The proposed new SI and consequences for legal metrology

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1. Introduction

In response to Resolution 1 of the International Conference on Weights and Measures (CGPM) [1], the OIML has taken a resolution (CIML Resolution no. 25) in 2011 [2] that encourages all members and relevant Technical Committees (TCs) to actively participate in the discussion and provide comments to a respective OIML Working Group, which consists of the authors. The intention of this article is to

- support the CGPM in their efforts to inform and alert user communities to the intention to redefine various units of the SI and to encourage consideration of the practical, technical, and legislative implications of such redefinitions, the emphasis being put here on possible consequences for legal metrology (chapters 2, 3 and 4),
- to present the outcome of the inquiry amongst OIML members and the TCs concerned (chapters 5 and 6).

2. The rationale for a new SI

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 (IPK) kept at the International Bureau of Weights and Measures (BIPM) [3]. Since the third verification of the national prototypes of the kilogram (NPK) against the IPK in the period 1989 to 1991 the stability of the IPK has been put into question, because the results of comparisons between the NPK and the IPK show some divergence with time, the average mass changes being in the order of 50 µg during a period of about 100 years. Whether these are due to a drift of the IPK, or of the NPK, or of both, could not be clarified so far.

Unknown changes in the mass unit influence the electrical units, because the definition of the ampere is related to the kilogram, see figure 1. Similarly, the definitions of the mole and candela also depend on the kilogram.

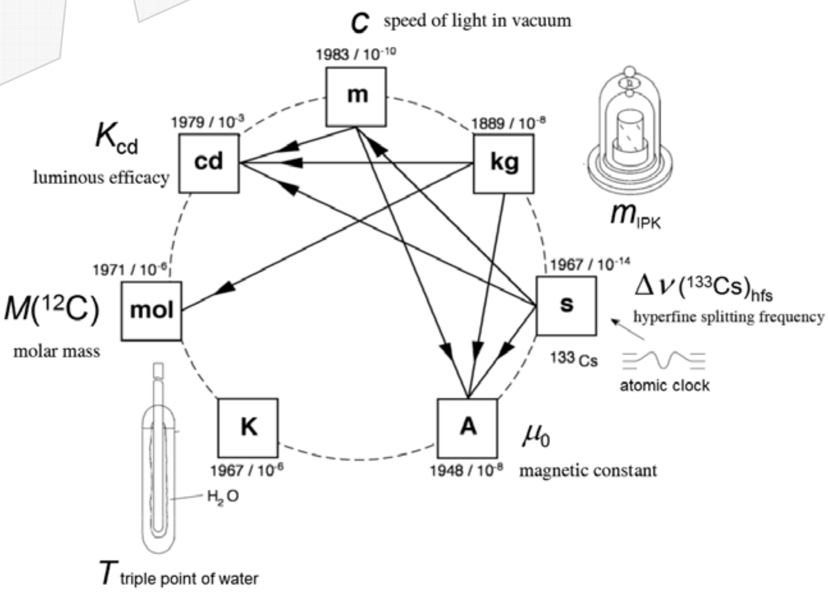

Fig. 1: The seven base units and its relationship in the current SI.

At its 21st meeting (1999) the International Conference on Weights and Measures (CGPM) therefore recommended that efforts be continued to refine experiments linking the unit of mass to fundamental constants with a view to a future "quantum-based" redefinition of the kilogram. Any new definition would need to be consistent within „some parts“ in 10^8 with the present definition to ensure continuity of mass values. This important condition has later (2010) been rendered more precisely by the Consultative Committee for Mass and Related Quantities (CCM). With a redefined kilogram, it will, in principle, be possible to realize the SI unit of mass at any place, at any time and by anyone as it is already possible for other SI base units such as the second.

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 would 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.

The kelvin is currently defined in terms of an intrinsic property of water (temperature of the triple point) that, while being an invariant of nature, in practice depends on the purity and isotopic composition of the water used. The kelvin would be better defined if it were linked to an exact numerical value of the Boltzmann constant k.

Redefining the mole so that it is linked to an exact numerical value of the Avogadro constant N_A would have the consequence that it is 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. This would thereby emphasize the distinction between the quantities "amount of substance" and "mass".

The uncertainties of the values of many other important fundamental constants and energy conversion factors would be eliminated or significantly reduced if h, e, k and N_A had exact numerical values when expressed in SI units.

Because of these many advantages the CGPM, at its 24th meeting in 2011, has taken its Resolution 1 „On the possible future revision of the International System of Units, the SI“ [1] that outlines the intention to redefine not only the kilogram, but all seven SI base units, in terms of invariants of nature and to express all definitions uniformly. With this, the CGPM and the International Committee of Weights and Measures (CIPM) clearly intend to revise the SI with a view that it continues to meet the needs of science, technology, and commerce in the 21st century.

3. The fundamentals of the new SI

The proposed changes to the SI can be summarized as follows [4].

