass Department of the BIPM on 31 October 2010. He also thanked the participants of the CCU meeting for their contributions and Dr Thomas for her support as Executive Secretary. Dr Thomas expressed her respect for Prof. Mills.

The 21st meeting of the CCU will be held in 2012.

November 2010
Jörn Stenger
Ian Mills
Claudine Thomas

Short summary of the 20th CCU meeting

The 20th CCU was a successful meeting in which important documents on the redefinition of the International System of Units, the SI, were considered, discussed, and approved. In summary, the results of the meeting and the advice the CCU is offering to the CIPM are as follows:

1. The CCU recognized that there remain small but significant discrepancies between the value of the Planck constant deduced from watt balance experiments and that which is likely to be announced from the Avogadro silicon 28 work in the near future, and it is, therefore, premature to recommend the redefinition of the units.

2. The CCU preferred neither to discuss nor to make recommendations as to the date at which such a redefinition will take place or the conditions to be satisfied before adopting the new definitions.

3. However, the CCU was firmly of the opinion that it is now time to declare to the wider scientific and user public exactly what is likely to be proposed, so that it can be properly and openly discussed. To this end it drew up a detailed Recommendation (see Annexes). The CCU offers this as a Draft Resolution that the CIPM might propose to the 24th meeting of the CGPM to be held in October 2011. This Recommendation was the result of much discussion during the meeting, but opinions converged, and in the end the text was approved and voted unanimously by all members of the CCU that were present at the meeting.

Annex: CCU Recommendation to the CIPM U 1 (2010)

Proposal to the CIPM on elements for a draft resolution for the CGPM at its 24th meeting on the revision of the International System of Units, the SI

On the future revision of the International System of Units, the SI

The General Conference

considering

- that the national metrology institutes (NMIs) as well as the International Bureau of Weights and Measures (BIPM) have rightfully expended significant effort during the last several decades to advance the International System of Units (SI) by extending the frontiers of metrology so that SI base units can be defined in terms of the invariants of nature – the fundamental physical constants or properties of atoms,
- that a prominent example of the success of such efforts is the current definition of the SI unit of length, the metre (17th CGPM, 1983, Resolution 1), which links it to an exact value of the speed of light in vacuum c, namely, 299 792 458 metre per second,
- that of the seven base units of the SI, only the kilogram is still defined in terms of a material artefact, namely, the international prototype of the kilogram (1st CGPM, 1889, 3rd CGPM, 1901), and that the definitions of the ampere, mole and candela depend on the kilogram,
- that although the international prototype has served science and technology well since it was sanctioned by the 1st CGPM in 1889, it has a number of important limitations, one of the most significant being that its mass is not explicitly linked to an invariant of nature and in consequence its long-term stability is not assured,
- that the 21st General Conference in 1999 adopted Resolution 7 in which it recommended that "national laboratories continue their efforts to refine experiments that link the unit of mass to fundamental or atomic constants with a view to a future redefinition of the kilogram",
- that many advances have been made in recent years in relating the mass of the international prototype to the Planck constant h, either by means of a watt balance or through measurements of the mass of a silicon atom,
- that the uncertainties of all SI electrical units realized directly or indirectly by means of the Josephson and quantum Hall effects together with the SI values of the Josephson and von Klitzing constants K_J and R_K could be significantly reduced if the kilogram were redefined so as to be linked to an exact numerical value of h, and if the ampere were to be redefined so as to be linked to an exact numerical value of the elementary charge e,
- that the kelvin is currently defined in terms of an intrinsic property of water that, while being an invariant of nature, in practice depends on the purity and isotopic composition of the water used,
- that it is possible to redefine the kelvin so that it is linked to an exact numerical value of the Boltzmann constant k,
- that it is also possible to redefine the mole so that it is linked to an exact numerical value of the Avogadro constant N_A, and is thus no longer dependent on the definition of the kilogram

even when the kilogram is defined so that it is linked to an exact numerical value of h, thereby emphasizing the distinction between amount of substance and mass,

