Redefining the SI at CGPM 2018: Some Fundamentals

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Defining the SI Via Fundamental Constants

- The proposed structure of the International System of Units is quite different from the one we have now

- We will move away from defined Base Units

  (s, m, kg, A, K, mol, cd)

- We will shift to defined constants

  ($\Delta\nu_{Cs}$, c, h, e, k_B, N_A, K_{cd})

- What does this mean? What will happen?

CGPM 2018: 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

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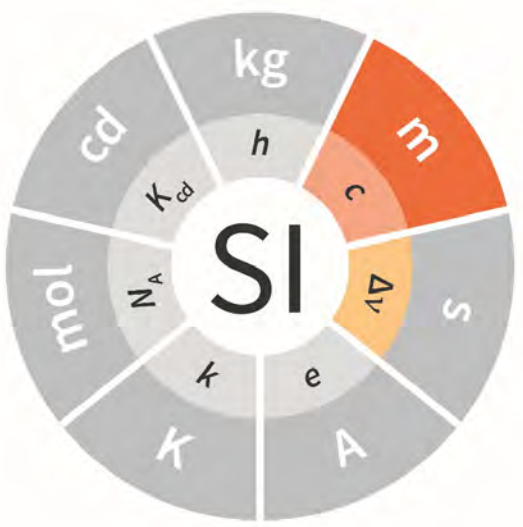

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~~NOT REALLY!~~

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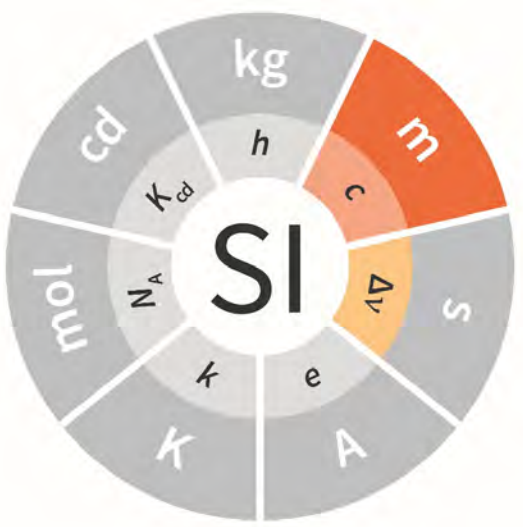

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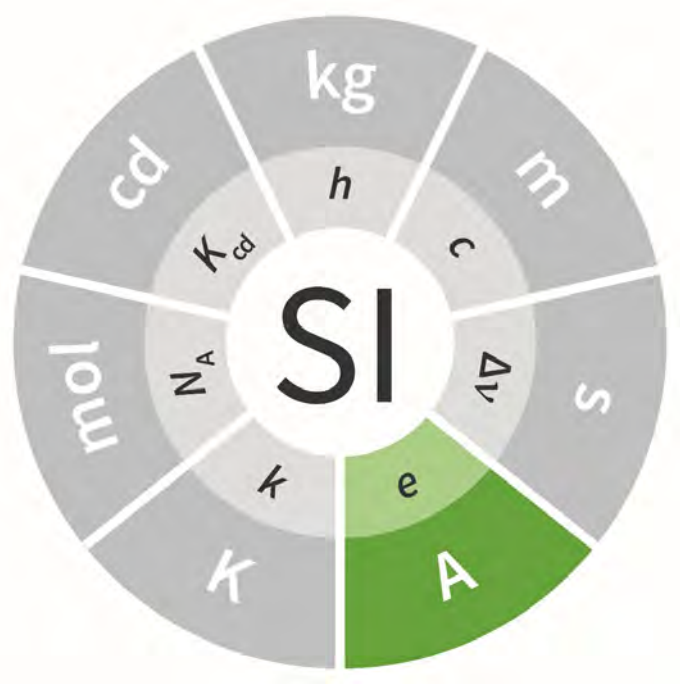
Redefining the ampere - A

- 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 $\Delta\nu_{Cs}$.