- **Keep the existing seven SI base units, but define them all in terms of seven well-recognized fundamental or atomic constants, such as the Planck constant *h*, see figure 2 and table 1.**

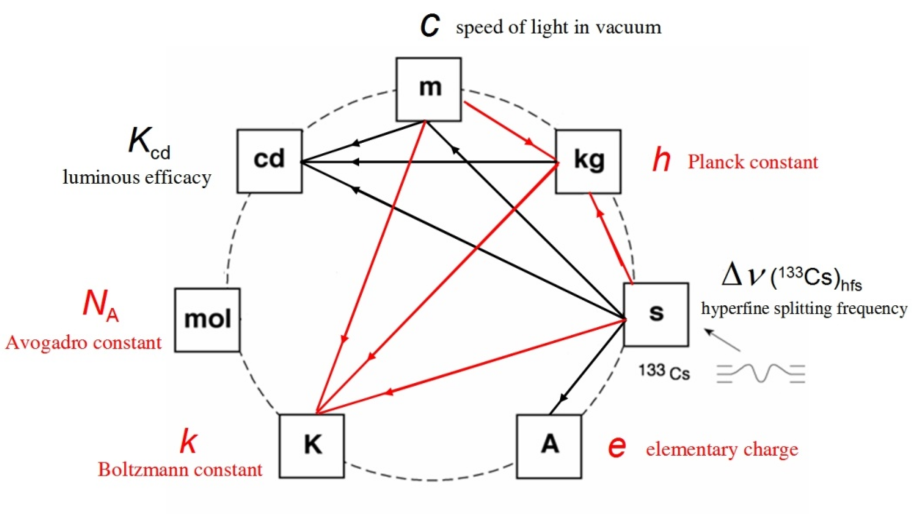

Fig. 2: Definition of and relationship between the seven base units in the proposed new SI. In the new SI all base units will be defined in terms of fundamental or atomic constants. The changes to the current SI are marked red.

base unit	**symbol**	**current SI**	**new SI**	**fundamental constant**
second	s	$\Delta\nu(^{133}\mathrm{Cs})_{\mathrm{hfs}}$	$\Delta\nu(^{133}\mathrm{Cs})_{\mathrm{hfs}}$	hyperfine splitting frequency
metre	m	c	c	speed of light in vacuum
kilogram	kg	m_{IPK}	h	Planck constant
ampere	A	μ_0	e	elementary charge
kelvin	K	T_{TPW}	k	Boltzmann constant
mole	mol	$M(^{12}\mathrm{C})$	N_A	Avogadro constant
candela	cd	K_{cd}	K_{cd}	luminous efficacy of a 540 THz source

Tab. 1: The seven SI base units and their reference in the current and new SI. The definitions of the four red marked base units will be changed, the others will remain.

The definitions for the second, the metre and the candela will remain unchanged, but the **kilogram** would be defined in terms of the Planck constant h, instead of the mass of the International Kilogram Prototype (IPK), the **ampere** in terms of the elementary charge e, instead of the magnetic constant μ_0, the **kelvin** in terms of the Boltzmann constant k, instead of the temperature of the triple point of water T, and the **mole** in terms of the Avogadro constant N_A, instead of the molar mass of carbon 12, $M(^{12}\mathrm{C})$.

- **Fix the values of all these constants to an exact number (with zero uncertainty), as it is already the case for the speed of light in vacuum, c = 299 792 458 meter per second.**

Table 2 shows the values of the seven fundamental or atomic constants that will be fixed in the new SI. The symbol X represents one or more additional digits to be added to the numerical values of h, e, k, and N_A, based on a CODATA adjustment, as soon as the CGPM considers the measurement uncertainties of the respective experiments sufficiently small.

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

Tab. 2: The International System of Units, the SI, will be the system of units in which seven fundamental or atomic constants are fixed, where the symbol X 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.

- **Use "explicit-constant" formulations to express the definitions of all seven SI base units in a uniform (but indirect) manner.**

As further explained in the Draft Chapter 2 of the 9th edition of the SI brochure [5], the new SI will be scaled so that the numerical values of seven constants are fixed, see table 2. Using the "explicit-constant" formulation each definition will state explicitly which numerical value it fixes [6].

For example, the second would still be defined in terms of the hyperfine splitting frequency of the ground state of the caesium 133 atom, $\Delta\nu(^{133}Cs)_{hfs}$, but the formulation would be changed into an "explicit-constant" one, where the unit (here the second) would be defined indirectly by specifying explicitly an exact value for $\Delta\nu(^{133}Cs)_{hfs}$ (9 192 631 770 hertz). The same would hold for the metre (defined in terms of the speed of light in vacuum c), and the candela (defined in terms of the luminous efficacy K_{cd} of monochromatic radiation of frequency 540 THz).

The new "explicit-constant" definition for the kilogram and its consequences are described in chapter 4.

- **Draw up specific "*mise en pratique*" for each base unit to explain how the units can be practically realized based on recommended top-level methods.**

A *mise en pratique* is a document containing a set of instructions and explanations how a base unit can be practically realized and disseminated to the users through primary and secondary standards. For example, the CCM is currently drafting a *mise en pratique* for the redefined kilogram. This will explain how the kilogram can be realized in the future by different primary methods (e.g. the „Avogadro method“ or the „Watt balance method“) to the Planck constant, *h*, using primary mass standards, and how the NPK or other secondary mass standards of National Metrology Institutes (NMI) can be linked to the primary mass standards and the Planck constant, see figures 3 and 4.

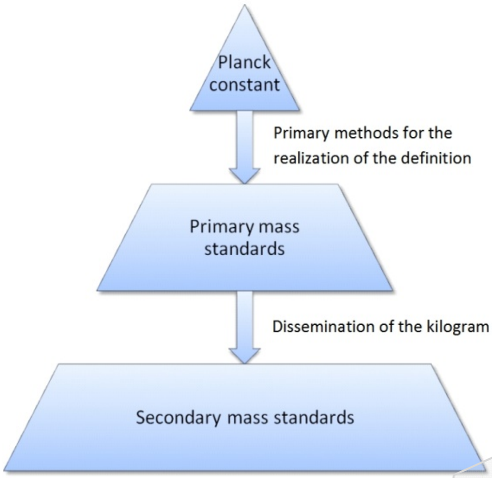

Fig. 3: Proposed future realization of the kilogram with primary methods that would link primary mass standards to the fundamental constant *h*, followed by the classical way of dissemination using the primary mass standards to calibrate secondary ones.

