Progress towards the revision of the SI

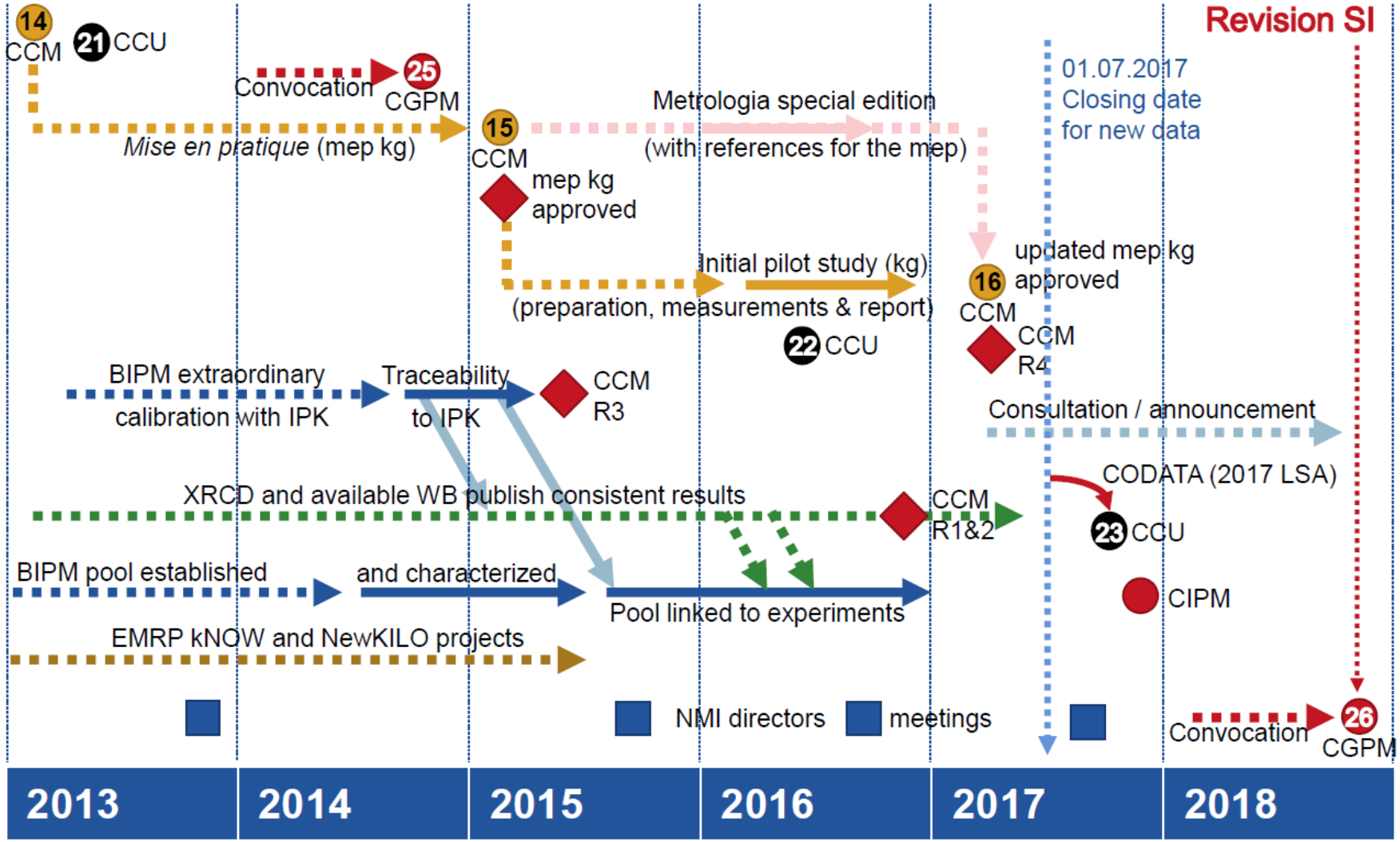
Estefanía de Mirandés

CCU executive secretary

BIPM

Bureau International des Poids et Mesures

Joint CCM and CCU roadmap for the new SI



◆ Conditions from CCM Recommendation G1 (2013)

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Special 2017 CODATA adjustment of h, e, k and N_A

- **Resolution 1 of the 24th CGPM (2011) :**

  The General Conference on Weights and Measures

  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,

- **Decision CIPM/104-9 (2015)**: The CIPM revised its Decision CIPM/103-30 and decided that experimental results to be used by the CODATA Task Group on Fundamental Constants in the evaluation of the fundamental constants leading to the fixed values for the defining constants of the new SI should be accepted for publication by **1 July 2017**

Bureau International des Poids et Mesures

Special 2017 CODATA adjustment of h, e, k and N_A

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Metrologia
Metrologia **55** (2018) L13–L16
https://doi.org/10.1088/1681-7575/aa950a

Short Communication

The CODATA 2017 values of h, e, k, and N_A for the revision of the SI

D B Newell[1], F Cabiati, J Fischer, K Fujii, S G Karshenboim, H S Margolis, E de Mirandés, P J Mohr, F Nez, K Pachucki, T J Quinn, B N Taylor, M Wang, B M Wood and Z Zhang

OPEN ACCESS
IOP Publishing | Bureau International des Poids et Mesures
Metrologia
Metrologia **55** (2018) 125–146
https://doi.org/10.1088/1681-7575/aa99bc

Data and analysis for the CODATA 2017 special fundamental constants adjustment*

Peter J Mohr, David B Newell, Barry N Taylor and Eite Tiesinga

ureau International des Poids et Mesures

2017 Key input data for the determination of *h*, *e*, *k* and N_A

TABLE I Key data for the determination of h, e, k, and N_A in the CODATA 2017 Special Adjustment. See Mohr *et al.* (2017) for a complete list of input data.

Source	Identification[a]	Quantity[b]	Value	Rel. stand. uncert u_r
Schlamminger *et al.* (2015)	NIST-15	h	$6.626\,069\,36(38) \times 10^{-34}$ J s	5.7×10^{-8}
Wood *et al.* (2017)	NRC-17	h	$6.626\,070\,133(60) \times 10^{-34}$ J s	9.1×10^{-9}
Haddad *et al.* (2017)	NIST-17	h	$6.626\,069\,934(88) \times 10^{-34}$ J s	1.3×10^{-8}
Thomas *et al.* (2017)	LNE-17	h	$6.626\,070\,40(38) \times 10^{-34}$ J s	5.7×10^{-8}
Azuma *et al.* (2015)	IAC-11	N_A	$6.022\,140\,95(18) \times 10^{23}$ mol^{-1}	3.0×10^{-8}
Azuma *et al.* (2015)	IAC-15	N_A	$6.022\,140\,70(12) \times 10^{23}$ mol^{-1}	2.0×10^{-8}
Bartl *et al.* (2017)	IAC-17	N_A	$6.022\,140\,526(70) \times 10^{23}$ mol^{-1}	1.2×10^{-8}
Kuramoto *et al.* (2017)	NMIJ-17	N_A	$6.022\,140\,78(15) \times 10^{23}$ mol^{-1}	2.4×10^{-8}
Moldover *et al.* (1988)	NIST-88	R	8.314 470(15) J mol^{-1} K^{-1}	1.8×10^{-6}
Pitre *et al.* (2009)	LNE-09	R	8.314 467(23) J mol^{-1} K^{-1}	2.7×10^{-6}
Sutton *et al.* (2010)	NPL-10	R	8.314 468(26) J mol^{-1} K^{-1}	3.2×10^{-6}
Pitre *et al.* (2011)	LNE-11	R	8.314 455(12) J mol^{-1} K^{-1}	1.4×10^{-6}
Pitre *et al.* (2015)	LNE-15	R	8.314 4615(84) J mol^{-1} K^{-1}	1.0×10^{-6}
Gavioso *et al.* (2015)	INRIM-15	R	8.314 4743(88) J mol^{-1} K^{-1}	1.1×10^{-6}
Pitre *et al.* (2017)	LNE-17	R	8.314 4614(50) J mol^{-1} K^{-1}	6.0×10^{-7}
de Podesta *et al.* (2017)	NPL-17	R	8.314 4603(58) J mol^{-1} K^{-1}	7.0×10^{-7}
Feng *et al.* (2017)	NIM-17	R	8.314 459(17) J mol^{-1} K^{-1}	2.0×10^{-6}
Gaiser *et al.* (2017)	PTB-17	$A_\epsilon(^4\mathrm{He})/R$	$6.221\,140(12) \times 10^{-8}$ m^3 K J^{-1}	1.9×10^{-6}
Qu *et al.* (2017)	NIM/NIST-17	k/h	$2.083\,6630(56) \times 10^{10}$ Hz K^{-1}	2.7×10^{-6}

