Bureau
International des
Poids et
Mesures

Frequently Asked Questions about the proposed Revised SI
(Updated October 2018)

Q1: What is going to change?

A1: The kilogram, kg, ampere, A, kelvin, K, and mole, mol, will have new definitions, but they will be so chosen that at the moment of change the magnitudes of the new units will be indistinguishable from those of the old units. The new definitions are expected to be approved by the 26th General Conference of Weights and Measures (CGPM) in November 2018 and to come into force on 20 May 2019.

Q2: So what is the point of changing to new definitions?

A2: Defining the kilogram in terms of fundamental physical constants will ensure its long-term stability, and hence its reliability, which is at present in doubt. The new definitions of the ampere and kelvin will significantly improve the accuracy with which electrical, and radiometric temperature measurements can be made. The impact on electrical measurements will be immediate: the most precise electrical measurements are already made using the Josephson and quantum Hall effects, and fixing the numerical values of the Planck constant h and the elementary electrical charge e in the new definitions of the units will lead to exact numerical values for the Josephson and von Klitzing constants. This will eliminate the current need to use conventional electrical units rather than SI units to express the results of electrical measurements (see A14). The conversion factor between measured radiance and thermodynamic temperature (the Stefan-Boltzmann constant) will be exact using the new definitions of the kelvin and kilogram, leading to improved temperature metrology as technology improves. The revised definition of the mole is simpler than the current definition, and it will help users of the SI to better understand the nature of the quantity “amount of substance” and its unit, the mole. All in all, the Revised SI will be a better fit to the technology of this century.

Q3: What about the definitions of the second, s, metre, m, and candela, cd?

A3: The definitions of the second, s, metre, m, and candela, cd, will not change, but the way the definitions are written will be revised to make them consistent in form with the new definitions for the kilogram, kg, ampere, A, kelvin, K, and mole, mol. These new wordings are expected to be approved by the 26th CGPM in November 2018 and to come into force on 20 May 2019.

Q4: What will happen to the International Prototype of the Kilogram (IPK) once the Revised SI takes effect? Will it go to a museum where the general public can at last see it?

A4: There are no plans to change the storage conditions for the IPK. It will remain at the BIPM and it will not be on display for the general public. The IPK will retain a bit of metrological interest and therefore it will be monitored very sporadically in the future to avoid as much as possible any surface damage. Measurements of the mass stability of the IPK in the future may help us extrapolate its mass stability in the recent past.

Q5: Will I get my standard of mass calibrated under the Revised SI in the same way as I do now?

A5: After the redefinition of the kilogram, you can continue sending your mass standard to your National Metrology Institute (NMI) for calibration or to a secondary calibration laboratory just as you do now. However, the traceability path that your NMI will use to link it to the SI kilogram will change.

Indeed, after the redefinition of the kilogram, the BIPM will organize an ongoing comparison among primary realizations of the kilogram and a *consensus value* of the kilogram will be determined from it. National Metrology Institutes having a realization of the kilogram will be requested to avail themselves of the *consensus value* 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.

Member States not having realizations of the new definition of the kilogram will have direct access to traceability to the same *consensus value* through the calibration services of the BIPM during the phase where the consensus value will be used.

Q6: Once laboratories can realize the kilogram themselves, how can we be sure that inter-laboratory results are compatible?

A6: In the case of the kilogram, when the *consensus value* will no longer be needed, all laboratories will need to demonstrate traceability to the definition of the kilogram, which will be based on physical constants. Since it is always possible to underestimate an experimental uncertainty or just to make a mistake, laboratories that claim the smallest uncertainties will compare results periodically to assess compatibility with their peers. A basic mechanism for this already exists and is widely used in metrology. It is based on the CIPM Mutual Recognition Arrangement established in 1999.

Q7: Will NMIs also be requested to avail themselves of a *consensus value* for the dissemination of the three other redefined units?

A7: No. The kilogram is a special case. Electrical units and the kelvin have been mentioned in A14 and A8. As for the mole, there will be no change to current practice.