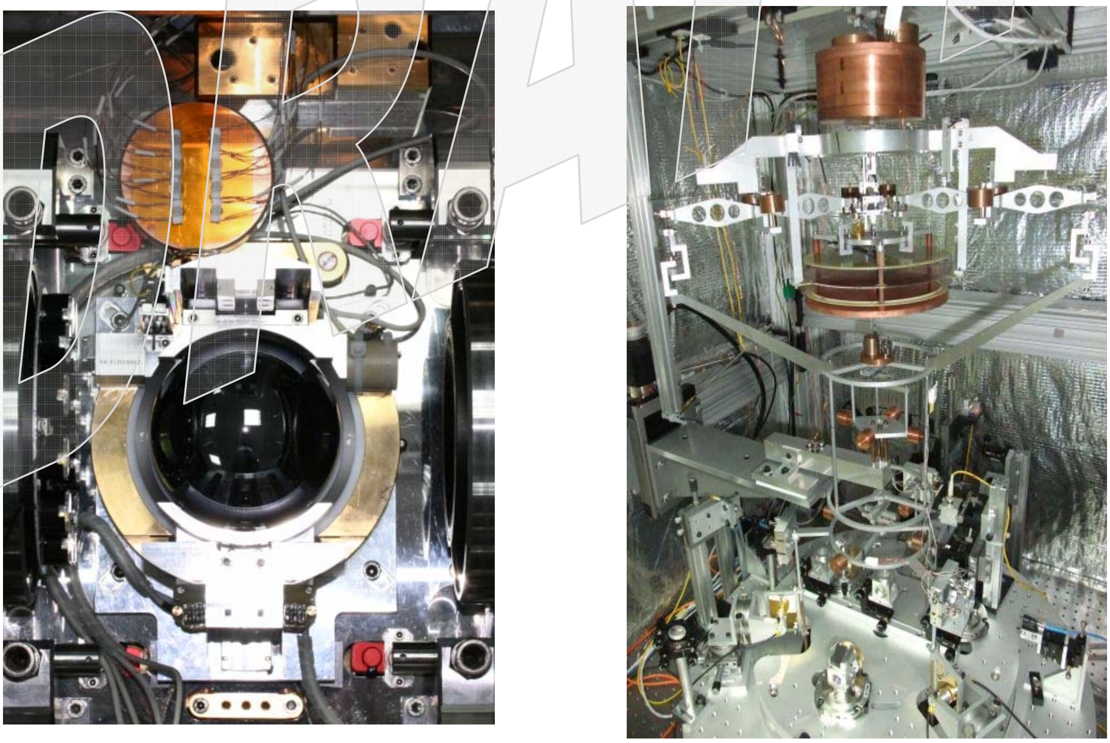

Fig. 4: Existing primary methods for the realization of the new kilogram are the „Avogadro method“ and the „Watt balance method“.
Left: View on a silicon 28 sphere used in the Avogadro experiment. The diameter of the sphere (about 90 mm), and hence its volume, is measured with a Fizeau interferometer, which forms part of the Avogadro experiment (source: PTB Braunschweig, Germany).
Right: View into the BIPM watt balance [7]

4. Redefinition of the kilogram

In the present SI, one kilogram is defined as exactly the mass of the IPK, see figure 5.

Fig. 5: The IPK kept at the BIPM in Sèvres. It still defines the unit of mass, the kilogram. Its mass, m_{IPK}, is defined to be exactly 1 kg with zero uncertainty. In the proposed new SI it will have non-zero uncertainty.

According to draft chapter 2 of the 9th SI brochure [5], the new "explicit-constant" definition of the kilogram would read:

"*The kilogram, kg, is the unit of mass; its magnitude is set by fixing the numerical value of the Planck constant, h, to be equal to exactly 6,626 06X • 10^{-34} when it is expressed in the unit s^{-1} m^2 kg, which is equal to J s.*"

The exact value for X, which will be fixed by the latest CODATA adjustment at the time of the redefinition [8], requires further experimental effort to reach a sufficiently small relative measurement uncertainty in the order of 10^{-8}.

Compared with the redefinition of other base units the redefinition of the kilogram is the most critical one, because of several reasons:

- Accurate weighings and mass determinations are of extraordinary importance in science, trade and industry, and also in daily life,
- There are partly very high demands on the accuracy of mass determinations. For example, E1 accredited mass laboratories keep reference standards with relative uncertainties between 2,5•10^{-8} and 5•10^{-8},
- As will be explained in chapter 5.2, if the value for the Planck constant *h* were fixed too early, there would be a risk for jumps in the order of 10^{-7} in mass values of mass standards, with consequences for the adjustment and verification of class E weights according to OIML R 111 [9].

The CCM has therefore, at its meeting in 2010, recommended the following conditions to be met before the kilogram is redefined in terms of fundamental constants [10]:

1. At least three independent experiments, including work both from watt balance and from International Avogadro Coordination projects, yield values of the relevant constants with relative standard uncertainties not larger than 5 parts in 10^8. At least one of these results should have a relative standard uncertainty not larger than 2 parts in 10^8.
2. For each of the relevant constants, values provided by the different experiments be consistent at the 95 % level of confidence.
3. Traceability of BIPM prototypes to the international prototype of the kilogram be confirmed.