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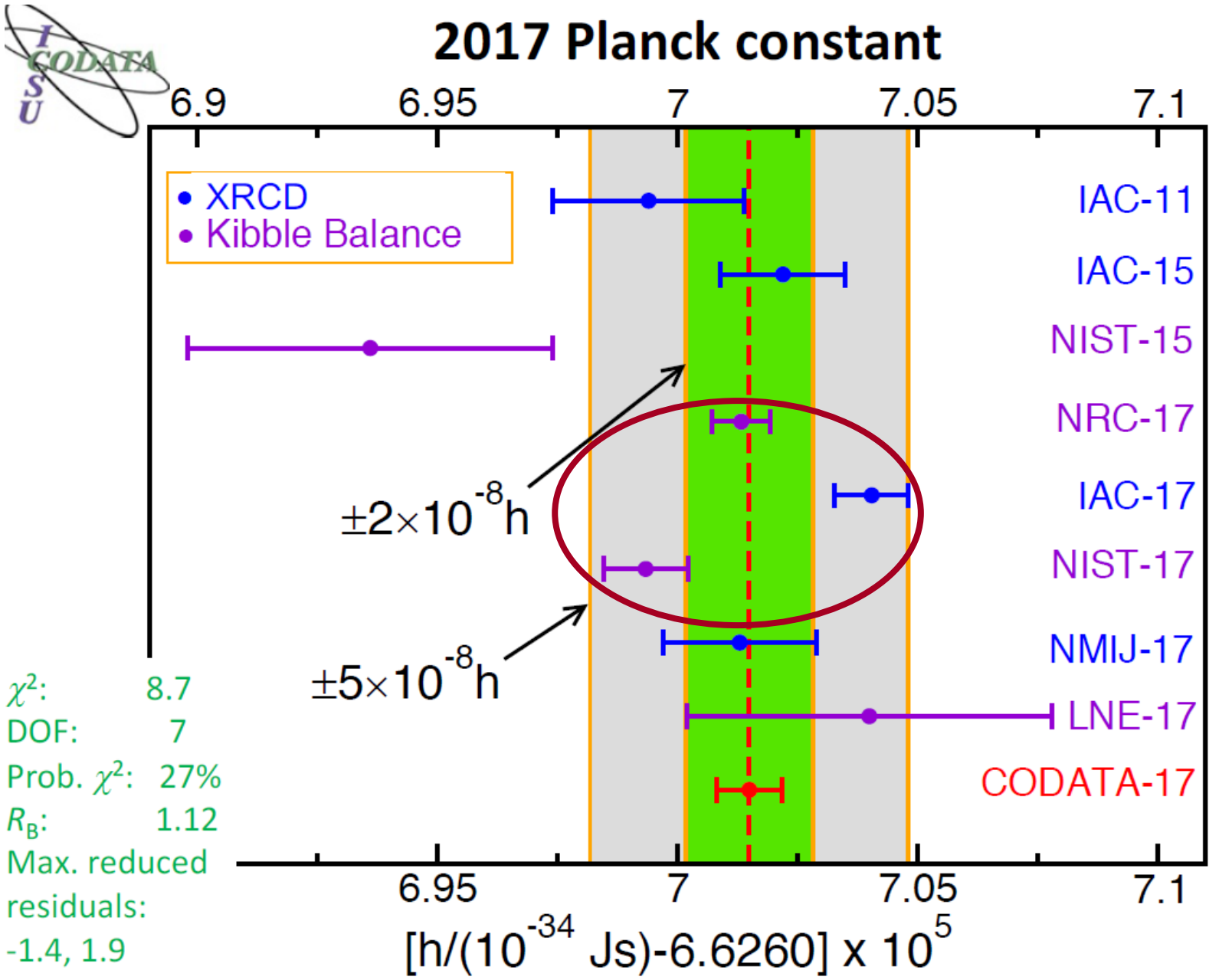

Green band: ±2 × 10^{-8}

Grey band: ±5 × 10^{-8}

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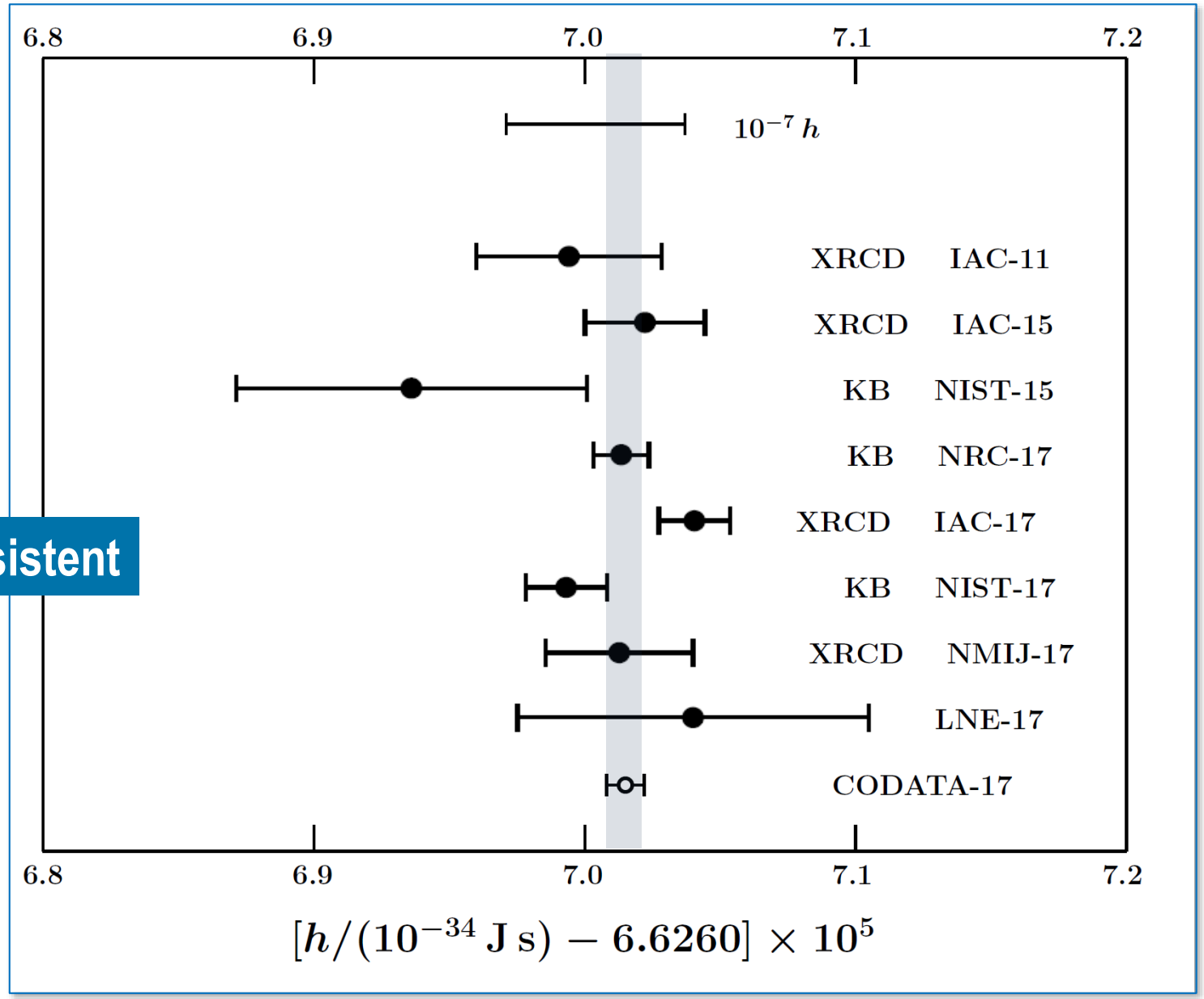
The Planck constant

Expansion factor of 1.7

- **Consistent**



CCM recommendation

https://www.bipm.org/cc/CCM/Allowed/16/06E_Final_CCM-Recommendation_G1-2017.pdf

RECOMMENDATION OF THE CONSULTATIVE COMMITTEE FOR MASS AND RELATED QUANTITIES SUBMITTED TO THE INTERNATIONAL COMMITTEE FOR WEIGHTS AND MEASURES

RECOMMENDATION G 1 (2017)
For a new definition of the kilogram in 2018

noting that the CCM will conduct an on-going key comparison of primary realizations of the kilogram that will capture and maintain a table of the experimental degrees of equivalence, which can be used to create a formal procedure for applying corrections relative to the consensus value,

requests those National Metrology Institutes having a realization of the kilogram to avail themselves of the consensus value (as determined from the ongoing comparison) when disseminating the unit of mass according to the new definition, until the dispersion in values becomes compatible with the individual realization uncertainties, thus preserving the international equivalence of calibration certificates and in accordance with the principles and agreed protocols of the CIPM Mutual Recognition Arrangement,

recommends that the CIPM undertakes the necessary steps to proceed with the planned redefinition of the SI at the next meeting of the CGPM, acknowledging the measures to be taken by the CCM to ensure integrity and continuity in the dissemination of the kilogram.