Q8: Will I get my thermometer calibrated under the Revised SI in the same way as I do now?

A8: Yes. The new definition of the kelvin has no immediate impact on the status of the widely-used ITS-90 and PLTS-2000 temperature scales. The Consultative Committee for Thermometry (CCT) has published information concerning immediate and future advantages of the new definition.

Q9: In the Revised SI the reference constant for the kilogram is the Planck constant *h*, with unit J s = kg m^2 s^{-1}. It would be much easier to comprehend if the reference constant had the unit of mass, the kg. Then we could say: "The kilogram is the mass of <*something*>", such as perhaps the mass of a specified number of carbon or silicon atoms. Would that not be a better definition?

A9: This is to some extent a matter of subjective judgement. However note that the reference constant used to define a unit does not *have* to be dimensionally the same as the unit (even though it may be conceptually simpler when this is the case). We already use several reference constants in the current SI that have a different unit to that being defined. For example the metre is defined using as reference constant the speed of light *c* with unit m/s, not a specified length in m. This definition has not been found unsatisfactory. This practice first began in 1960, with the present definition of the ampere which is based on the fixed value of a constant whose unit is kg m s^{-2} A^{-2}. (The new definition of the ampere will be simpler.)

Although it may seem intuitively preferable to define the kilogram using a mass as the reference constant, using the Planck constant has other advantages. For example, if both *h* and *e* are exactly known as proposed in the Revised SI, then both the Josephson and von Klitzing constants K_J and R_K will be exactly known, with great advantages for electrical metrology. (Physics tells us that we cannot fix both *h* and the mass of <*something*>, for instance the mass of a carbon 12 atom $m(^{12}C)$, without consequently redefining the second in a very impractical way.)

Q10: Despite the answer to Q9 above, there are still people who question the wisdom of defining the kilogram by using *h* as a reference rather than by using $m(^{12}C)$. One of the arguments they use is that the Kibble[1] balance (KB) experiment to determine *h* uses a complex apparatus that is difficult to use and expensive to build, in comparison with the XRCD (x-ray crystal density) experiment to measure the mass of a silicon 28 atom, and hence the mass of a carbon 12 atom. What are the principal reasons for choosing *h* rather than $m(^{12}C)$ as the reference constant for the kilogram?

A10: These are really two unrelated questions:

1. Why choose *h* rather than $m(^{12}C)$ as the reference constant for the kilogram?
2. Does the choice of *h* or $m(^{12}C)$ determine whether the kilogram will be realized in practice by a KB experiment or by the XRCD experiment?

1. Once the numerical value of a constant is given a fixed value, the constant need not, indeed cannot, be measured subsequently. For example, in 1983 when the SI was modified by making the speed of light in vacuum, *c*, the reference constant for the metre, the long history of measuring *c* abruptly ended. This was an enormous benefit to science and technology, in part because *c* enters into so many domains of science and technology that every time there was a change to the recommended SI value of *c*, the values of numerous constants and conversion factors related to *c*

---

[1] To recognize Bryan Kibble's invention of the watt balance

needed to be updated. The decision to define the numerical value of c as exact was obviously correct.

Similarly, h is the fundamental constant of quantum physics and consequently its SI value is used in many diverse fields of modern science and technology. Changes to the recommended value of h as experiments improve are at best annoying and at worst confusing. The rationale for defining the numerical value of h is similar to that for defining c, but has the specific advantages in electrical metrology given in A2.

Of course $m(^{12}\mathrm{C})$ is undeniably a constant and is undeniably important, especially for chemistry and the physics of atoms. This is because atomic weights (if you are a chemist), also known as relative atomic masses (if you are a physicist), are all based on $m(^{12}\mathrm{C})$. Nevertheless, atomic weights do not depend on the present definition of the kilogram and, of course, they will be unaffected by a new definition.