- that the uncertainties of the values of many other important fundamental constants and energy conversion factors would be eliminated or greatly reduced if h, e, k and N_A had exact numerical values when expressed in SI units,
- that the 23rd General Conference in 2007 adopted Resolution 12 in which it outlined the work that should be carried out by the NMIs, the BIPM and the International Committee for Weights and Measures (CIPM) together with its Consultative Committees (CCs) so that new definitions of the kilogram, ampere, kelvin, and mole in terms of fundamental constants could be adopted,
- that, although this work has progressed well, not all the requirements have been satisfied and so the International Committee is not yet ready to make a final proposal,
- that, nevertheless, a clear and detailed explanation of what is likely to be proposed can now be presented,

takes note of the intention of the International Committee to propose a revision of the SI as follows:

the International System of Units, the SI, will be the system of units scaled so that

- the ground state hyperfine splitting frequency of the caesium 133 atom $\Delta\nu(^{133}\mathrm{Cs})_{\mathrm{hfs}}$ is exactly 9 192 631 770 hertz,
- the speed of light in vacuum c is exactly 299 792 458 metre per second,
- the Planck constant h is exactly $6.626\ 06\mathrm{X} \times 10^{-34}$ joule second,
- the elementary charge e is exactly $1.602\ 17\mathrm{X} \times 10^{-19}$ coulomb,
- the Boltzmann constant k is exactly $1.380\ 6\mathrm{X} \times 10^{-23}$ joule per kelvin,
- the Avogadro constant N_A is exactly $6.022\ 14\mathrm{X} \times 10^{23}$ reciprocal mole,
- the luminous efficacy K_{cd} of monochromatic radiation of frequency 540×10^{12} Hz is exactly 683 lumen per watt,

where

(i) the hertz, joule, coulomb, lumen, and watt, with unit symbols Hz, J, C, lm, and W, respectively, are related to the units second, metre, kilogram, ampere, kelvin, mole, and candela, with unit symbols s, m, kg, A, K, mol, and cd, respectively, according to $\mathrm{Hz} = \mathrm{s}^{-1}$, $\mathrm{J} = \mathrm{m}^2\ \mathrm{kg}\ \mathrm{s}^{-2}$, $\mathrm{C} = \mathrm{s\ A}$, $\mathrm{lm} = \mathrm{cd}\ \mathrm{m}^2\ \mathrm{m}^{-2} = \mathrm{cd\ sr}$, and $\mathrm{W} = \mathrm{m}^2\ \mathrm{kg}\ \mathrm{s}^{-3}$,

(ii) the symbol X here and elsewhere in this document represents one or more additional digits to be added to the numerical values of h, e, k, and N_A, using values based on the most recent CODATA adjustment,

from which it follows that the SI will continue to have the present set of seven base units, in particular

- the kilogram will continue to be the unit of mass, but its magnitude will be set by fixing the numerical value of the Planck constant to be equal to exactly $6.626\ 06\mathrm{X} \times 10^{-34}$ when it is expressed in the unit $\mathrm{m}^2\ \mathrm{kg}\ \mathrm{s}^{-1}$, which is equal to J s;

- the ampere will continue to be the unit of electric current, but its magnitude will be set by fixing the numerical value of the elementary charge to be equal to exactly 1.602 17X $\times 10^{-19}$ when it is expressed in the unit s A, which is equal to C;
- the kelvin will continue to be the unit of thermodynamic temperature, but its magnitude will be set by fixing the numerical value of the Boltzmann constant to be equal to exactly 1.380 6X $\times 10^{-23}$ when it is expressed in the unit m^2 kg s^{-2} K^{-1}, which is equal to J K^{-1};
- the mole will continue to be the unit of amount of substance of a specified elementary entity, which may be an atom, molecule, ion, electron, any other particle or a specified group of such particles, but its magnitude will be set by fixing the numerical value of the Avogadro constant to be equal to exactly 6.022 14X $\times 10^{23}$ when it is expressed in the unit mol^{-1}.