In addition, CCM Recommendation G1 (2010) states that

4. the CODATA recommended values be adopted for the relevant fundamental constants,
5. the associated CODATA relative standard uncertainties be suitably considered when the initial uncertainty is assigned to the international prototype of the kilogram,
6. a pool of reference standards be established at the BIPM to facilitate the dissemination of the new definition of the kilogram,
7. the BIPM and a sufficient number of National Metrology Institutes continue to operate, develop or improve facilities or experiments that allow the realization of the kilogram to be maintained with a relative standard uncertainty not larger than 2 parts in 10^8.
8. the uncertainty component arising from the practical realization of the unit be suitably taken into account.

The above CCM recommendations, especially the first three, have not yet been met, but researchers are actively working to understand the differences in the experimental results and close the gaps. Currently, there are only two experiments that have achieved published relative uncertainties smaller than $5 \cdot 10^{-8}$ ($3{,}6 \cdot 10^{-8}$ for the NIST watt balance [11] and $3 \cdot 10^{-8}$ for the International Avogadro Coordination experiments [12]). These results are discrepant by $1.7 \cdot 10^{-7}$ as seen in figure 6. The discrepancy between the recently published result of the NRC watt balance [13] and the one of the NIST watt balance [11] is even larger and amounts to about $2.6 \cdot 10^{-7}$ (see figure 6).

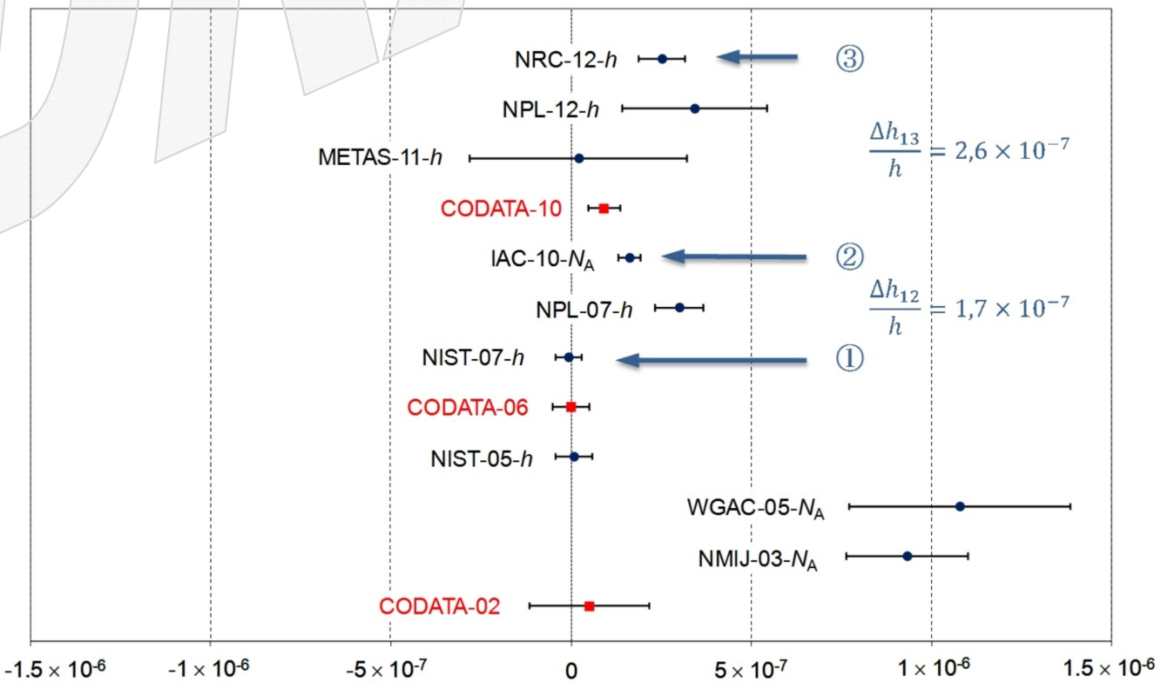

Fig. 6: Measurement results for the Avogadro constant N_A with standard uncertainties (k = 1), represented as relative deviations from the CODATA 2006 value (N_A = 6.02214179(30) × 10^{23} mol^{-1}). The results for Planck's constant, h, (watt balance) and for K_J (voltage balance) have been converted by means of the CODATA 2006 constants. Explanations: "NPL-07-*h*", for instance, means: NPL's result in 2007 for a measurement of h. WGAC: CCM Working Group Avogadro Constant, IAC: International Avogadro Coordination. Currently, the three results with the smallest uncertainties are: (1) NIST-07-*h* ($u_r = 3.6 \cdot 10^{-8}$), (2) IAC-10-N_A ($u_r = 3.0 \cdot 10^{-8}$) and (3) NRC-12-*h* ($u_r = 6.5 \cdot 10^{-8}$)

5. The impact on legal metrology

In response to Resolution 1 of the CGPM, OIML has taken a resolution (Resolution no. 25) at the 43rd CIML meeting in 2011 [2] that „*encourages all its Members and relevant Technical Committees, in particular TC 2, TC 9, TC 9/SC 3 and TC 11, to actively participate in the discussion and provide comments to the ad-hoc OIML Working Group "New SI"...*".

Based on this resolution an inquiry was performed amongst all members of the CIML and the OIML Technical Committees TC 2 *Units of measurement*, TC 9 *Mass and density*, TC 9/SC 3 *Weights* and TC 11 *Temperature* in order to explore in more detail the possible practical consequences of a revised SI in general, and a redefined kilogram in particular, with the aim to provide an official statement on the proposed revision of the SI to the CGPM in October 2012.