2. No. The choice of which reference constant is used to define the kilogram does not imply any particular method to realize the kilogram, and none is mentioned in Draft Resolution A (CGPM 2018). We do know that any realization must be traceable to h since h will be the reference constant in the new definition of the kilogram. However, it is also known that $h/m(^{12}\mathrm{C}) = Q$, where Q represents a product of exact numerical factors and experimentally-determined constants. The relative standard uncertainty of Q is only 4.5×10^{-10} based on the current recommended values of the constants involved. An apparatus, such as the KB, which measures a 1 kg mass standard directly in terms of h (through electrical measurements made with quantum devices) and auxiliary measurements of length and time can be used to realize the kilogram. However, an experiment that measures a 1 kg mass standard in terms of $m(^{12}\mathrm{C})$, as in the XRCD project, also has the potential to realize the kilogram. This is because $m(^{12}\mathrm{C})Q = h$, and thus the price to pay for arriving at h by way of $m(^{12}\mathrm{C})$ is the added uncertainty of Q, which is negligible in the context of realizing the new definition. It is premature to speculate whether one type of realization will prevail in the long run or whether different types will coexist. At present, all such experiments are difficult and expensive.

Q11: Are the seven base quantities and base units in the current SI going to change in the Revised SI?

A11: No. The seven base quantities (time, length, mass, electric current, thermodynamic temperature, amount of substance, luminous intensity) and corresponding base units (second, metre, kilogram, ampere, kelvin, mole, candela) will remain unchanged.

Q12: Are the 22 coherent derived units with special names and symbols going to change?

A12: No, the 22 coherent derived units with special names and symbols will remain unchanged in the Revised SI.

Q13: Are the names and symbols of the multiple and sub-multiple prefixes (kilo for 10^3, milli for 10^{-3}, etc.) going to change in the Revised SI?

A13: No, the names and symbols for the prefixes will remain unchanged.

Q14: Will the magnitudes of any of the units change in the Revised SI?

A14: No. So-called “continuity conditions” have been established to help ensure that there will be no change in magnitude of any of the SI base units, and hence no change in any units derived from the base units.

(There is a small exception involving electrical units: since 1990, the electrical units used in practice have been based on conventional values for the Josephson constant and the von Klitzing constant rather than on their present SI definitions. Today, we know that there are small offsets between the conventional and the SI values. The revised SI will bring the practical electrical units back into the SI. This will lead to a one-time change of + 0.1 parts per million (ppm) for voltage values and of + 0.02 ppm for resistance values when expressed in the units of the Revised SI.)

Q15: How can you fix the value of a fundamental constant like *h* to define the kilogram, and *e* to define the ampere, and so on? How do you know what value to fix them to? What if it emerges that you have chosen the wrong value?

A15: We do not fix – or change – the <u>*value*</u> of any constant that we use to define a unit. The values of the fundamental constants are constants of nature and we only fix the <u>*numerical value*</u> of each constant when expressed <u>*in its SI unit*</u>. By fixing its numerical value we define the magnitude of the unit in which we measure that constant at present.

Example: If c is the *value* of the speed of light, $\{c\}$ is its *numerical value*, and $[c]$ is the *unit*, so that

$$c = \{c\}\ [c] = 299\ 792\ 458 \text{ m/s}$$

then the value c is the product of the number $\{c\}$ times the unit $[c]$, and the value never changes. However the factors $\{c\}$ and $[c]$ may be chosen in different ways such that the product c remains unchanged.

In 1983 it was decided to fix the number $\{c\}$ to be exactly 299 792 458, which then defined the unit of speed $[c]$ = m/s. Since the second, s, was already defined, the effect was to define the metre, m. The number $\{c\}$ in the new definition was chosen so that the magnitude of the unit m/s was unchanged, thereby ensuring continuity between the new and old definitions of the units.