The General Conference

further notes that since

- the new definitions of the kilogram, ampere, kelvin and mole are intended to be of the explicit-constant type, that is, a definition in which the unit is defined indirectly by specifying explicitly an exact value for a well-recognized fundamental constant,
- the existing definition of the metre is linked to an exact value of the speed of light in vacuum, which is also a well-recognized fundamental constant,
- the existing definition of the second is linked to an exact value of a well-defined property of the caesium atom, which is also an invariant of nature,
- although the existing definition of the candela is not linked to a fundamental constant, it may be viewed as being linked to an exact value of an invariant of nature,
- it would enhance the understandability of the International System if all of its base units were of similar wording,

the International Committee will also propose

the reformulation of the existing definitions of the second, metre and candela in completely equivalent forms, which might be the following:

- the second, s, is the unit of time; its magnitude is set by fixing the numerical value of the ground state hyperfine splitting frequency of the caesium 133 atom, at rest and at a temperature of 0 K, to be equal to exactly 9 192 631 770 when it is expressed in the unit s^{-1}, which is equal to Hz;
- the metre, m, is the unit of length; its magnitude is set by fixing the numerical value of the speed of light in vacuum to be equal to exactly 299 792 458 when it is expressed in the unit m s^{-1};
- the candela, cd, is the unit of luminous intensity in a given direction; its magnitude is set by fixing the numerical value of the luminous efficacy of monochromatic radiation of frequency 540×10^{12} Hz to be equal to exactly 683 when it is expressed in the unit m^{-2} kg^{-1} s^3 cd sr, or cd sr W^{-1}, which is equal to lm W^{-1}.

In this way, the definitions of all seven base units will be seen to follow naturally from the set of seven constants given above.

In consequence, on the date chosen for the implementation of the revision of the SI

- the definition of the kilogram in force since 1889 based upon the mass of the international prototype of the kilogram (1st CGPM, 1889, 3rd CGPM, 1901) will be abrogated;
- the definition of the ampere in force since 1948 (9th CGPM, 1948) based upon the definition proposed by the International Committee (CIPM, 1946, Resolution 2) will be abrogated;
- the conventional values of the Josephson constant K_{J-90} and of the von Klitzing constant R_{K-90} adopted by the International Committee (CIPM, 1988, Recommendations 1 and 2) at the request of the General Conference (18th CGPM, 1987, Resolution 6) for the establishment of representations of the volt and the ohm using the Josephson and Quantum Hall effects, respectively, will be abrogated;
- the definition of the kelvin in force since 1967/68 (13th CGPM, 1967/68, Resolution 4) based upon a less explicit, earlier definition (10th CGPM, 1954, Resolution 3) will be abrogated;
- the definition of the mole in force since 1971 (14th CGPM, 1971, Resolution 3) based upon a definition whereby the molar mass of carbon 12 had the exact value 0.012 kg mol^{-1} will be abrogated;
- the existing definitions of the metre, second and candela in force since they were adopted by the 17th CGPM (1983, Resolution 1), the 13th CGPM (1967/68, Resolution 1) and the 16th CGPM (1979, Resolution 3), respectively, will be abrogated.

The General Conference

further notes that on the same date

- the mass of the international prototype of the kilogram $m(\mathcal{K})$ will be exactly 1 kg but with a relative uncertainty equal to that of the recommended value of h just before redefinition and that subsequently its value will be determined experimentally,
- that the magnetic constant (permeability of vacuum) μ_0 will be exactly $4\pi \times 10^{-7}$ H m^{-1} but with a relative uncertainty equal to that of the recommended value of the fine-structure constant α and that subsequently its value will be determined experimentally,
- that the thermodynamic temperature of the triple point of water T_{TPW} will be exactly 273.16 K but with a relative uncertainty equal to that of the recommended value of k just before redefinition and that subsequently its value will be determined experimentally,
- that the molar mass of carbon 12 $M(^{12}C)$ will be exactly 0.012 kg mol^{-1} but with a relative uncertainty equal to that of the recommended value of N_A just before redefinition and that subsequently its value will be determined experimentally.