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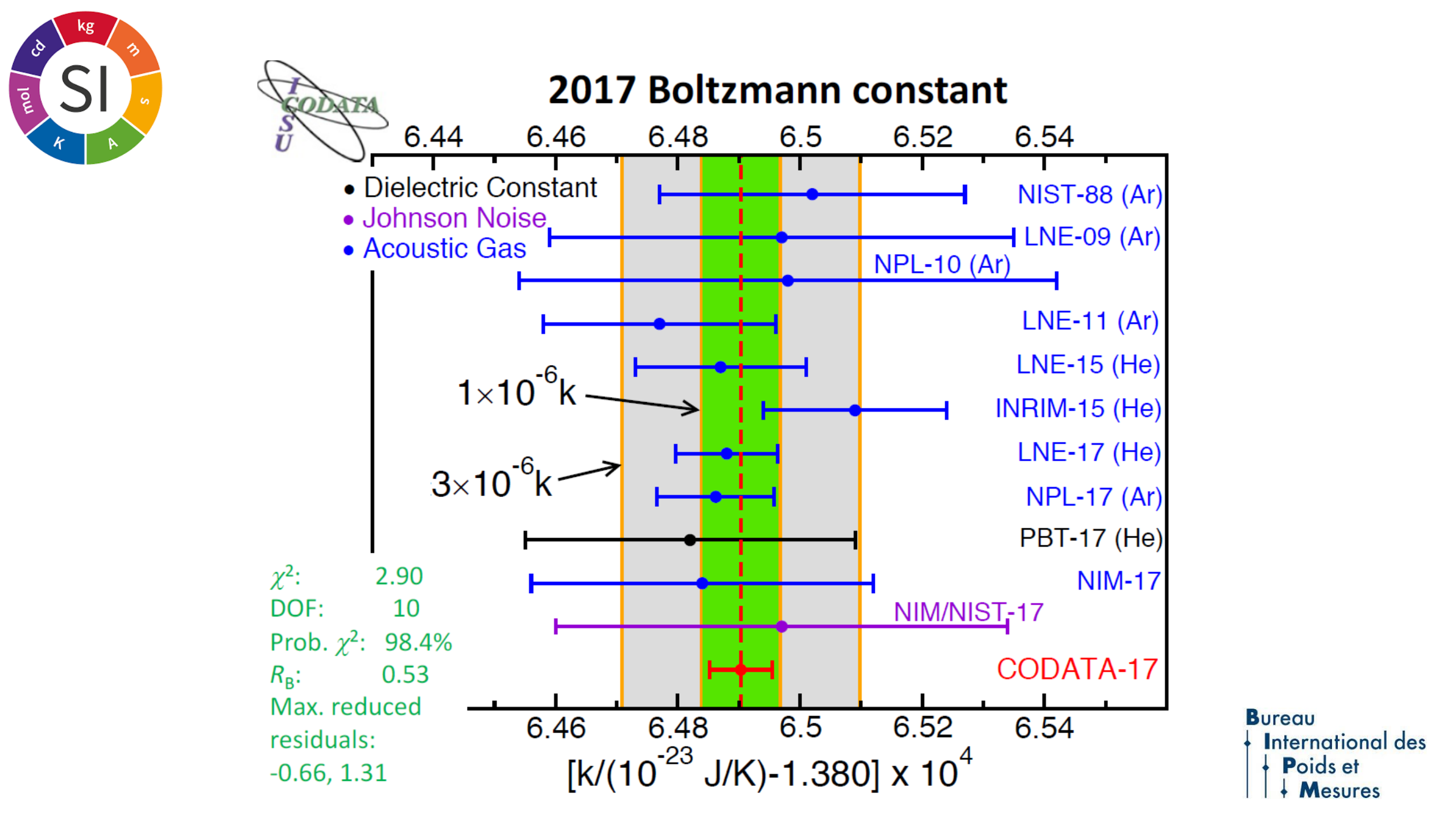

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CCT recommendation

https://www.bipm.org/cc/CCT/Allowed/Summary_reports_and_strategy/Recommendation-CCT-T1-2017-EN.pdf

RECOMMENDATIONS OF THE
CONSULTATIVE COMMITTEE FOR THERMOMETRY
SUBMITTED TO THE INTERNATIONAL COMMITTEE FOR WEIGHTS AND MEASURES

RECOMMENDATION T 1 (2017)

For a new definition of the kelvin in 2018

considering

(...)

- that the determination of k is based now on three fundamentally different methods, of which at least one result for each has a relative standard uncertainty less than 3 parts in 10^6,
- that all requirements of CCT for the new definition of the kelvin have been fulfilled,

(...)

recommends

- that the CIPM finalises the unit redefinitions through agreeing to fix the values of the fundamental physical constants, from which a fixed numerical value of the Boltzmann constant with 8 digits will be adopted for the redefinition of the kelvin,

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Final agreed values of the four fundamental constants to be fixed

The CODATA 2017 Values of h, e, k, and N_A

Quantity	Value
h	$6.626\,070\,15 \times 10^{-34}$ J s
e	$1.602\,176\,634 \times 10^{-19}$ C
k	$1.380\,649 \times 10^{-23}$ J K^{-1}
N_A	$6.022\,140\,76 \times 10^{23}$ mol^{-1}

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Consistency from present SI to revised SI

A requirement by the CGPM (2011) is that the revised SI be consistent with the present SI

- **Resolution 1 of the 24th CGPM (2011)**
  - The values of $m(\mathcal{K})$, μ_0, T_{TPW}, and $M(^{12}\mathrm{C})$ remain consistent with their exact values in present SI

- **Decision CIPM/105-15 of the 105th CIPM (2016)**
  - The exact values of h, e, and N_{A} are chosen such that $m(\mathcal{K})$, μ_0, and $M(^{12}\mathrm{C})$ remain consistent within their relative standard uncertainties.
  - The exact value of k is chosen such that T_{TPW} remains consistent at the level it can be presently realized

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Consistency from present SI to revised SI

- **International prototype of the kilogram:**

  $m(\mathcal{K})/1\ \mathrm{kg} = 1.000\ 000\ 000(10)$

- **Permeability of vacuum:**

  $\mu_0/4\pi \times 10^{-7}\ \mathrm{H\ m^{-1}} = 1.000\ 000\ 000\ 20(23)$

- **Triple point of water:**

  $T_{\mathrm{TPW}}/273.16\ \mathrm{K} = 1.000\ 000\ 02(37)$

- **Molar mass of the carbon 12 atom:**

  $M(^{12}\mathrm{C})/0.012\ \mathrm{kg\ mol^{-1}} = 1.000\ 000\ 000\ 37(45)$

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Mesures

CCU recommendation

https://www.bipm.org/cc/CCU/Allowed/23/CCU_Final_Recommendation_U1_2017.pdf

RECOMMENDATION OF THE CONSULTATIVE COMMITTEE FOR UNITS TO BE SUBMITTED TO THE INTERNATIONAL COMMITTEE FOR WEIGHTS AND MEASURES

RECOMMENDATION U1 (2017)

On the possible redefinition of the kilogram, ampere, kelvin and mole in 2018

The Consultative Committee for Units (CCU), at its 23rd meeting in 2017,

(...)

recommends

- that the CIPM undertakes the necessary steps to proceed with the planned redefinition of the kilogram, ampere, kelvin and mole at the 26th CGPM in 2018.

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CIPM decision in October 2017

https://www.bipm.org/en/committees/cipm/meeting/106.html

CIPM/106-10

The International Committee for Weights and Measures (CIPM) welcomed recommendations regarding the redefinition of the SI from its Consultative Committees.

The CIPM noted that the agreed conditions for the redefinition are now met and decided to submit draft Resolution A to the 26th meeting of the General Conference on Weights and Measures (CGPM) and to undertake all other necessary steps to proceed with the planned redefinition of the kilogram, ampere, kelvin and mole.