Redefining the ampere - A

Since

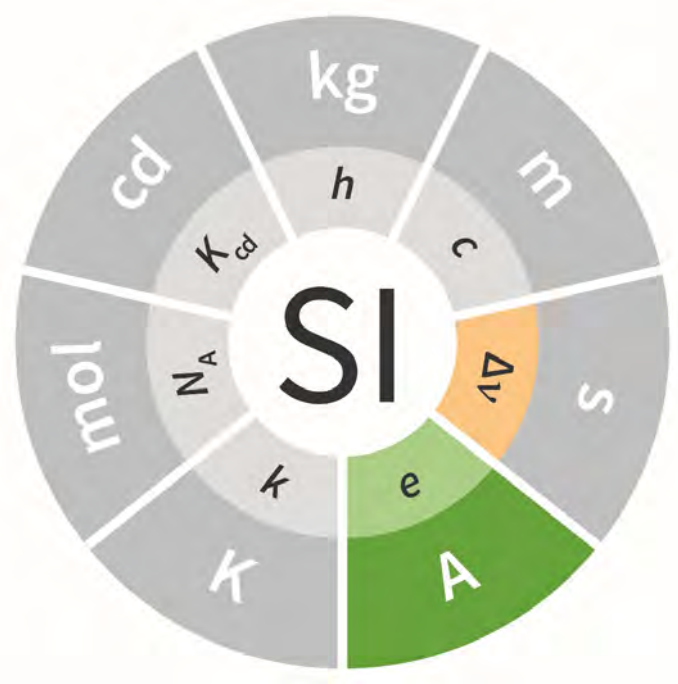
$1\ A = 1\ C\ s^{-1}$

And

$e = 1.602\ 176\ 634 \times 10^{-19}$ C

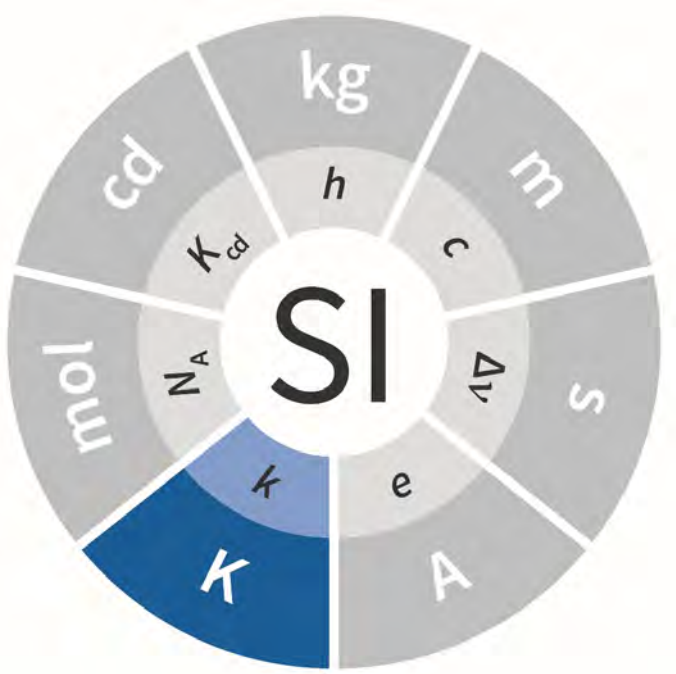
We have

1 A ~ 6.25×10^{18} electrons / second

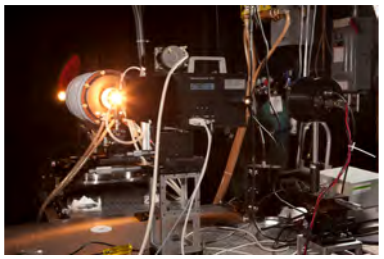


Redefining the kelvin - K

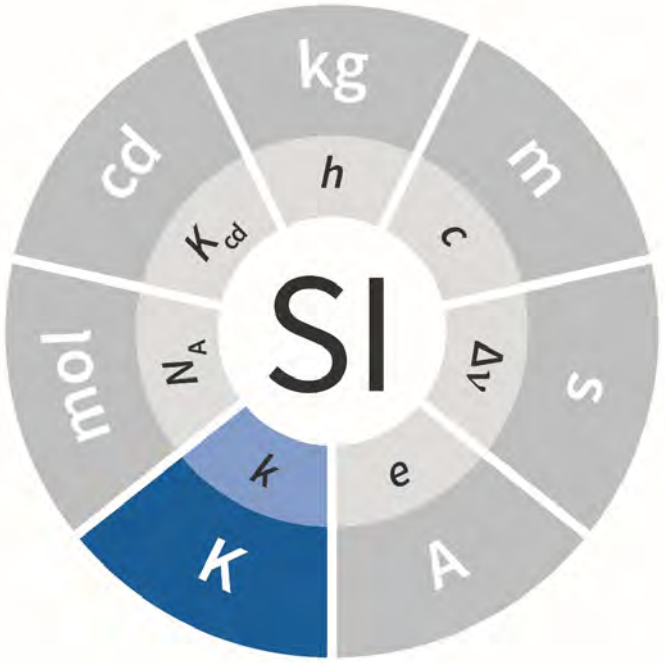
- The kelvin, symbol K, is the SI unit of thermodynamic temperature. It is defined by taking the fixed numerical value of the Boltzmann constant k to be $1.380\,649 \times 10^{-23}$ when expressed in the unit J K^{-1} , which is equal to kg m^2 s^{-2} K^{-1} , where the kilogram, metre and second are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