The General Conference

encourages

researchers in national metrology institutes, the BIPM and academic institutions to complete and make known to the scientific community in general and to CODATA in particular, the outcome of their work relevant to the determination of the constants h, e, k, and N_A, and

invites

- CODATA to continue to provide adjusted values of the fundamental physical constants based on all relevant information available and to make the results known to the

International Committee through its Consultative Committee for Units since these CODATA values and uncertainties will be those used for the revised SI,

- the International Committee to make a proposal for the revision of the SI as soon as the recommendations of Resolution 12 of the 23rd meeting of the General Conference are fulfilled, in particular the preparation of *mises en pratique* for the new definitions of the kilogram, ampere, kelvin and mole, and also the raising of wide public awareness of the proposed revision of the SI.

Annexe: Recommandation du Comité consultatif des unités (CCU) présentée au Comité international des poids et mesures (CIPM) U 1 (2010)

Propositions faites au CIPM concernant un projet de résolution sur la révision du Système international d'unités (SI) à soumettre à la CGPM lors de sa 24^e^ réunion

Sur la révision à venir du Système international d'unités (SI)

La Conférence générale des poids et mesures (CGPM),
considérant

- que les laboratoires nationaux de métrologie et le Bureau international des poids et mesures (BIPM) ont, à juste titre, déployé des efforts considérables au cours de ces dernières décennies afin de faire progresser le Système international d'unités (SI), en repoussant les limites de la métrologie, de façon à ce que les unités de base du SI puissent être définies en s'appuyant sur les constantes de la nature – les constantes physiques fondamentales ou les propriétés des atomes,
- qu'un exemple marquant du succès de ces efforts est la définition actuelle de l'unité de longueur du SI, le mètre (17e réunion de la CGPM, 1983, Résolution 1), qui relie l'unité à une valeur exacte de la vitesse de la lumière dans le vide *c*, à savoir 299 792 458 mètres par seconde,
- que parmi les sept unités de base du SI, seul le kilogramme est encore défini à partir d'un objet matériel (artefact), à savoir le prototype international du kilogramme (1re réunion de la CGPM, 1889 ; 3e réunion de la CGPM, 1901), et que les définitions de l'ampère, de la mole et de la candela dépendent du kilogramme,
- que, bien que le prototype international ait rendu des services à la science et la technologie depuis qu'il a été sanctionné par la CGPM lors de sa 1re réunion en 1889, son utilisation présente des limites importantes, l'une des plus significatives étant que sa masse n'est pas explicitement reliée à une constante de la nature et que, par conséquent, sa stabilité à long terme ne peut être garantie,
- que la CGPM, lors de sa 21e réunion en 1999, a adopté la Résolution 7, laquelle recommande que « les laboratoires nationaux poursuivent leurs efforts pour affiner les expériences qui relient l'unité de masse à des constantes fondamentales ou atomiques et qui pourraient, dans l'avenir, servir de base à une nouvelle définition du kilogramme »,
- que de nombreux progrès ont été effectués ces dernières années pour relier la masse du prototype international à la constante de Planck *h*, à l'aide de l'expérience de la balance du watt ou de mesures de la masse d'un atome de silicium,
- que les incertitudes associées à l'ensemble des unités électriques du SI réalisées, directement ou indirectement, au moyen de l'effet Josephson et de l'effet Hall quantique et à partir des valeurs dans le SI des constantes de Josephson et de von Klitzing, K_J et R_K, pourraient être réduites de manière significative si le kilogramme était redéfini de façon à ce qu'il soit relié à une valeur numérique exacte de *h*, et si l'ampère était redéfini de façon à ce qu'il soit relié à une valeur numérique exacte de la charge élémentaire *e*,