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Draft Resolution A

Draft Resolution A

On the revision of the International System of Units (SI)

The General Conference on Weights and Measures (CGPM), at its 26th meeting,

considering

- the essential requirement for an International System of Units (SI) that is uniform and accessible world-wide for international trade, high-technology manufacturing, human health and safety, protection of the environment, global climate studies and the basic science that underpins all these,
- that the SI units must be stable in the long term, internally self-consistent and practically realizable being based on the present theoretical description of nature at the highest level,
- that a revision of the SI to meet these requirements was proposed in Resolution 1 adopted unanimously by the CGPM at its 24th meeting (2011) that laid out in detail a new way of defining the SI based on a set of seven defining constants, drawn from the fundamental constants of physics and other constants of nature, from which the definitions of the seven base units are deduced,
- that the conditions set by the CGPM at its 24th meeting (2011), confirmed at its 25th meeting (2014), before such a revised SI could be adopted have now been met,

decides that, effective from 20 May 2019, the International System of Units, the SI, is the system of units in which:

- the unperturbed ground state hyperfine transition frequency of the caesium 133 atom $\Delta\nu_{Cs}$ is 9 192 631 770 Hz,
- the speed of light in vacuum c is 299 792 458 m/s,
- the Planck constant h is $6.626\,070\,15 \times 10^{-34}$ J s,
- the elementary charge e is $1.602\,176\,634 \times 10^{-19}$ C,
- the Boltzmann constant k is $1.380\,649 \times 10^{-23}$ J/K,
- the Avogadro constant N_A is $6.022\,140\,76 \times 10^{23}$ mol^{-1},
- the luminous efficacy of monochromatic radiation of frequency 540×10^{12} Hz, K_{cd}, is 683 lm/W,

where 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 $Hz = s^{-1}$, $J = m^2\ kg\ s^{-2}$, $C = A\ s$, $lm = cd\ m^2\ m^{-2} = cd\ sr$, and $W = m^2\ kg\ s^{-3}$.

Bureau International des Poids et Mesures

Draft Resolution A

decides that, effective from 20 May 2019, the International System of Units, the SI, is the system of units in which:

- the unperturbed ground state hyperfine transition frequency of the caesium 133 atom $\Delta\nu_{Cs}$ is 9 192 631 770 Hz,
- the speed of light in vacuum c is 299 792 458 m/s,
- the Planck constant h is $6.626\,070\,15 \times 10^{-34}$ J s,
- the elementary charge e is $1.602\,176\,634 \times 10^{-19}$ C,
- the Boltzmann constant k is $1.380\,649 \times 10^{-23}$ J/K,
- the Avogadro constant N_A is $6.022\,140\,76 \times 10^{23}$ mol^{-1},
- the luminous efficacy of monochromatic radiation of frequency 540×10^{12} Hz, K_{cd}, is 683 lm/W,

where 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 $Hz = s^{-1}$, $J = m^2\ kg\ s^{-2}$, $C = A\ s$, $lm = cd\ m^2\ m^{-2} = cd\ sr$, and $W = m^2\ kg\ s^{-3}$.

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invites the International Committee for Weights and Measures (CIPM) to produce a new edition of its Brochure entitled "*The International System of Units*" in which a full description of the revised SI will be given.

Appendix 1. Abrogation of former definitions of the base units

It follows from the new definition of the SI described above that, effective from 20 May 2019:

- the definition of the second in force since 1967/68 (13th meeting of the CGPM, Resolution 1) is abrogated,
- the definition of the metre in force since 1983 (17th meeting of the CGPM, Resolution 1) is abrogated,
- the definition of the kilogram in force since 1889 (1st meeting of the CGPM, 1889, 3rd meeting of the CGPM, 1901) based upon the mass of the international prototype of the kilogram is abrogated,
- the definition of the ampere in force since 1948 (9th meeting of the CGPM) based upon the definition proposed by the CIPM (1946, Resolution 2) is abrogated,
- the definition of the kelvin in force since 1967/68 (13th meeting of the CGPM, Resolution 4) is abrogated,
- the definition of the mole in force since 1971 (14th meeting of the CGPM, Resolution 3) is abrogated,
- the definition of the candela in force since 1979 (16th meeting of the CGPM, Resolution 3) is abrogated,
- the decision to adopt the conventional values of the Josephson constant K_{J-90} and of the von Klitzing constant R_{K-90} taken by the CIPM (1988, Recommendations 1 and 2) at the request of the CGPM (18th meeting of the CGPM, 1987, Resolution 6) for the establishment of representations of the volt and the ohm using the Josephson and quantum Hall effects, respectively, is abrogated.

Appendix 2. Status of constants previously used in the former definitions

It follows from the new definition of the SI described above, and from the recommended values of the 2017 special adjustment of the Committee on Data for Science and Technology (CODATA) on which the values of the defining constants are based, that effective from 20 May 2019:

- the mass of the international prototype of the kilogram $m(K)$ is equal to 1 kg within a relative standard uncertainty equal to that of the recommended value of h at the time this Resolution was adopted, namely 1.0×10^{-8} and that in the future its value will be determined experimentally,
- the vacuum magnetic permeability μ_0 is equal to $4\pi \times 10^{-7}$ H m^{-1} within a relative standard uncertainty equal to that of the recommended value of the fine-structure constant α at the time this Resolution was adopted, namely 2.3×10^{-10} and that in the future its value will be determined experimentally,
- the thermodynamic temperature of the triple point of water T_{TPW} is equal to 273.16 K within a relative standard uncertainty closely equal to that of the recommended value of k at the time this Resolution was adopted, namely 3.7×10^{-7}, and that in the future its value will be determined experimentally,
- the molar mass of carbon 12, $M(^{12}\mathrm{C})$, is equal to 0.012 kg mol^{-1} within a relative standard uncertainty equal to that of the recommended value of $N_{\mathrm{A}}h$ at the time this Resolution was adopted, namely 4.5×10^{-10}, and that in the future its value will be determined experimentally.

Appendix 3. The base units of the SI

Starting from the new definition of the SI described above in terms of fixed numerical values of the defining constants, definitions of each of the seven base units are deduced by taking, as appropriate, one or more of these defining constants to give the following set of definitions, effective from 20 May 2019:

- The second, symbol s, is the SI unit of time. It is defined by taking the fixed numerical value of the caesium frequency $\Delta\nu_{Cs}$, the unperturbed ground-state hyperfine transition frequency of the caesium 133 atom, to be 9 192 631 770 when expressed in the unit Hz, which is equal to s^{-1}.

- The metre, symbol m, is the SI unit of length. It is defined by taking the fixed numerical value of the speed of light in vacuum c to be 299 792 458 when expressed in the unit m/s, where the second is defined in terms of $\Delta\nu_{Cs}$.

- The kilogram, symbol kg, is the SI unit of mass. It is defined by taking the fixed numerical value of the Planck constant h to be $6.626\,070\,15 \times 10^{-34}$ when expressed in the unit J s, which is equal to kg m^2 s^{-1}, where the metre and the second are defined in terms of c and $\Delta\nu_{Cs}$.

- The ampere, symbol A, is the SI unit of electric current. It is defined by taking the fixed numerical value of the elementary charge e to be $1.602\,176\,634 \times 10^{-19}$ when expressed in the unit C, which is equal to A s, where the second is defined in terms of $\Delta\nu_{Cs}$.

- The kelvin, symbol K, is the SI unit of thermodynamic temperature. It is defined by taking the fixed numerical value of the Boltzmann constant k to be $1.380\,649 \times 10^{-23}$ when expressed in the unit J K^{-1}, which is equal to kg m^2 s^{-2} K^{-1}, where the kilogram, metre and second are defined in terms of h, c and $\Delta\nu_{Cs}$.

- The mole, symbol mol, is the SI unit of amount of substance. One mole contains exactly $6.022\,140\,76 \times 10^{23}$ elementary entities. This number is the fixed numerical value of the Avogadro constant, N_A, when expressed in the unit mol^{-1} and is called the Avogadro number.

  The amount of substance, symbol n, of a system is a measure of the number of specified elementary entities. An elementary entity may be an atom, a molecule, an ion, an electron, any other particle or specified group of particles.

- The candela, symbol cd, is the SI unit of luminous intensity in a given direction. It is defined by taking the fixed numerical value of the luminous efficacy of monochromatic radiation of frequency 540×10^{12} Hz, K_{cd}, to be 683 when expressed in the unit lm W^{-1}, which is equal to cd sr W^{-1}, or cd sr kg^{-1} m^{-2} s^3, where the kilogram, metre and second are defined in terms of h, c and $\Delta\nu_{Cs}$.