Redefining the kelvin - K

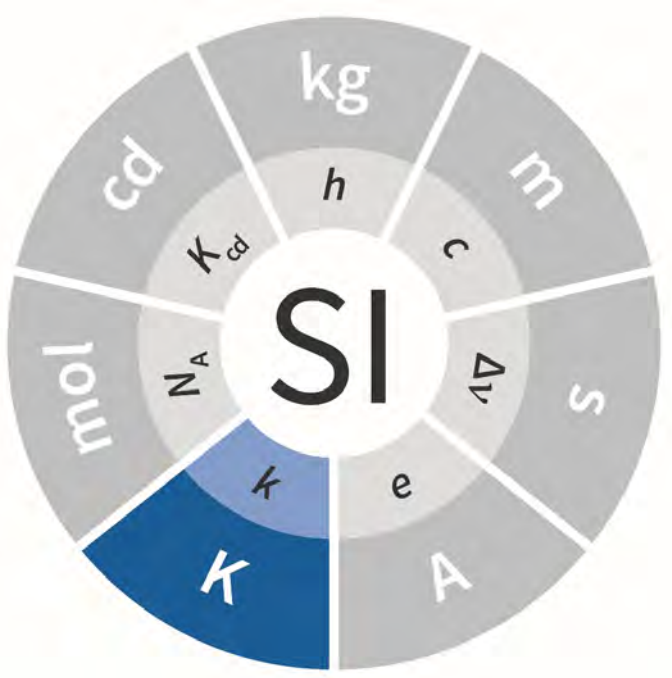


- Four main experimental techniques were used to determine *k*:
  - Acoustic gas thermometry
  - Spectral band radiometric thermometry
  - Polarizing gas thermometry
  - Johnson noise thermometry



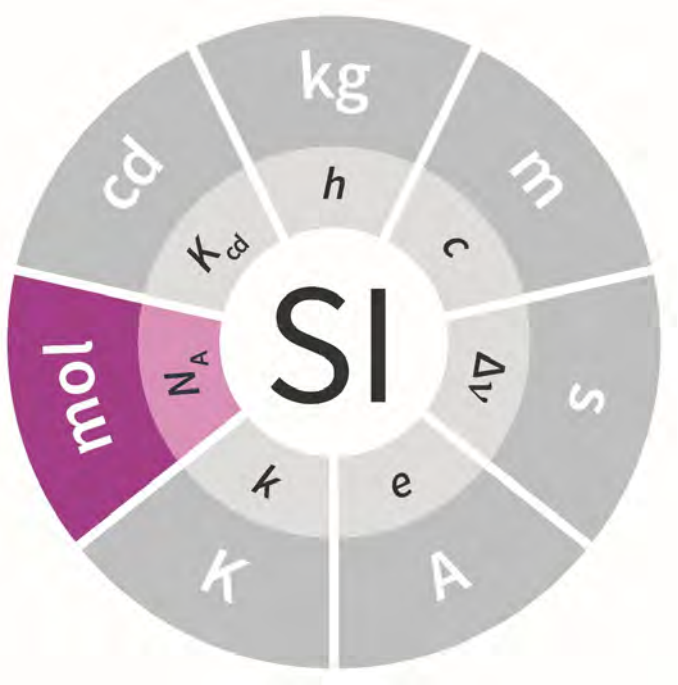
Redefining the kelvin - K

- Triple Point of Water temperature *does not change* at the time of redefinition (though it will inherit some uncertainty)
- The ITS-90 *does not change*: most thermometers will still be calibrated using the International Temperature Scale for the near future