- que la définition actuelle du kelvin se fonde sur une propriété intrinsèque de l'eau qui, bien qu'étant une constante de la nature, dépend dans la pratique de la pureté et de la composition isotopique de l'eau utilisée,
- qu'il est possible de redéfinir le kelvin de façon à le relier à une valeur numérique exacte de la constante de Boltzmann k,
- qu'il est également possible de redéfinir la mole de façon à la relier à une valeur numérique exacte de la constante d'Avogadro N_A, de sorte qu'elle ne dépende plus de la définition du kilogramme, même lorsque le kilogramme sera défini de façon à le relier à une valeur numérique exacte de h, ce qui mettrait en évidence la distinction entre les grandeurs quantité de matière et masse,
- que les incertitudes liées aux valeurs d'autres constantes fondamentales et facteurs de conversion d'énergie importants seraient éliminées ou réduites de façon considérable si h, e, k et N_A avaient des valeurs numériques exactes lorsqu'elles sont exprimées en unités du SI,
- que la CGPM, lors de sa 23^e réunion en 2007, a adopté la Résolution 12 qui expose le travail à accomplir par les laboratoires nationaux de métrologie, le BIPM et le Comité international des poids et mesures (CIPM), ainsi que ses Comités consultatifs, afin que les nouvelles définitions du kilogramme, de l'ampère, du kelvin et de la mole fondées sur des constantes fondamentales puissent être adoptées,
- que, bien que des progrès notables aient été réalisés, tous les objectifs fixés par cette résolution n'ont pas été atteints, ce qui ne permet pas au CIPM de soumettre une proposition finalisée,
- qu'il est néanmoins désormais possible de présenter une version claire et détaillée de ce qui sera sans doute proposé,

prend acte de l'intention du CIPM de proposer une révision du SI qui se présenterait de la manière suivante :

le Système international d'unités (SI) sera le système d'unités dimensionné de façon à ce que

- la fréquence de la transition hyperfine dans l'état fondamental de l'atome de césium 133 $\Delta\nu(^{133}\mathrm{Cs})_{\mathrm{hfs}}$ soit égale à exactement 9 192 631 770 hertz,
- la vitesse de la lumière dans le vide c soit égale à exactement 299 792 458 mètres par seconde,
- la constante de Planck h soit égale à exactement 6,626 06X $\times 10^{-34}$ joule seconde,
- la charge élémentaire e soit égale à exactement 1,602 17X $\times 10^{-19}$ coulomb,
- la constante de Boltzmann k soit égale à exactement 1,380 6X $\times 10^{-23}$ joule par kelvin,
- la constante d'Avogadro N_A soit égale à exactement 6,022 14X $\times 10^{23}$ par mole,
- l'efficacité lumineuse K_{cd} d'un rayonnement monochromatique de fréquence 540 $\times 10^{12}$ Hz soit égale à exactement 683 lumens par watt,

où

(i) les unités hertz, joule, coulomb, lumen et watt, qui ont respectivement pour symboles Hz, J, C, lm, et W, sont reliées aux unités seconde, mètre, kilogramme, ampère, kelvin, mole et candela, qui ont respectivement pour symboles s, m, kg, A, K, mol, et cd, selon les relations $\mathrm{Hz} = \mathrm{s}^{-1}$, $\mathrm{J} = \mathrm{m}^2\ \mathrm{kg}\ \mathrm{s}^{-2}$, $\mathrm{C} = \mathrm{s}\ \mathrm{A}$, $\mathrm{lm} = \mathrm{cd}\ \mathrm{m}^2\ \mathrm{m}^{-2} = \mathrm{cd}\ \mathrm{sr}$, et $\mathrm{W} = \mathrm{m}^2\ \mathrm{kg}\ \mathrm{s}^{-3}$,