SI Brochure

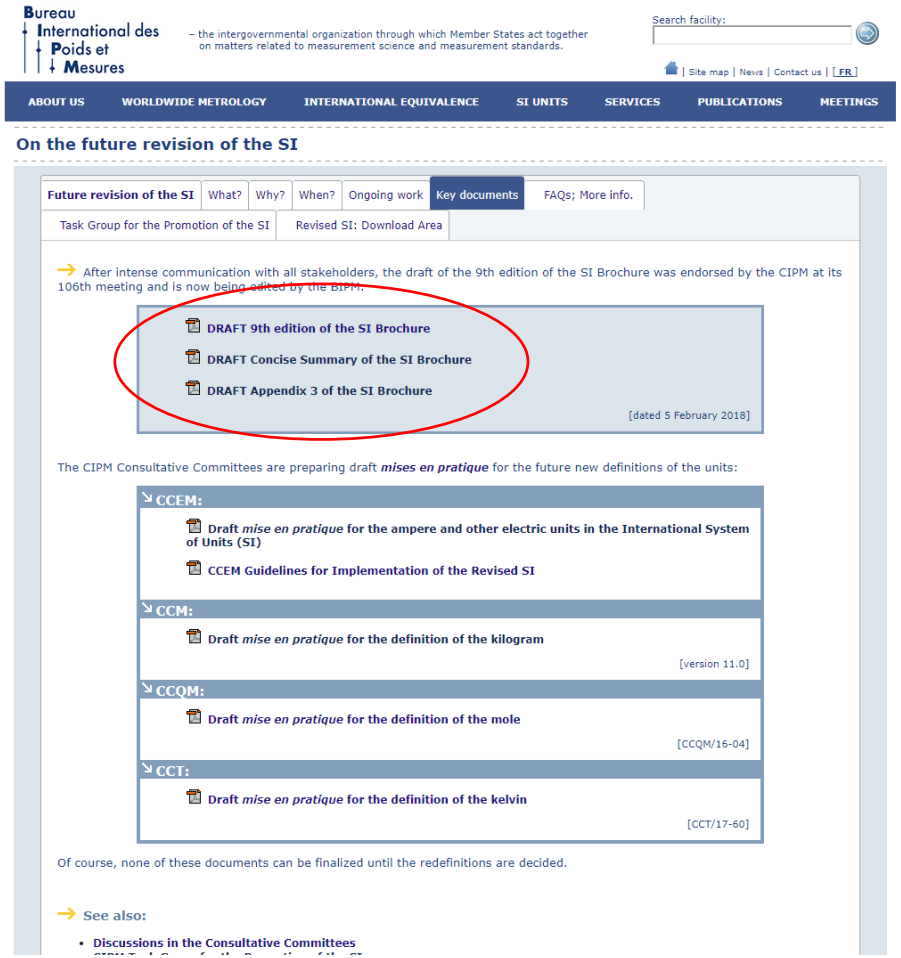
- The draft of the 9th Edition of the SI Brochure is in its final stage

  - Minor editorial improvements pending
  - French translation is ongoing.
  - The CCU has accepted to include a side note including the **var** and the **gal** in the 9th SI Brochure
  - The CCU has decided to reject all requests to include further non-SI units in the 9th SI Brochure
  - A new wording of the definition of the mole in the revised SI has been agreed with the CCQM and IUPAC
  - Appendix 1 (the list of decisions of the CGPM and the CIPM) will be kept both in printed form in the 9th Brochure and as an online appendix.
  - Appendix 3 (Units for photochemical and photobiological quantities) has been updated by the CCPR and will be kept as an online appendix in the 9th Brochure.
  - Concise Summary in its final version. Translation to French completed.

Bureau International des Poids et Mesures

CCU documents now available in the BIPM open webpages

https://www.bipm.org/en/measurement-units/rev-si/



https://www.bipm.org/en/measurement-units/rev-si/

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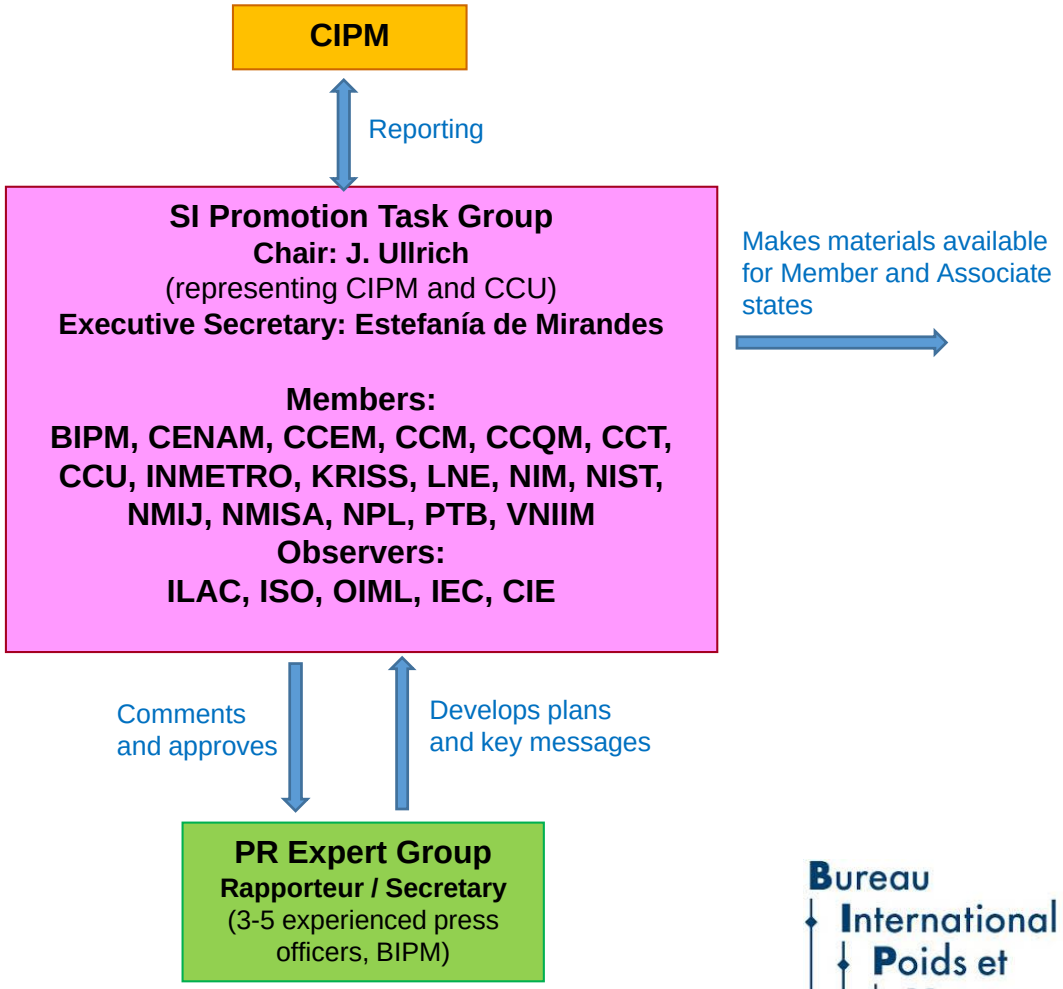
CIPM Task group for the promotion of the SI

… and guest participants from RMO's



Bureau International des Poids et Mesures

Official campaign for the promotion of the revision of the SI

20 May 2018

World metrology day

CGPM:
13-16 November 2018

BIPM awareness webpage
Brand Book
Press pack
Speaker's notes
Key messages
FAQs
CC's joint statement
NMI's promotional material
.
.
.