The responses received from the Technical Committees and some CIML members are summarized in the following.

5.1 General comments on the proposed new SI

General comments related to the new SI were received from TC 2, TC 9, TC9/SC3 and some CIML members. They signalize that

- the proposed new SI is generally supported if it has a sound, reliable experimental basis. The final decision is to be made by the CGPM considering all experimental data and the benefits of a revised SI,
- the new SI definitions will most likely have no impact on routine measurements of time, length, luminous intensity, electric current, temperature, amount of substance, and derived quantities,
- the biggest potential impact may be on highly accurate mass measurements. These comments are in line with recent publications [14, 15, 16],
- there is still work to be done to inform and educate the legal metrology field, manufacturers, test labs and end users about the changes and ensure that a new SI will remain understandable to all those who need to use it. This is in line with CGPM Resolution 1 (2011) which itself invites "*the CIPM to continue its work towards improved formulations for the definitions of the SI base units in terms of fundamental constants, having as far as possible a more easily understandable description for users in general, consistent with scientific rigour and clarity*".

5.2 Impact on mass measurement

Comments related to the redefinition of the kilogram and its possible impact on mass measurement were received from TC2, TC9, TC9/SC3 and some CIML members. They concern

- the continuity and accuracy of mass measurements,
- the traceability of mass measurements
- the practical realization and dissemination of the redefined kilogram
- the present uncertainties claimed in OIML R111 for high-precision weights

As to the **continuity and accuracy** it was stated that from the OIML and practical metrology point of view the new definition of the kilogram can only be accepted if the 2010 CCM conditions are met <u>and</u> if a sufficient number of independent realizations of the definition (Avogadro with silicon 28 spheres or watt balances) will be simultaneously available and maintained (see chapter 4). The ideal situation would be reached if the present uncertainty for the calibration and measurement capabilities of mass standards at the highest accuracy level (see figure 7) remains the same before and after the new definition. This being said, a slight increase of the measurement uncertainty for mass calibrations at the highest accuracy level would be acceptable in exchange of the expected better long term stability of the kilogram.

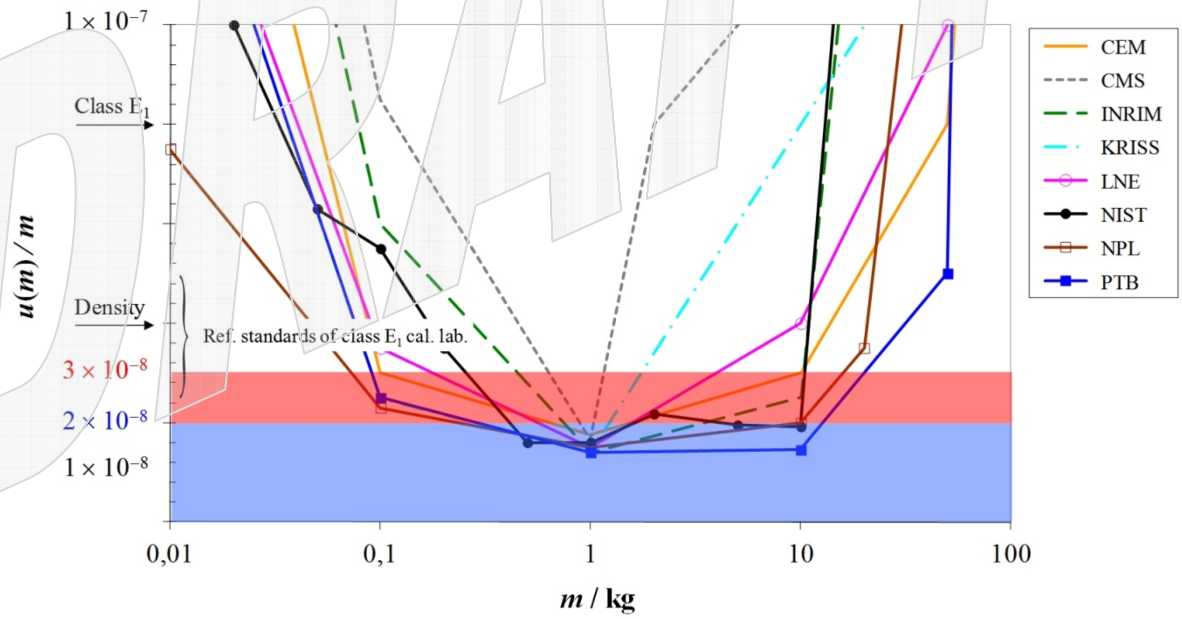

Fig. 7: Calibration and Measurement Capabilities (CMCs) for mass standards in the range from 10 g to 100 kg of eight selected NMIs [17] compared with different uncertainty limits for the realization of a redefined kilogram (blue and red marked range) [14], relative standard uncertainties of primary density standards (see pointer “Density”), reference standards of class E1 calibration laboratories (see range indicated), and for class E1 weights themselves (see pointer “Class E1”). The blue marked range indicates the relative standard uncertainty required by the CCM for the best realization of the new kilogram (Avogadro or watt balance method). The red marked range indicates the relative standard uncertainties that can best be reached after the redefinition of the kilogram, if the CCM conditions were met.

A thorough examination of the realization, dissemination chain and uncertainty propagation for the redefined kilogram shows that [14]:

- if the above CCM recommendations are closely observed and met, no serious changes in the calibration chain of mass standards will occur,

- even if the CCM recommendations are met, the uncertainty values in the "calibration and measurement capabilities" (CMCs) of NMIs will increase by up to a factor of 2 (see figure 7),

- if the CCM recommendations were not met, mass standards of high accuracy with a relative uncertainty smaller or equal $5 \cdot 10^{-8}$, as presently offered by NMIs, would no longer be available, and there would be the risk that accredited calibration laboratories would no longer be able to calibrate class E1 weights according to OIML R 111 (2004).

