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A further short history of the SI prefixes

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Abstract

A short history of the development and adoption of the SI prefixes since 1964 is provided, following on from the last time a similar article was written, with special attention paid to the recent extension to the range of SI prefixes following the 27th General Conference on Weights and Measures in 2022. A brief future look is also presented.

Keywords: SI, prefixes, units, metrology, history of science

(Some figures may appear in colour only in the online journal)

1. Introduction

Together with the SI base units and SI derived units, the SI prefixes form the basis of the international system of units (SI) as we now know it [1]. The SI prefixes allow the formation of decimal multiples and sub-multiples of the SI units. They are convenient for expressing the values of quantities that are much larger than or much smaller than the SI unit, such that the numerical value presented is on the 'human scale' (between 0.1 and 1000, and ideally between 1 and 100). This makes measurement results easy to conceptualise, communicate and interpret, over time, between locations and across different technical disciplines.

In 1966, shortly after the 12th General Conference on Weights and Measures (CGPM) had added the SI prefixes femto (for 10^{-15}) and atto (for 10^{-18}) to the system, De Boer published a short history of the prefixes up to that date [2]. In conclusion, he reflected, 'it may well be that in future further extension will be needed but for the time being this does not seem necessary'. In over half a century since then it has indeed proved necessary to extend the range of SI prefixes. This article relates that progress and the reasoning behind the changes, especially the recent update approved by the 27th CGPM[1], and also provides a brief discussion of possible developments in future.

2. Discussion

2.1. 1964–2017

The period from the 12th CGPM in 1964 to the 15th CGPM in 1975 represented an unusual period during which the coverage of SI prefixes was asymmetrical. (An asymmetry had previously existed prior to the formalisation of the SI between 1904 and 1935 when myria, for 10^4, was adopted but with the submultiple range extending only as far as milli, for 10^{-3}.) In 1964 the need to represent the small dimensions occurring in nuclear physics and the requirement to measure with increasing precision time intervals relevant to stable atomic phenomena had required extension of the range of SI prefixes for the submultiples 10^{-15}: femto (f); and 10^{-18}: atto (a). However, no similar extension to the range of multiples had been made. Immediately after this extension, the International Committee for Weights and Measures' (CIPM) Consultative Committee for Units (CCU[2]: established in 1964 to replace the Commission for the System of Units set up by the CIPM in 1954) began considering an extension to higher multiples, even discussing

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[1] All CGPM resolutions may be found on the BIPM website: https://bipm.org/en/committees/cg/cgpm/cgpm-resolutions.
[2] All CCU meeting reports may be found on the BIPM website: https://bipm.org/en/committees/cc/ccu/publications.

the reintroduction of compound, or double, prefixes as a way to achieve this. In 1974 the CCU, somewhat reluctantly, accepted the need to address the magnitudes then associated with measurement of the frequency range of electromagnetic radiation, world energy usage, and radioactivity when expressed in becquerels, by reviving a proposal first made at the CCU in 1971 to expand the range of prefixes with the multiples 10^{15}: peta (P); and 10^{18}: exa (E). This was adopted at the 15th CGPM in 1975. Discussion on prefixes continued. The CCU in 1974 had already begun to discuss what names and symbols might be required for further expansion of the range of SI prefixes, and at the CCU meeting in 1976 there had been proposals for entirely different nomenclatures for expressing powers of 10 not employing SI prefixes at all. These proposals were consulted upon but there was no appetite for further change at the time.

No significant discussion then occurred until 1990 when the CCU discussed expanding the range of SI prefixes to between 10^{24} and 10^{-24}. At the time the argument to expand the range in the sub-multiple direction derived mainly from the magnitude of the Avogadro constant and the need to express molecular quantities in SI units whose magnitude was more suited to molar quantities. Analytical chemistry and spectroscopic techniques had advanced to the stage where small fractions of an attomole (the smallest amount that could be specified using the then current SI prefixes) could be detected, especially for macromolecules. It was also noted that the attojoule, aJ, and the attogram, ag, were too large for the purpose of scientists who routinely dealt with single molecules. There were no similar arguments at that time to extend the range of prefixes for positive powers of ten up to 10^{24}, aside perhaps from use in astronomy, but it was stated that it would seem foolish to extend the range at one end without a similar extension at the other. Adapting the suggestions from the 1974 CCU meeting, the proposal was made to expand the range to between 10^{24} and 10^{-24} using for 10^{21}: zetta (Z); for 10^{-21}: zepto (z); for 10^{24}: yotta (Y); and for 10^{-24}: yocto (y). This was adopted by the 19th CGPM in 1991.