(ii) le symbole X dans le présent document correspond à un ou plusieurs chiffres qui devront être ajoutés aux valeurs numériques de h, e, k, et N_A selon les valeurs résultant de l'ajustement le plus récent fourni par la CODATA,

ce qui signifie que le SI continuera à être établi sur les sept unités de base actuelles et que notamment

- le kilogramme restera l'unité de masse mais son amplitude sera déterminée en fixant la valeur numérique de la constante de Planck à exactement 6,626 06X $\times 10^{-34}$ lorsqu'elle sera exprimée en m^2 kg s^{-1}, unité égale au joule seconde, J s,
- l'ampère restera l'unité de courant électrique mais son amplitude sera déterminée en fixant la valeur numérique de la charge élémentaire à exactement 1,602 17X $\times 10^{-19}$ lorsqu'elle sera exprimée en s A, unité égale au coulomb, C,
- le kelvin restera l'unité de température thermodynamique mais son amplitude sera déterminée en fixant la valeur numérique de la constante de Boltzmann à exactement 1,380 6X $\times 10^{-23}$ lorsqu'elle sera exprimée en m^2 kg s^{-2} K^{-1}, unité égale au joule par kelvin, J K^{-1},
- la mole restera l'unité de quantité de matière d'une entité élémentaire spécifique, c'est-à-dire un atome, une molécule, un ion, un électron, ou toute autre particule ou groupe particulier de telles particules, mais son amplitude sera déterminée en fixant la valeur numérique de la constante d'Avogadro à exactement 6,022 14X $\times 10^{23}$ lorsqu'elle sera exprimée en mol^{-1}.

La Conférence générale des poids et mesures (CGPM),

note également

- que les nouvelles définitions du kilogramme, de l'ampère, du kelvin et de la mole seront rédigées en utilisant une formulation dite « à constante explicite », c'est-à-dire une définition dans laquelle l'unité est définie indirectement en donnant explicitement une valeur exacte à une constante fondamentale reconnue,
- que la définition actuelle du mètre est reliée à une valeur exacte de la vitesse de la lumière dans le vide, qui est également une constante fondamentale reconnue,
- que la définition actuelle de la seconde est reliée à une valeur exacte caractérisant une propriété bien définie de l'atome de césium, qui constitue également une constante de la nature,
- que la définition existante de la candela n'est pas liée à une constante fondamentale mais qu'elle peut être considérée comme étant reliée à une valeur exacte d'une constante de la nature,
- que l'intelligibilité du Système international d'unités serait renforcée si toutes ses unités de base étaient définies en utilisant la même formulation,

c'est pourquoi le Comité international des poids et mesures proposera également

de reformuler les définitions actuelles de la seconde, du mètre et de la candela selon une forme complètement équivalente qui pourrait être la suivante :

- la seconde, s, est l'unité de temps ; son amplitude est déterminée en fixant la valeur numérique de la fréquence de la transition hyperfine de l'état fondamental de l'atome de césium 133 au repos, à une température de 0 K, à exactement 9 192 631 770 lorsqu'elle est exprimée en s^{-1}, unité égale au hertz, Hz,

- le mètre, m, est l'unité de longueur ; son amplitude est déterminée en fixant la valeur numérique de la vitesse de la lumière dans le vide à exactement 299 792 458 lorsqu'elle est exprimée en m s^{-1},
- la candela, cd, est l'unité d'intensité lumineuse dans une direction donnée ; son amplitude est déterminée en fixant la valeur numérique de l'efficacité lumineuse d'un rayonnement monochromatique d'une fréquence de 540×10^{12} Hz à exactement 683 lorsqu'elle est exprimée en m^{-2} kg^{-1} s^3 cd sr ou en cd sr W^{-1}, unité égale au lumen par watt, lm W^{-1}.

Il sera ainsi manifeste que les définitions des sept unités de base du SI découlent naturellement des sept constantes précédemment indiquées.