20 May 2019

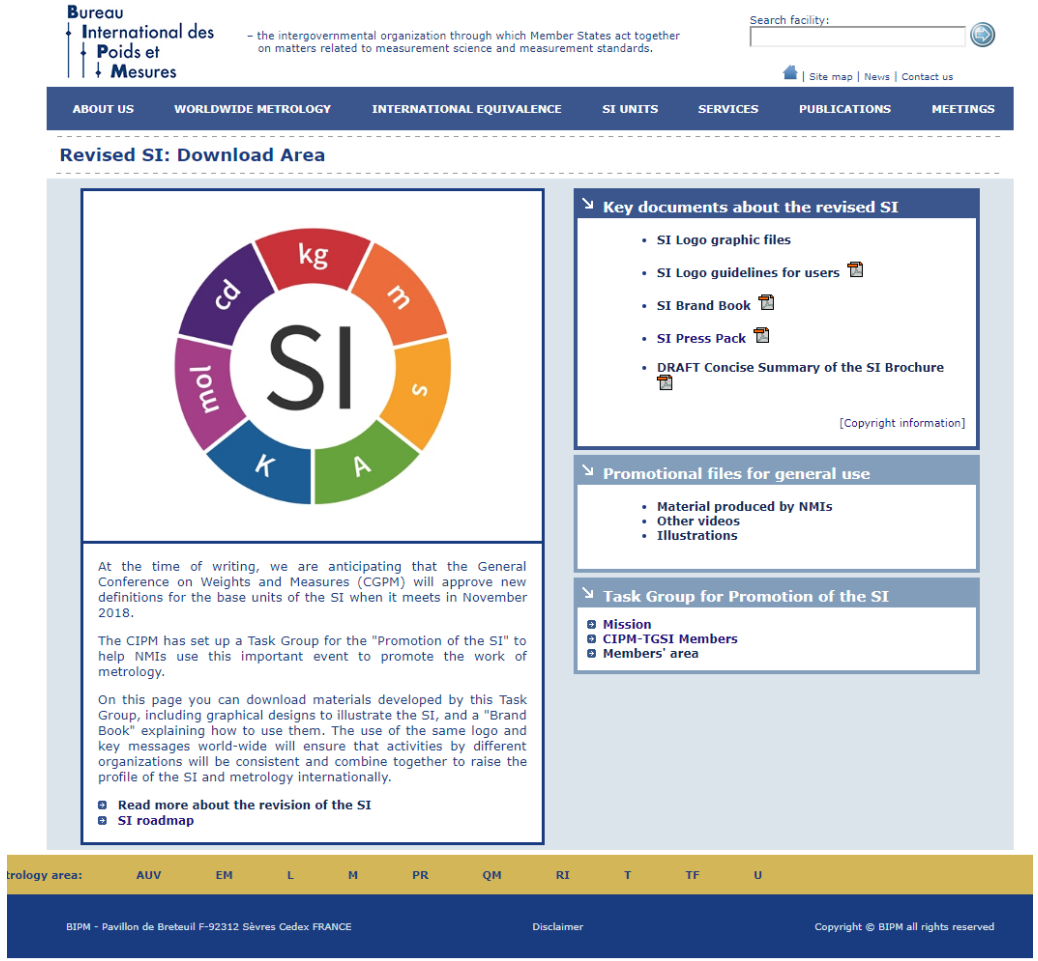
World metrology day

Redefinitions come into force

Bureau International des Poids et Mesures

BIPM public webpage containing all the promotional material developed by the Task Group

https://www.bipm.org/en/si-download-area/



Bureau International des Poids et Mesures

Brand Book updated in April 2018 and sent to NMIs

https://www.bipm.org/utils/common/pdf/SI-Brand-Book.pdf

Bureau International des Poids et Mesures

Future Revision of the SI

Brand Book V2

April 2018

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Bureau International des Poids et Mesures

Press pack updated in May 2018 and sent to NMIs for the launching of the campaign

https://www.bipm.org/utils/common/pdf/SI-Press-Pack.pdf

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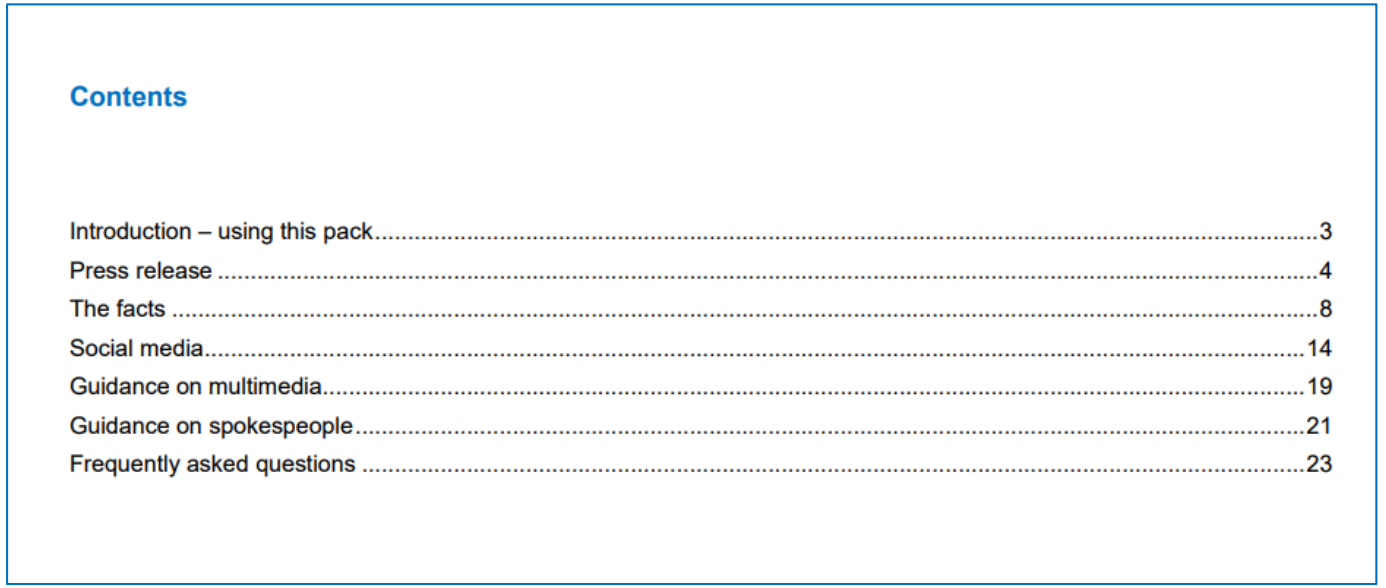
Forthcoming Revision of the SI

SI Campaign Launch - Press Pack

May 2018



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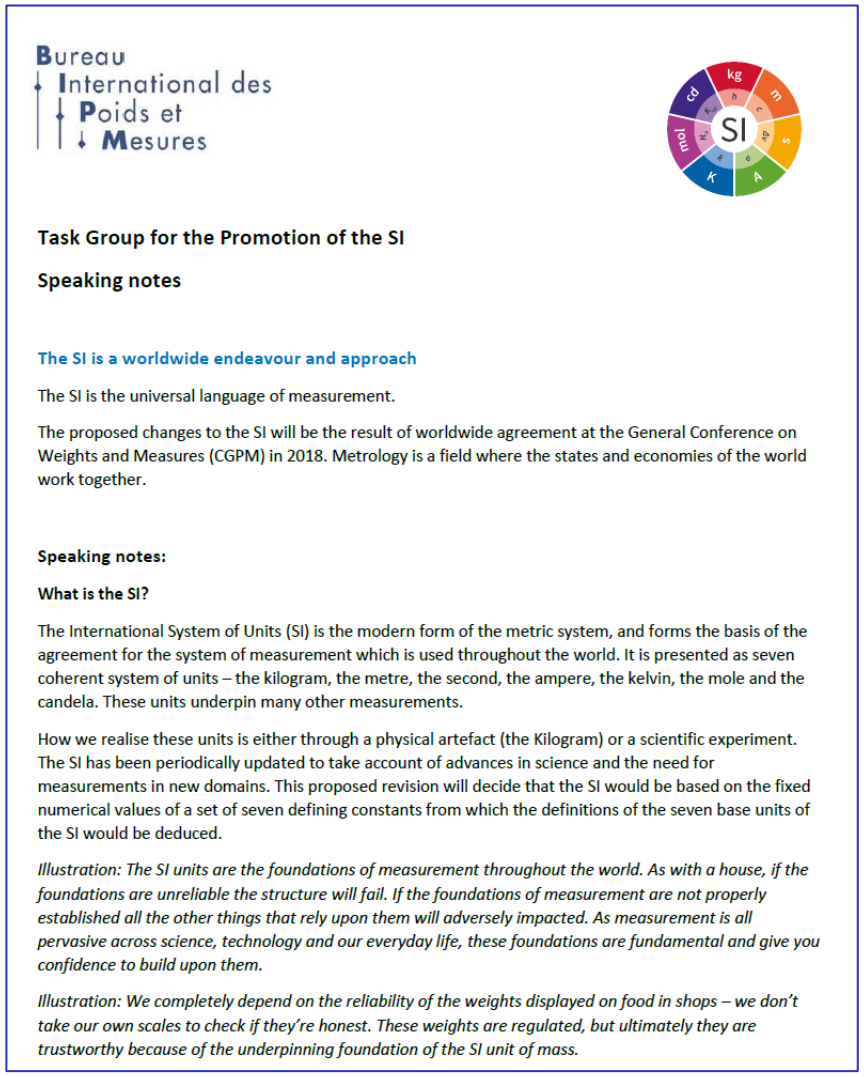
Speaking Notes and Key Messages produced by the Task Group



Bureau International des Poids et Mesures

Task Group for the Promotion of the SI

Speaking notes

The SI is a worldwide endeavour and approach

The SI is the universal language of measurement.

The proposed changes to the SI will be the result of worldwide agreement at the General Conference on Weights and Measures (CGPM) in 2018. Metrology is a field where the states and economies of the world work together.

Speaking notes:

What is the SI?

The International System of Units (SI) is the modern form of the metric system, and forms the basis of the agreement for the system of measurement which is used throughout the world. It is presented as seven coherent system of units – the kilogram, the metre, the second, the ampere, the kelvin, the mole and the candela. These units underpin many other measurements.

How we realise these units is either through a physical artefact (the Kilogram) or a scientific experiment. The SI has been periodically updated to take account of advances in science and the need for measurements in new domains. This proposed revision will decide that the SI would be based on the fixed numerical values of a set of seven defining constants from which the definitions of the seven base units of the SI would be deduced.