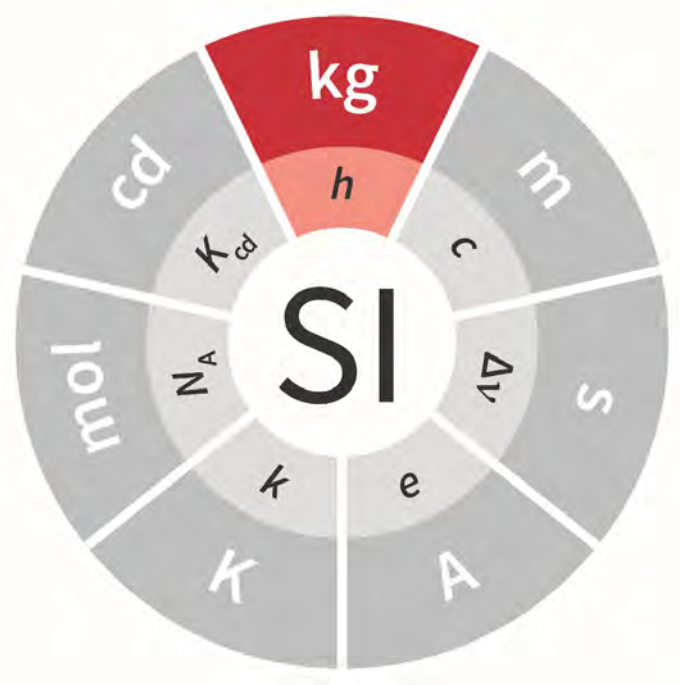
Redefining the mole - mol

- The mole, symbol mol, is the SI unit of amount of substance. One mole contains exactly 6.022 140 76 × 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.

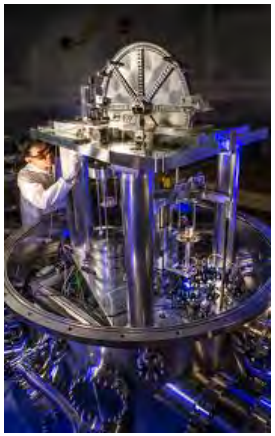


Redefining the kilogram - kg

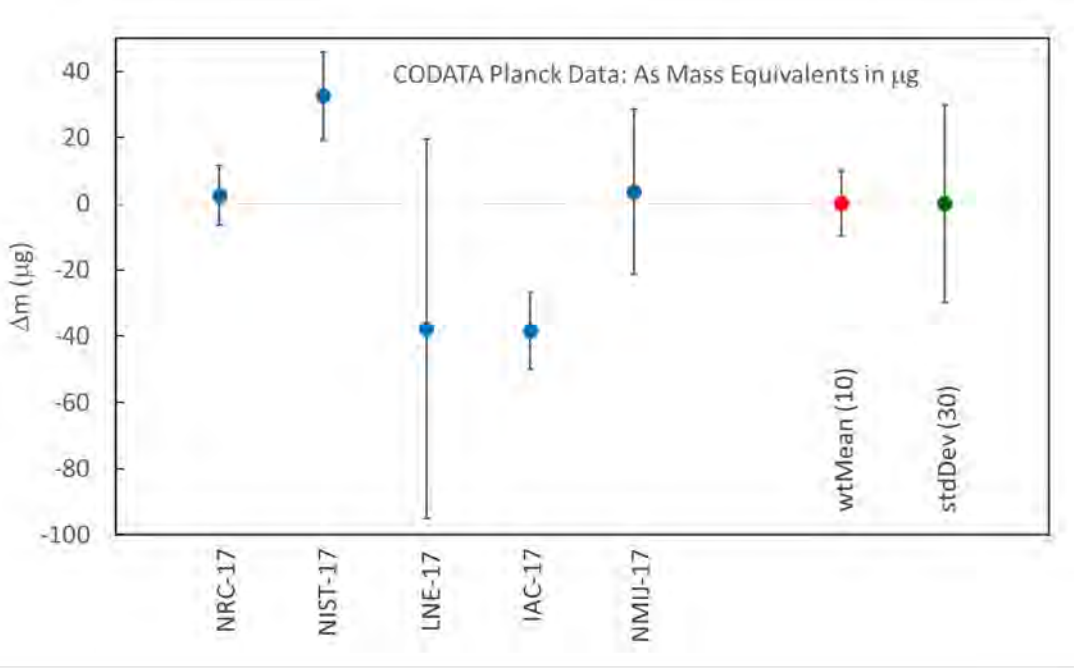
- The kilogram, symbol kg, is the SI unit of mass. It is defined by taking the fixed numerical value of the Planck constant *h* to be $6.626\,070\,15 \times 10^{-34}$ when expressed in the unit J s, which is equal to kg m^2 s^{-1} , where the metre and the second are defined in terms of *c* and $\Delta\nu_{Cs}$.