En conséquence, à la date choisie pour mettre en œuvre la révision du SI

- la définition du kilogramme en vigueur depuis 1889, établie à partir de la masse du prototype international du kilogramme (1re réunion de la CGPM, 1889 ; 3e réunion de la CGPM, 1901), sera abrogée ;
- la définition de l'ampère en vigueur depuis 1948 (9e réunion de la CGPM, 1948), établie à partir de la définition proposée par le Comité international des poids et mesures (CIPM, 1946, Résolution 2), sera abrogée ;
- les valeurs conventionnelles de la constante de Josephson K_{J-90} et de la constante de von Klitzing R_{K-90} adoptées par le Comité international des poids et mesures (CIPM, 1988, Recommandations 1 et 2) à la demande de la CGPM (18e réunion de la CGPM, 1987, Résolution 6) pour l'établissement des représentations du volt et de l'ohm à l'aide des effets Josephson et Hall quantique, respectivement, seront abrogées ;
- la définition du kelvin en vigueur depuis 1967/68 (13e réunion de la CGPM, 1967/68), établie à partir d'une définition antérieure moins explicite (10e réunion de la CGPM, 1954, Résolution 3), sera abrogée ;
- la définition de la mole en vigueur depuis 1971 (14e réunion de la CGPM, 1971, Résolution 3), selon laquelle la masse molaire du carbone 12 a la valeur exacte de 0,012 kg mol^{-1}, sera abrogée ;
- les définitions existantes du mètre, de la seconde et de la candela, en vigueur depuis leur adoption par la CGPM lors de ses 17e (1983, Résolution 1), 13e (1967/68, Résolution 1) et 16e (1979, Résolution 3) réunions respectivement, seront abrogées.

La Conférence générale des poids et mesures (CGPM),

prend en considération qu'à la même date

- la masse du prototype international du kilogramme $m(\mathcal{K})$ sera exactement 1 kg, avec cependant une incertitude relative égale à celle de la valeur recommandée de h juste avant la redéfinition, puis sa valeur sera déterminée de façon expérimentale,
- la constante magnétique (la perméabilité du vide) μ_0 sera exactement $4\pi \times 10^{-7}$ H m^{-1}, avec cependant une incertitude relative égale à celle de la valeur recommandée de la constante de structure fine α, puis sa valeur sera déterminée de façon expérimentale,
- la température thermodynamique du point triple de l'eau T_{TPW} sera exactement 273,16 K, avec cependant une incertitude relative égale à celle de la valeur recommandée de k juste avant la redéfinition, puis sa valeur sera déterminée de façon expérimentale,

- la masse molaire du carbone 12 $M(^{12}\mathrm{C})$ sera exactement 0,012 kg mol^{-1}, avec cependant une incertitude relative égale à celle de la valeur recommandée de N_{A} juste avant la redéfinition, puis sa valeur sera déterminée de façon expérimentale.

La Conférence générale des poids et mesures (CGPM),

encourage

les chercheurs des laboratoires nationaux de métrologie, du BIPM et des institutions universitaires à poursuivre leurs travaux sur la détermination des constantes de h, e, k, et N_{A}, et à en transmettre les résultats à la communauté scientifique en général et à la CODATA en particulier,

et invite

- la CODATA à continuer à fournir des valeurs pour les constantes fondamentales de la physique ajustées à partir de toutes les données pertinentes disponibles, ainsi qu'à transmettre les résultats au CIPM par l'intermédiaire du Comité consultatif des unités, puisque ce sont les valeurs et incertitudes de la CODATA qui seront utilisées pour la révision du SI,
- le CIPM à lui proposer de réviser le SI dès que les recommandations de la Résolution 12 adoptée par la GGPM à sa 23$^{\mathrm{e}}$ réunion seront satisfaites, en particulier la préparation des mises en pratique des nouvelles définitions du kilogramme, de l'ampère, du kelvin et de la mole, ainsi qu’une plus grande sensibilisation du grand public au projet de révision du SI.