The CCU meeting in 1995 noted that the use of the jansky (10^{-26} W m^{-2} Hz^{-1}) in radio astronomy suggested the need for SI prefixes for 10^{-27} and 10^{-30}. It is relevant to later discussions to note that this CCU meeting also produced a recommendation that, considering usage in computing, the SI prefixes should only be used to represent powers of ten and not powers of two. The International Electrotechnical Commission (IEC) was invited to propose names and symbols for prefixes denoting powers of two for use in information technology. These were published in 1999, using kibi (Ki) up to exbi (Ei) (for 2^{10} up to 2^{60}) representing kilobinary through to exabinary [3]. By 2005 these IEC binary prefixes were expanded to match the range of SI prefixes with binary counterparts, up to yobi (Yi) for 2^{80}, representing yottabinary (but of course only for multiples, not submultiples) [4].

Discussion of the extension of the range of SI prefixes continued in the CCU until 2001, again including consideration of the use of compound prefixes, at which point the committee agreed not to proceed further with any of the suggestions. After this, the topic was not raised again at the CCU until 2019.

Table 1. The SI prefixes adopted at the 27th CGPM in 2022.

Multiplying factor	SI prefix name	SI prefix symbol
10^{27}	ronna	R
10^{-27}	ronto	r
10^{30}	quetta	Q
10^{-30}	quecto	q

2.2. 2017–2022

A further 31 years passed between 1991 and 2022 before the range of available SI prefixes was further extended. This represented the longest gap between extensions of the range since prefixes were first adopted within the Metre Convention in 1879.

The most recent extension had its origins in late 2017 when the author heard a BBC 'more or less' radio programme on naming large numbers [5]. This contained the disturbing revelation that proposals of unofficial prefix names for describing digital storage in excess of yottabytes were rapidly gaining support and notoriety in the popular scientific media. Two of the suggestions made were brontobyte (from 'brontosaurus') and hellabyte (from 'hell of a big number'). (Indeed, the Google unit converter function was already stating '1 hellabyte = 1000 yottabytes' [6].) This introduced a new driver for extending the range of SI prefixes: ensuring unofficial names did not get adopted *de facto*. Digital storage and data science were clearly also areas where developments in science and technology, such as the predicted advent of quantum computing and the exponential increase in the size of the global datasphere, required prefixes covering an expanded range of orders of magnitude. When considered together with the traditional and ever-present wish to increase SI prefix usage in communities where the current range is not fit for purpose (for instance astronomy and particle physics) it was obvious that action was required. It was also clear that the digital storage and data science community actively used SI prefixes with the non-SI units bit and byte considerably more frequently than the IEC binary prefixes, did not use scientific notation (e.g. 10^{24} bytes), and could not use words to describe these large numbers (e.g. 'septillion' for 10^{24}) since these have never been universally standardised.

It was considered unbalanced not to extend the range downwards to 10^{-30}, even though there was no immediate requirement for this save for the ever-present desire to increase the use of SI prefixes in communities that do not currently use them (e.g. for replacing the jansky in radio astronomy). Similarly, during the last extension to the range of SI prefixes the pressing requirement was only for an extension of submultiple prefixes, but nevertheless an extension was made to the multiple prefixes as well. This was prescient since had this not been done the requirements of data science would have long since outstripped what was provided by the exabyte.

The names and symbols for new SI prefixes cause significant interest in the media. This is understandable, but it is the decision about whether to expand the range which should be taken most seriously. In the end the choice of names is not so critical, although it seems critical before the choice is made.