As to the **traceability of mass measurements** it was pointed out, that OIML Document D 2 [18], ISO 17025 [19] in general and OIML Recommendation R 111 [9] in particular require traceability of measurements under legal control to be traceable to SI units. R 111 defines E1 weights as weights intended to ensure traceability between national mass standards, with values derived from the IPK [9]. This language in R 111 needs to be revised under a new SI to indicate that E1 weights will be traceable to the new SI definition of the kilogram and not the IPK. It is considered important that under a new SI weights according to OIML R 111 remain traceable to the SI, and that there is no confusion possible between any new definition of the unit of mass and the „conventional mass“ (or „conventional value of mass“) as defined in OIML D 28 [20] for practical reasons.

TC 3/SC 9 rejects any concept of a non-SI „practical mass“, be it a „conventional value of the kilogram“ or „conventional kilogram“ [21], or a „usual mass“ or „practical mass“ [22]. Such concepts would disconnect the world of practical measurements (legal metrology) from the world of fundamental constants and the SI. In addition, any such concept would lead to confusion with the „conventional mass“ as defined in R 111. It is mentioned that all „non-SI“ concepts will be rendered superfluous if the Avogadro and watt balance experiments have reached sufficiently low uncertainties, and their discrepancies are resolved.

As to the **practical realization and dissemination** of the new kilogram it is emphasized that there is a need for a comprehensive *mise en pratique* (see chapter 2), where, because of the expected impact on practical mass measurements, the OIML through the CCM should be involved in the development process. That *mise en pratique* should give due consideration to the delivery of the new mass unit, the use of possible vacuum transfer devices for primary mass standards, the new role of the existing national mass standards and platinum-iridium prototypes, the role and use of watt balances as one possible primary method to realize the new definition, the consistency and the long-term stability of the mass values provided by different primary watt balances.

As to the **present uncertainties specified in OIML R111** for high-precision weights there is some concern that current claimed mass uncertainties of E1 weights do not reflect the observed instabilities in mass artefacts, including the „hidden“ uncertainty of the IPK, and that OIML should consider revising R111 to define more realistic uncertainties of mass in a redefined SI.

Here it must be responded, that the current definition of the kilogram has up to now never suffered from any limitations due to a possible, never proven drift of the IPK. It has quite successfully guaranteed up to now, that - all over the world - high-precision mass standards and weights of OIML accuracy classes E1 and E2 are calibrated and used in the global market without any problems, the CMCs (see figure 7) being the basis. To estimate "more realistic uncertainties" is not possible without respective experimental data which are not yet available.

It is also mentioned that a premature redefinition of the kilogram, not taking into account the above mentioned CCM conditions, would bear the risk of jumps in the order of $1 \cdot 10^{-7}$. Figure 8 shows the long-term mass changes of platinum-iridium kilogram prototypes since 1889 compared to the values for *h* resulting from the CODATA adjustments since 1998 [16]. The CODATA values jump within four years by up to $1 \cdot 10^{-7}$ which is a factor two worse than the assumed („hidden") instability of the IPK during the past hundred years. These jumps are due to the very active experimental work on determination of *h* which is on-going across the globe. It is obvious that jumps of such an order must be avoided if at all possible for mass calibrations, because of the consequences for high-precision mass standards and E1 weights which would have to be corrected on the calibration certificates from mass calibration laboratories.