Illustration: The SI units are the foundations of measurement throughout the world. As with a house, if the foundations are unreliable the structure will fail. If the foundations of measurement are not properly established all the other things that rely upon them will adversely impacted. As measurement is all pervasive across science, technology and our everyday life, these foundations are fundamental and give you confidence to build upon them.

Illustration: We completely depend on the reliability of the weights displayed on food in shops – we don't take our own scales to check if they're honest. These weights are regulated, but ultimately they are trustworthy because of the underpinning foundation of the SI unit of mass.

Questions adressed:

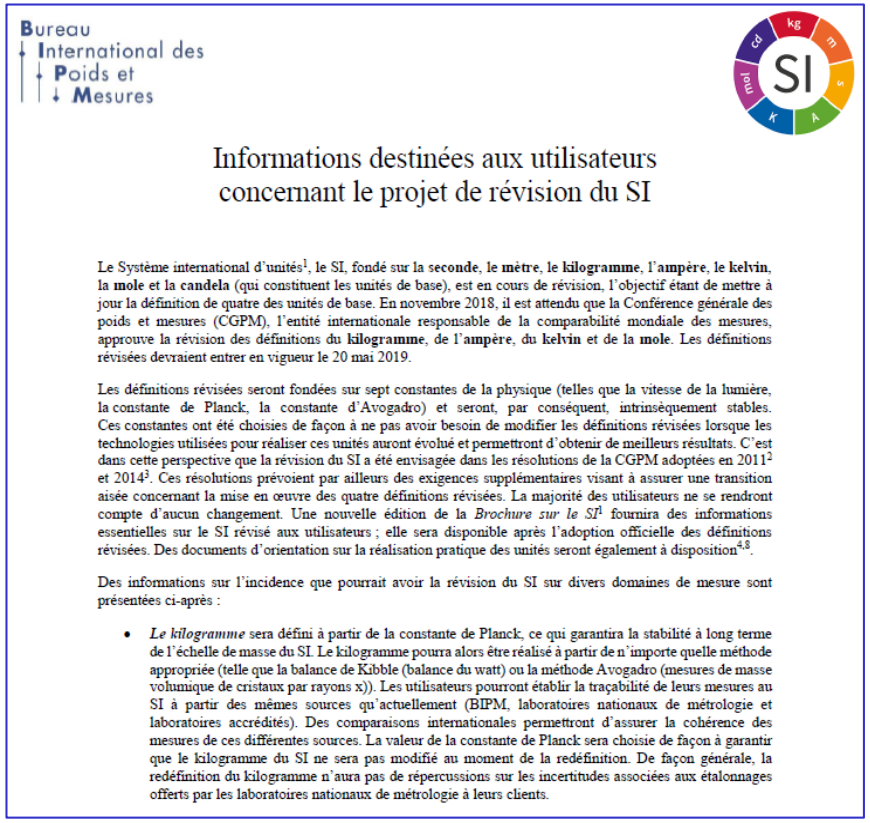
- What is the SI?
- Who is involved in agreeing the SI?
- What is wrong with the old system?
- What are the aims of the redefinition of the SI?
- What will future-proofing enable?
- What is the impact of the changes

Each question is fully answered and a key message per question is provided

Bureau International des Poids et Mesures

Joint CC statement now translated to French, Spanish and German

and widely distributed within the NMIs



Bureau International des Poids et Mesures

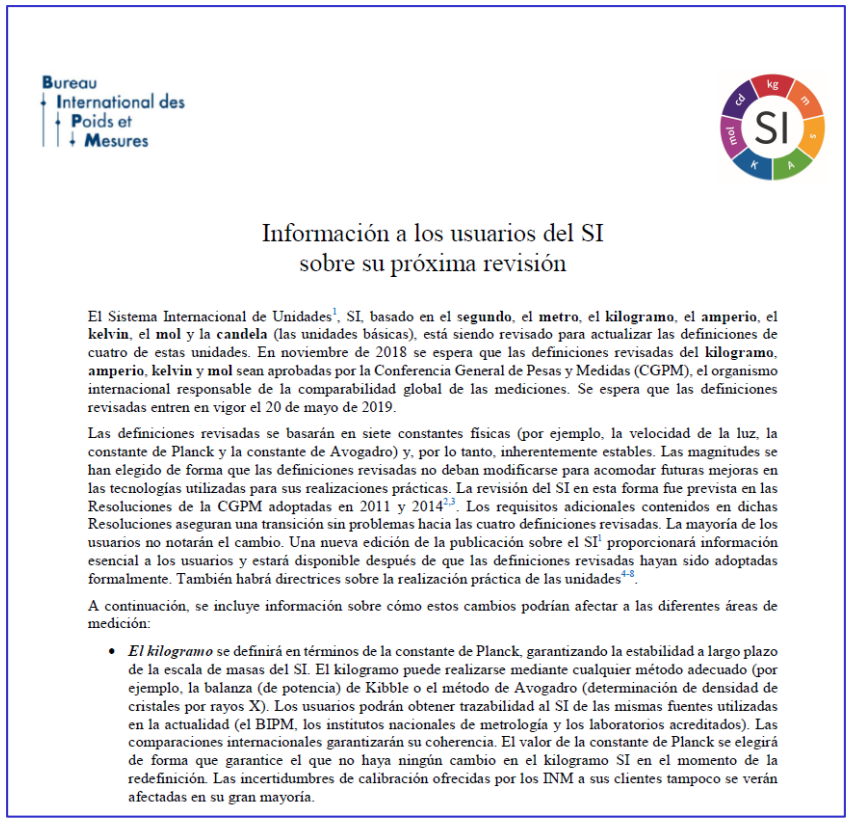
Informations destinées aux utilisateurs concernant le projet de révision du SI

Le Système international d'unités[1], le SI, fondé sur la **seconde**, le **mètre**, le **kilogramme**, l'**ampère**, le **kelvin**, la **mole** et la **candela** (qui constituent les unités de base), est en cours de révision, l'objectif étant de mettre à jour la définition de quatre des unités de base. En novembre 2018, il est attendu que la Conférence générale des poids et mesures (CGPM), l'entité internationale responsable de la comparabilité mondiale des mesures, approuve la révision des définitions du **kilogramme**, de l'**ampère**, du **kelvin** et de la **mole**. Les définitions révisées devraient entrer en vigueur le 20 mai 2019.

Les définitions révisées seront fondées sur sept constantes de la physique (telles que la vitesse de la lumière, la constante de Planck, la constante d'Avogadro) et seront, par conséquent, intrinsèquement stables. Ces constantes ont été choisies de façon à ne pas avoir besoin de modifier les définitions révisées lorsque les technologies utilisées pour réaliser ces unités auront évolué et permettront d'obtenir de meilleurs résultats. C'est dans cette perspective que la révision du SI a été envisagée dans les résolutions de la CGPM adoptées en 2011[2] et 2014[3]. Ces résolutions prévoient par ailleurs des exigences supplémentaires visant à assurer une transition aisée concernant la mise en œuvre des quatre définitions révisées. La majorité des utilisateurs ne se rendront compte d'aucun changement. Une nouvelle édition de la *Brochure sur le SI*[1] fournira des informations essentielles sur le SI révisé aux utilisateurs ; elle sera disponible après l'adoption officielle des définitions révisées. Des documents d'orientation sur la réalisation pratique des unités seront également à disposition[4-8].

Des informations sur l'incidence que pourrait avoir la révision du SI sur divers domaines de mesure sont présentées ci-après :

- *Le kilogramme* sera défini à partir de la constante de Planck, ce qui garantira la stabilité à long terme de l'échelle de masse du SI. Le kilogramme pourra alors être réalisé à partir de n'importe quelle méthode appropriée (telle que la balance de Kibble (balance du watt) ou la méthode Avogadro (mesures de masse volumique de cristaux par rayons x)). Les utilisateurs pourront établir la traçabilité de leurs mesures au SI à partir des mêmes sources qu'actuellement (BIPM, laboratoires nationaux de métrologie et laboratoires accrédités). Des comparaisons internationales permettront d'assurer la cohérence des mesures de ces différentes sources. La valeur de la constante de Planck sera choisie de façon à garantir que le kilogramme du SI ne sera pas modifié au moment de la redéfinition. De façon générale, la redéfinition du kilogramme n'aura pas de répercussions sur les incertitudes associées aux étalonnages offerts par les laboratoires nationaux de métrologie à leurs clients.