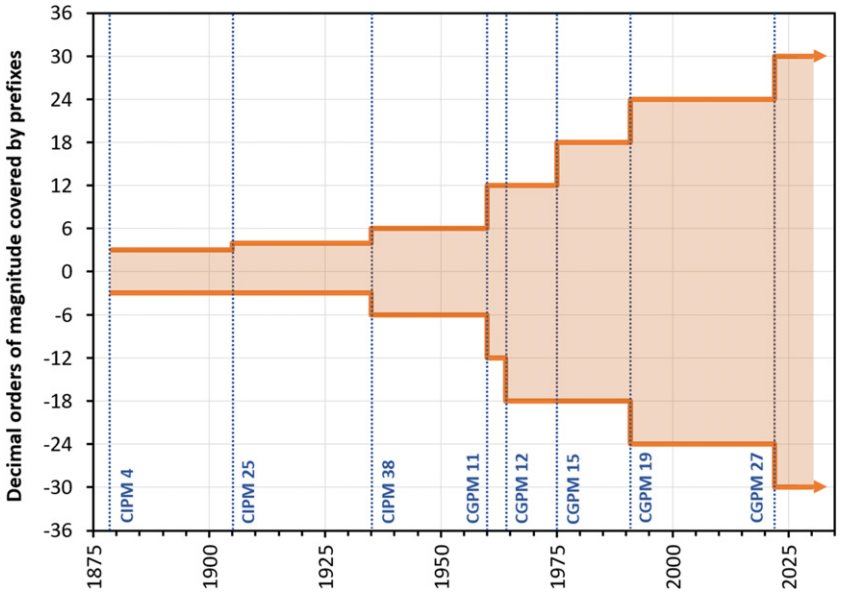

Figure 1. The evolution over time of the range of prefixes adopted within the Metre Convention since 1875. The shaded area shows the range of magnitudes covered and the dotted lines indicate the timing of CIPM decision or CGPM resolution resulting in an expansion to the range, and the associated meeting number.

For those who use the new prefixes they will become well used and familiar regardless. The choice of symbol (and thereby the initial letter of the name) is more important to get right because these should not clash with existing usage. A review of existing symbols for SI prefixes, SI units and commonly used non-SI units demonstrated that only two letters were currently available for use in the English alphabet: 'r' and 'q'. Using these in reverse alphabetical order mirrored the practice in 1991 when the SI prefix range was last extended. The use of characters outside the English alphabet was excluded because of the requirement for universal digital reproduction, data transfer and machine readability.

Many different mechanisms for creating prefix names have been used in the past. More recently these have relied (rather tangentially) on using the Latin and Greek numbers for the power to which 1000 is raised to produce the prefix multiplier. These words are then suitably modified, changing the initial letter to match the prefix symbol and the final letter to an 'a' for multiples or an 'o' for sub-multiples, to obtain a word that runs together acceptably with unit names when written and spoken, and does not have unintended meanings in other languages. Basing the names loosely on the Greek for nine, *ennea* (for $(10^3)^9$) and the Greek and Latin for ten, *deka* and *decem* (for $(10^3)^{10}$) the author proposed for 10^{27}: ronna (R); for 10^{-27}: ronto (r); for 10^{30}: quetta (Q); and for 10^{-30}: quecto (q). (Originally 'quecca' had been suggested for 10^{30} but was too close to a profane meaning in Portuguese.)

The author's proposals were consulted upon within the scientific literature [7] and at the CCU in 2019 and 2021 [8, 9], and met with general approval. It was also recognised that the proposal represented a neutral addition to the SI, which was useful but whose use was not mandatory. As such, even if the new SI prefixes were not widely adopted, nothing would be lost and no disbenefit or confusion would be caused [10]. And so it was that the 27th CGPM in 2022 decided to extend the range of available SI prefixes, as shown in table 1.

The evolution over time of the range of prefixes adopted within the Metre Convention since 1875 is shown in figure 1.

2.3. 2022 onwards

The expanded range of SI prefixes up to 10^{30} ought to prompt an update to IEC 80000-13 [4] to provide an analogous expansion to the range of prefixes for binary multiples. Following past convention these would be robi (Ri) for 2^{90} (from ronnabinary: $(2^{10})^9$) and quebi (Qi) for 2^{100} (from quettabinary: $(2^{10})^{10}$).

There will always be suggestions for new SI prefix names in the popular science media and even in the scientific literature since it remains an area of great fascination. So long as there is no real pressing technical need for an expansion to the range it is unlikely that any of these proposals would be become adopted *de facto*. When a genuine requirement for a further expansion to the range of SI prefixes arises, it will be necessary to reintroduce compound prefixes since no letters in the English alphabet remain available for new prefix symbols (assuming characters from other alphabets remain excluded). Compound prefixes were used prior to the formalisation of the SI in 1960. Their reintroduction would require rules for usage to be established. Suggestions for these have already been made by the author [11]. They could be formed quite simply by allowing only either quetta or quecto as the second prefix for multiples or submultiples, respectively. Therefore, for multiples this would give kiloquetta (kQ), megaquetta (MQ), gigaquetta (GQ) etc, and for submultiples this would give milliquecto (mq), microquecto (μq), nanoquecto (nq) etc.

It has also been suggested by the author that in future non-decimal prefixes might be of use in chemistry to allow small

quantities of elementary entities to be conveniently expressed in amount of substance terms rather than as a simple count of those entities [12].

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