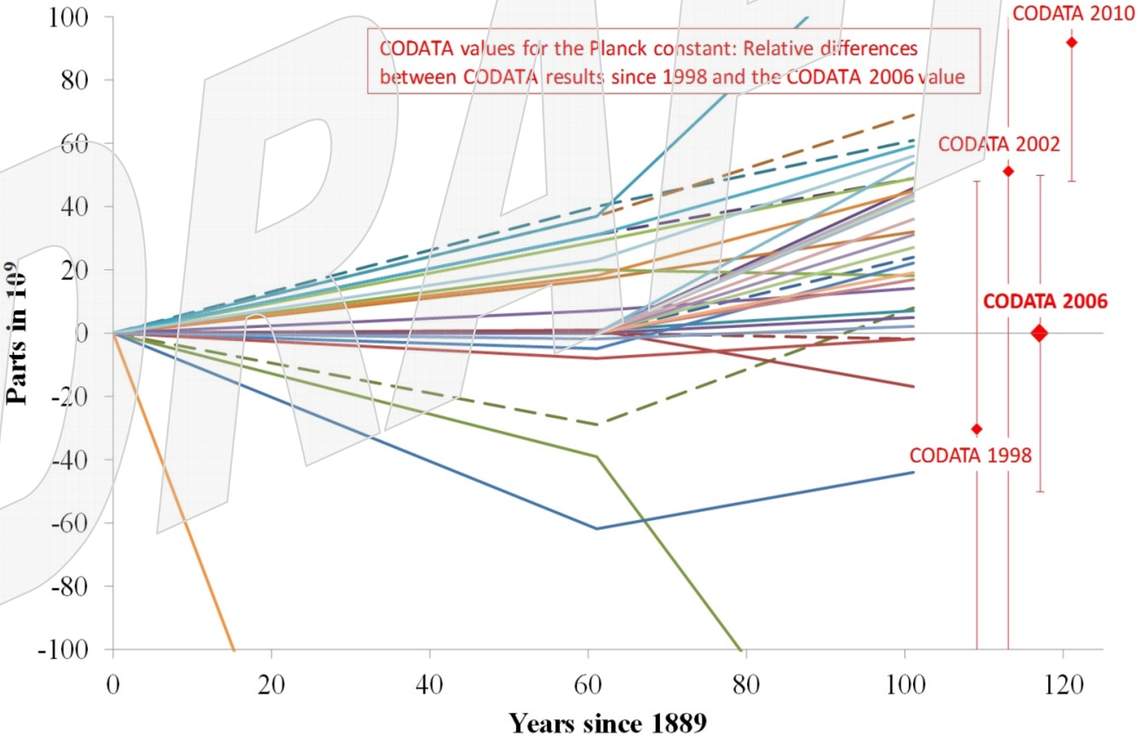

Fig. 8: Mass changes of the six official copies of the IPK (dashed lines) and national kilogram prototypes no. 2 through 55 against the IPK since 1889 [23], compared with relative changes of CODATA values for the Planck constant, *h*, since 1998, where the CODATA 2006 value was (arbitrarily) chosen as reference value.

In summary it is concluded that the redefinition of the kilogram is still considered critical by the legal metrology community in the field of mass, mainly due to a possible negative impact on high-accuracy mass measurements, if the kilogram is redefined <u>prematurely</u> without a close observation of the respective conditions set up by the CCM, with consequences for the continuity, accuracy and traceability of future mass measurements under legal control.

5.3 Impact on temperature measurement

Comments related to the redefinition of the kelvin and its possible impact on temperature measurement were received from TC 11 and some CIML members.

To meet the need for most routine temperature measurements, International Temperature Scales (ITS) have been defined and are recipes for the realization of highly reproducible and precise temperature standards in close accord with the best thermodynamic measurements of the time. These scales have been based on sets of fixed points, the defined temperatures of equilibrium states of specified pure substances. Thus, the quantity determined in the vast majority of present-day temperature measurements is not thermodynamic temperature T but T90, as defined by the ITS of 1990 (ITS-90).

The new definition for the kelvin will have little immediate impact on the status of ITS-90. For the foreseeable future, most temperature measurements in the core temperature range from about −200 °C to 960 °C will continue to be made using standard platinum resistance thermometers calibrated according to ITS-90. Because ITS-90 will remain intact, with defined values of T90 for all of the fixed points, the uncertainties in T90 will not change: they will continue to be dominated by uncertainties in the fixed-point realizations and the non-uniqueness of the platinum resistance thermometers, typically totalling less than 1 mK [24].

It is expected that any future changes in the temperature scale will be much smaller than the tolerances associated with current documentary standards for thermocouples and industrial platinum resistance thermometers used in legal metrology. Therefore, no requirement is anticipated for any future change in temperature scales to propagate to the documentary standards.

If the 2010 CODATA recommended value of the Boltzmann constant were taken to be exact and used to define the kelvin, the relative uncertainty in k, currently 0.91×10^{-6}, would be transferred to the thermodynamic temperature of the triple-point of water, TTPW. This means that if such a new definition were to be adopted today, our best estimate of the value of TTPW would still be 273.16 K, but instead of this value being exact as a result of the definition of the kelvin as is now the case, the standard uncertainty of TTPW would be 0.25 mK. In practice, the change in definition will only affect measurements made close to 0 °C because the uncertainties of the thermodynamic temperatures well away from this are very much larger than 0.25 mK. There is no experiment where the slightly increased uncertainties of thermodynamic temperatures would present a problem to metrology or the wider research community. Experts in thermometry are not aware of any new technology for a primary thermometer providing a significantly improved uncertainty at TTPW. Consequently, there will be no change of the assigned value of TTPW for the foreseeable future.

However, the ITS-90 will no longer be the only practical option for temperature measurement. The most immediate and beneficial consequence of the change is for temperatures above ~1000 °C where primary thermometers may offer users a lower thermodynamic uncertainty than is currently available with ITS-90. Therefore, the mise en pratique for the kelvin will be expanded to describe recognized primary methods for measuring thermodynamic temperature, and the sources of uncertainty associated with the measurements [25].

In summary it is concluded that the legal metrology community in the field of thermometry welcomes the proposal for a new SI and seems to be well prepared for the new definition of the temperature unit kelvin.

5.4 Impact on the measurement of other SI quantities

The redefinition of the ampere, the unit of the electric current, will eliminate the need to use conventional electric units. It will rather allow electric measurements to be expressed in SI units, including measurements of the electric voltage and resistance. This will practically not affect electrical measurements under legal control.

There is a different situation for the mole, the unit of the amount of substance. Especially chemists are used to a definition of the mole that is closely linked to the kilogram, the unit of mass, where the mole is defined on the basis of (exactly) 0,012 kg of carbon 12 and the molar mass constant is exactly 1 g per mol. In the new SI the mole will be defined in terms of the Avogadro constant, N_A, and thus independently of the new kilogram, defined in terms of the Planck constant, h. Although this will have practically no effect on routine measurements in chemistry, the respective community seems to be reluctant to the new definition, because the consequence will be that the new „molar mass constant“ will no longer be exactly 1, and it will have an uncertainty.

The OIML, via the TC 2 Secretariat, will continue to cooperate with the Consultative Committee for Units (CCU) to achieve best consistency between the new kilogram and the new mole.

6. Summary and OIML statement

In response to Resolution 1 of the CGPM (2011) the following statement on the proposed „New SI“ has been approved by the 14th International Conference of the OIML and the 47th CIML Meeting (Resolution no. X): ((Note: X will be replaced after the CIML 2012 meeting))

The OIML supports the CGPM's intention to revise the SI in order that it will continue to meet the needs of science, technology, and commerce in the 21st century.