kg : What about the kilogram?

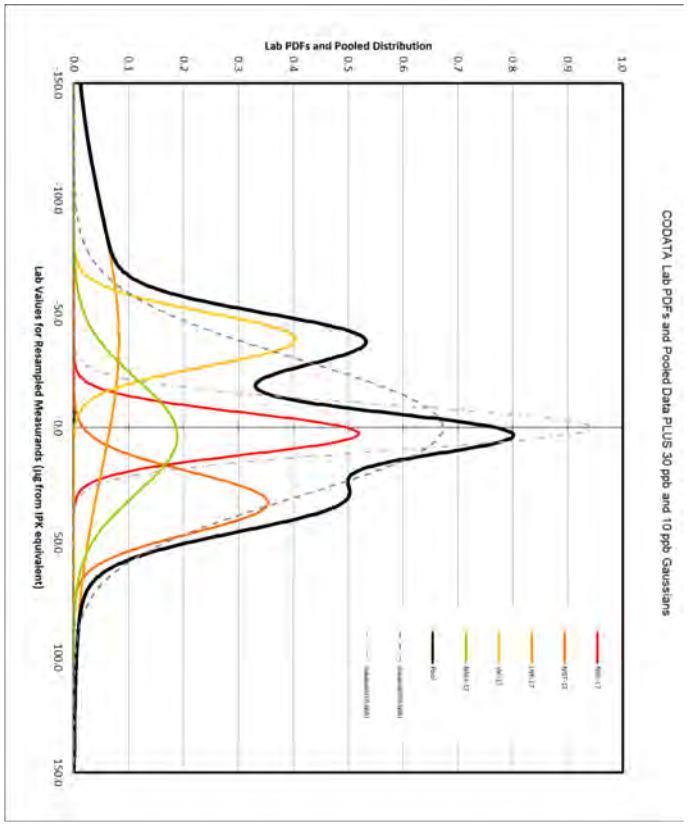


The CODATA 2017 Value for *h*



- The weighted mean was used to set the value of *h*
- The laboratory Planck data are consistent within an *expanded interval*
- The uncertainty of this weighted mean approach to *h* is 10 μg and that "jumps" over to the IPK

The CODATA 2017 Value for *h*



- BUT the individual data would not yield *consistent* kg values for calibrations by different labs (yet…)

- SO a “Consensus Value” for traceable calibrations will be adopted by the CCM for an *interim period* while the calibration science matures

kg : Mass Scales Won't Change, BUT…

- The SIM kilogram Dissemination Project is underway!

SIM kilogram Dissemination Project

- A major new project is being launched by SIM MWG-Mass

- NRC and NIST have acquired and characterized a special set of masses for use across the hemisphere
- It's not just a "regional calibration" exercise, it is a joint science project

- 28 SIM countries participating so far, more are welcome!

SIM kilogram Dissemination Project

- Each participating NMI will receive a stainless steel mass for use in their country
- All artefacts were produced from one of two source rods, a unique element in our experiment

- All artefacts satisfy OIML Class E1 criteria

SIM kilogram Dissemination Project

- Project will monitor and maintain traceability across SIM geography
- Includes control artefacts and sorption stacks for surface information plus environmental monitoring sensors
- All preparations, cleaning, initial characterization now complete

- Recalibration at NRC and NIST every 2 years will tell us valuable information about drift, transport, wear / use, etc.

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- Gracias !
  - Merci !
    - Obrigado!
      - Thank you !