Bureau International des Poids et Mesures

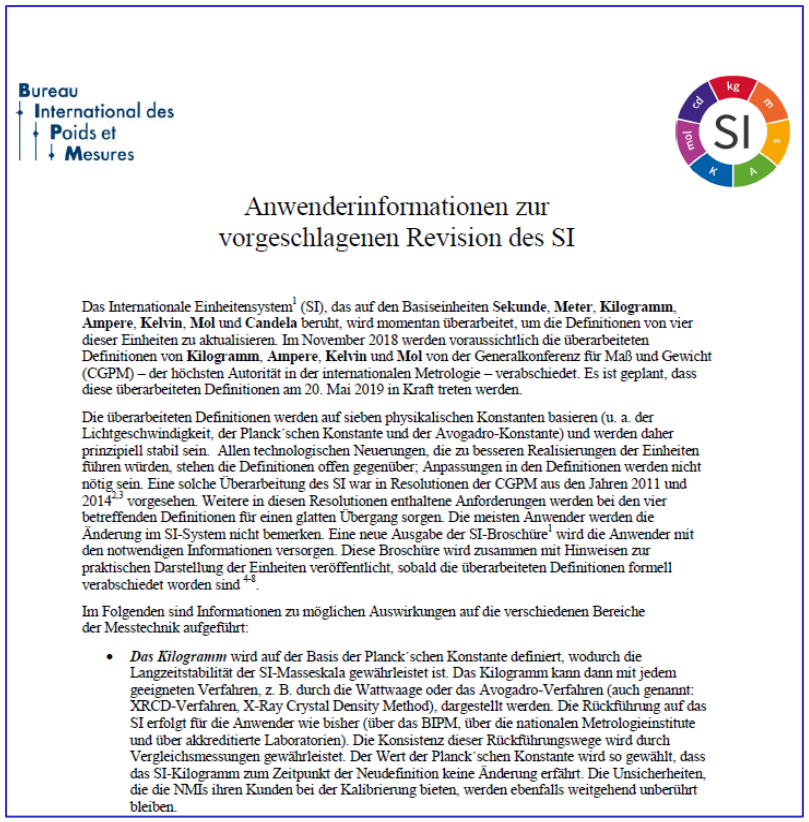
Información a los usuarios del SI sobre su próxima revisión

El Sistema Internacional de Unidades[1], SI, basado en el **segundo**, el **metro**, el **kilogramo**, el **amperio**, el **kelvin**, el **mol** y la **candela** (las unidades básicas), está siendo revisado para actualizar las definiciones de cuatro de estas unidades. En noviembre de 2018 se espera que las definiciones revisadas del **kilogramo**, **amperio**, **kelvin** y **mol** sean aprobadas por la Conferencia General de Pesas y Medidas (CGPM), el organismo internacional responsable de la comparabilidad global de las mediciones. Se espera que las definiciones revisadas entren en vigor el 20 de mayo de 2019.

Las definiciones revisadas se basarán en siete constantes físicas (por ejemplo, la velocidad de la luz, la constante de Planck y la constante de Avogadro) y, por lo tanto, inherentemente estables. Las magnitudes se han elegido de forma que las definiciones revisadas no deban modificarse para acomodar futuras mejoras en las tecnologías utilizadas para sus realizaciones prácticas. La revisión del SI en esta forma fue prevista en las Resoluciones de la CGPM adoptadas en 2011 y 2014[2,3]. Los requisitos adicionales contenidos en dichas Resoluciones aseguran una transición sin problemas hacia las cuatro definiciones revisadas. La mayoría de los usuarios no notarán el cambio. Una nueva edición de la publicación sobre el SI[1] proporcionará información esencial a los usuarios y estará disponible después de que las definiciones revisadas hayan sido adoptadas formalmente. También habrá directrices sobre la realización práctica de las unidades[1-8].

A continuación, se incluye información sobre cómo estos cambios podrían afectar a las diferentes áreas de medición:

- *El kilogramo* se definirá en términos de la constante de Planck, garantizando la estabilidad a largo plazo de la escala de masas del SI. El kilogramo puede realizarse mediante cualquier método adecuado (por ejemplo, la balanza (de potencia) de Kibble o el método de Avogadro (determinación de densidad de cristales por rayos X). Los usuarios podrán obtener trazabilidad al SI de las mismas fuentes utilizadas en la actualidad (el BIPM, los institutos nacionales de metrología y los laboratorios acreditados). Las comparaciones internacionales garantizarán su coherencia. El valor de la constante de Planck se elegirá de forma que garantice el que no haya ningún cambio en el kilogramo SI en el momento de la redefinición. Las incertidumbres de calibración ofrecidas por los INM a sus clientes tampoco se verán afectadas en su gran mayoría.



Bureau International des Poids et Mesures

Anwenderinformationen zur vorgeschlagenen Revision des SI

Das Internationale Einheitensystem[1] (SI), das auf den Basiseinheiten **Sekunde**, **Meter**, **Kilogramm**, **Ampere**, **Kelvin**, **Mol** und **Candela** beruht, wird momentan überarbeitet, um die Definitionen von vier dieser Einheiten zu aktualisieren. Im November 2018 werden voraussichtlich die überarbeiteten Definitionen von **Kilogramm**, **Ampere**, **Kelvin** und **Mol** von der Generalkonferenz für Maß und Gewicht (CGPM) – der höchsten Autorität in der internationalen Metrologie – verabschiedet. Es ist geplant, dass diese überarbeiteten Definitionen am 20. Mai 2019 in Kraft treten werden.

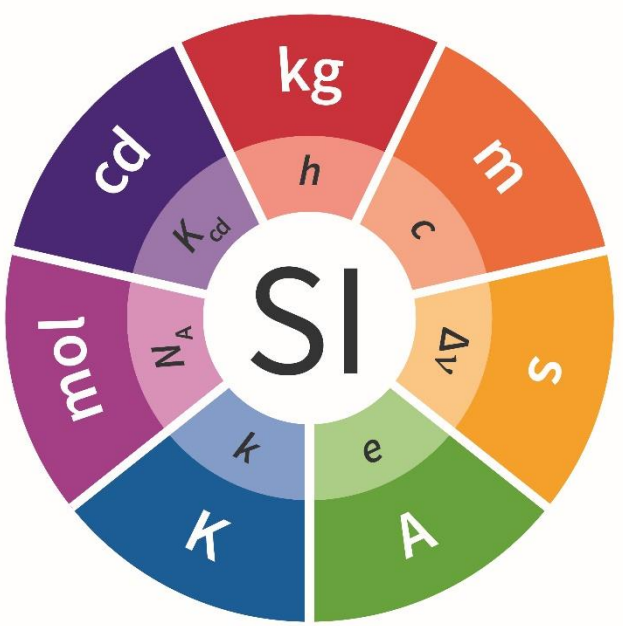
Die überarbeiteten Definitionen werden auf sieben physikalischen Konstanten basieren (u. a. der Lichtgeschwindigkeit, der Planck´schen Konstante und der Avogadro-Konstante) und werden daher prinzipiell stabil sein. Allen technologischen Neuerungen, die zu besseren Realisierungen der Einheiten führen würden, stehen die Definitionen offen gegenüber; Anpassungen in den Definitionen werden nicht nötig sein. Eine solche Überarbeitung des SI war in Resolutionen der CGPM aus den Jahren 2011 und 2014[2,3] vorgesehen. Weitere in diesen Resolutionen enthaltene Anforderungen werden bei den vier betreffenden Definitionen für einen glatten Übergang sorgen. Die meisten Anwender werden die Änderung im SI-System nicht bemerken. Eine neue Ausgabe der SI-Broschüre[1] wird die Anwender mit den notwendigen Informationen versorgen. Diese Broschüre wird zusammen mit Hinweisen zur praktischen Darstellung der Einheiten veröffentlicht, sobald die überarbeiteten Definitionen formell verabschiedet worden sind [4-8].

Im Folgenden sind Informationen zu möglichen Auswirkungen auf die verschiedenen Bereiche der Messtechnik aufgeführt:

- *Das Kilogramm* wird auf der Basis der Planck´schen Konstante definiert, wodurch die Langzeitstabilität der SI-Masseskala gewährleistet ist. Das Kilogramm kann dann mit jedem geeigneten Verfahren, z. B. durch die Wattwaage oder das Avogadro-Verfahren (auch genannt: XRCD-Verfahren, X-Ray Crystal Density Method), dargestellt werden. Die Rückführung auf das SI erfolgt für die Anwender wie bisher (über das BIPM, über die nationalen Metrologieinstitute und über akkreditierte Laboratorien). Die Konsistenz dieser Rückführungswege wird durch Vergleichsmessungen gewährleistet. Der Wert der Planck´schen Konstante wird so gewählt, dass das SI-Kilogramm zum Zeitpunkt der Neudefinition keine Änderung erfährt. Die Unsicherheiten, die die NMIs ihren Kunden bei der Kalibrierung bieten, werden ebenfalls weitgehend unberührt bleiben.

26th meeting of the General Conference: 13-16 November 2018 in Versailles

https://www.bipm.org/en/cgpm-2018/



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