From the inquiry amongst the OIML Technical Committees TC 2, TC 9, TC9/SC 3 and TC 11, and the CIML members, it is concluded that the new SI definitions are considered to have little to no impact on routine measurements of time, length, luminous intensity, electric current, temperature, amount of substance, and related derived SI quantities. A potential impact may be on accurate mass measurements using weights of classes E1 and E2 according to OIML R 111. Only careful adherence to the 2010 Recommendations of the CCM will preserve the continuity, accuracy and traceability of future mass measurements.

The OIML supports the intention of the CGPM to further improve formulations for the definitions of the SI base units so that the new SI remains understandable to all those who need it.

Finally it is mentioned that, on the basis of Resolution 1 of the CGPM (2011) [1], members of „user communities“ and the „general public“, for instance, CIML members, Corresponding members and representatives of OIML liaison organizations, are invited to submit other comments directly to the BIPM.

7. Acknowledgement

The support and valuable input of several CIML members and the chairpersons of Technical Committees, especially Richard Goblirsch (TC 2), John Barton (TC 9), Michael Borys (TC 9/SC 3) and Joachim Fischer (TC 11) is highly appreciated.

8. References

[1] http://www.bipm.org/utils/en/pdf/24_CGPM_Resolution_1.pdf

[2] http://www.oiml.org/download/docs/ciml/46_ciml_resolutions_english.pdf

[3] http://www.bipm.org/en/si/new_si/why.html

[4] http://www.bipm.org/en/si/new_si/what.html

[5] http://www.bipm.org/utils/common/pdf/si_brochure_draft_ch2.pdf

[6] http://www.bipm.org/en/si/new_si/explicit_constant.html

[7] http://www.bipm.org/en/scientific/elec/watt_balance/wb_bipm.html

[8] CODATA, Latest (2010) values of the constants, http://physics.nist.gov/cuu/Constants/

[9] OIML R 111-1, "Weights of classes E1, E2, F1, F2, M1, M1–2, M2, M2–3 and M3, Part 1: Metrological and technical requirements", ed. 2004, http://www.oiml.org/publications/R/R111-1-e04.pdf

[10] Recommendation G 1 (2010), "Considerations on a new definition of the kilogram", http://www.bipm.org/utils/common/pdf/CCM12.pdf#page=23

[11] R. L. Steiner, E. R. Williams, R. Liu and D. B. Newell, "Uncertainty improvements of the NIST electronic kilogram", IEEE Trans. Instrum. Meas., vol. 56, pp. 592-596, 2007

[12] B. Andreas, Y. Azuma, G. Bartl, P. Becker, H. Bettin, M. Borys, I. Busch, M. Gray, P. Fuchs, K. Fujii, H. Fujimoto, E. Kessler, M. Krumrey, U. Kuetgens, N. Kuramoto, G. Mana, P. Manson, E. Massa, S. Mizushima, A. Nicolaus, A. Picard, A. Pramann, O. Rienitz, D. Schiel, S. Valkiers, A. Waseda, "Determination of the Avogadro constant by counting the atoms in a 28Si crystal", Phys. Rev. Lett., vol. 106, 030801, 2011

[13] A. G. Steele, J. Meija, C. A. Sanchez, L. Yang, B. M. Wood, R. E. Sturgeon, Z. Mester and A. D. Inglis, "Reconciling Planck constant determinations via watt balance and enriched-silicon measurements at NRC Canada", Metrologia, vol. 49, pp. L8–L10, 2012

[14] M. Gläser, M. Borys, D. Ratschko and R. Schwartz, "Redefinition of the kilogram and the impact on its future dissemination", Metrologia, vol. 47, pp. 419–428, 2010

[15] R. Davis, "Proposed change to the definition of the kilogram: Consequences for legal metrology", OIML Bulletin, vol. LII, pp. 5-12, 2011

[16] R. Schwartz, M. Borys, "The proposed new SI: consequences for mass metrology", XX IMEKO World Congress 2012 (to be published)

[17] Calibration and Measurement Capabilities – CMCs, http://kcdb.bipm.org/appendixC/

[18] OIML D 2, "Legal units of measurement", ed. 2007, http://www.oiml.org/publications/D/D002-e07.pdf

[19] ISO/IEC 17025, "General requirements for the competence of testing and calibration laboratories", ed. 2005

[20] OIML D 28, "Conventional value of the result of weighing in air", ed. 2004, http://www.oiml.org/publications/D/D028-e04.pdf

[21] Mills et al. 2005, Metrologia 42 71–80

[22] Quinn 2010, CCM Working Document CCM/10-5/rev1

[23] G. Girard, "The third periodic verification of national prototypes of the kilogram (1988–1992) ", Metrologia, vol. 31, pp. 317–336, 1994

[24] J. Fischer, S. Gerasimov, K. D. Hill, G. Machin, M. R. Moldover, L. Pitre, P. Steur, M. Stock, O. Tamura, H. Ugur, D. R. White, I. Yang, J. Zhang: Preparative Steps Towards the New Definition of the Kelvin in Terms of the Boltzmann Constant. Int. J. Thermophys. 28, 2007, 1753–1765

[25] D. C. Ripple, R. Davis, B. Fellmuth, J. Fischer, G. Machin, T. Quinn, P. Steur, O. Tamura, D. R. White: The Roles of the Mise en Pratique for the Definition of the Kelvin. Int. J. Thermophys. 31, 2010, 1795–1808