Q16: OK, you actually only fix the <u>*numerical value*</u> of the constant expressed in its <u>*unit*</u>. For the kilogram, for example, you choose to fix the numerical value $\{h\}$ of the Planck constant expressed in its unit $[h] = \text{kg m}^2\ \text{s}^{-1}$. But the question remains: suppose a new experiment shortly after you change the definition suggests that you chose a wrong numerical value for $\{h\}$, what then?

A16: After making the change, the mass of the international prototype of the kilogram (the IPK), which has defined the kilogram since 1889, will have to be determined by experiment. If we have chosen a “wrong value” it simply means that the new experiment will tell us that the mass of the IPK is not exactly 1 kg in the Revised SI.

This situation would only affect macroscopic mass measurements; the masses of atoms and the values of other constants related to quantum physics would not be affected. Continuing with the definition of the kilogram agreed in 1889 would continue the practice of using a reference quantity (i.e. the mass of the IPK) that we cannot be sure is not changing with time compared to a true invariant such as the mass of an atom or the Planck constant.

There has been much debate over the years about how much the mass of the IPK might be changing with respect to the mass of a true physical constant. The advantage of the new definition will be that we will be certain that the reference constant used to define the kilogram is a true invariant.

Q17: Each of the fundamental constants used to define a unit has an uncertainty; its value is not known exactly. But it is proposed to fix its numerical value exactly. How can you do that? What has happened to the uncertainty?

A17: The present definition of the kilogram fixes the mass of the IPK to be one kilogram exactly with zero uncertainty, $u_r(m_{IPK}) = 0$. The Planck constant is at present experimentally determined, and has a relative standard uncertainty of 1.0 part in 10^8, $u_r(h) = 1.0 \times 10^{-8}$.

In the new definition the value of h will be known exactly in terms of its SI unit so that $u_r(h) = 0$. But the mass of the IPK would have to be experimentally determined, and it would have a relative uncertainty of about $u_r(m_{IPK}) = 1.0 \times 10^{-8}$. Thus the uncertainty is not lost in the new definition, but it moves to become the uncertainty of the previous reference that is no longer used, as in the table below.

Constant used	*Current SI*		*Revised SI*	
to define the kilogram	*status*	*uncertainty*	*status*	*uncertainty*
mass of the IPK, $m(\mathcal{K})$	exact	0	expt.	1.0×10^{-8}
Planck constant, h	expt.	1.0×10^{-8}	exact	0

Q18: The unit of the Planck constant is the unit of action, J s = kg m^2 s^{-1}. How does fixing the numerical value of the Planck constant define the kilogram?

A18: Fixing the numerical value of h actually defines the unit of action, J s = kg m^2 s^{-1}. But if we have already defined the second, s, to fix the numerical value of the caesium hyperfine transition frequency $\Delta\nu_{Cs}$, and the metre, m, to fix the numerical value of the speed of light in vacuum, c, then fixing the magnitude of the unit kg m^2 s^{-1} has the effect of defining the unit kg.

Q19: Are not the proposed definitions of the base units in the Revised SI circular definitions, and therefore unsatisfactory?

A19: No, they are not circular. A circular definition is one that makes use of the result of the definition in formulating the definition. The words for the individual definitions of the base units in the Revised SI specify the *numerical value* of each chosen reference constant to define the corresponding unit, but this does not make use of the result to formulate the definition.

Q20: Can we still check the consistency of physics if we fix the values of all the fundamental constants?

A20: We are not fixing the values of all the fundamental constants, only the *numerical values* of a small subset and combinations of the constants in this subset. This has the effect of changing the definitions of the units, but not the equations of physics, and it cannot prevent researchers from checking the consistency of the equations.

Q21: The physical constants *c*, *h* and *e* will all have fixed numerical values. But doesn't this fix the value of the fine-structure constant, which must not be given a fixed value?

A21: No. The value of the fine-structure constant will continue to be determined by experiment. In the SI, the fine-structure constant has always depended on c, h, e and μ_0. The fourth constant is the vacuum magnetic permeability, which presently defines the ampere but in the Revised SI will be determined experimentally from a measurement of the fine-structure constant.