Whack a mole

October 23 is (unofficially) known by some chemists as Mole Day. Andrea Taroni attempts to get to grips with the concept of the mole itself, and the imminent change to its definition.

While it may not be entirely obvious to those of us sitting on this side of the Atlantic, the American style of writing dates has allowed a number of chemistry enthusiasts to declare the period between 6:02 a.m. and 6:02 p.m. on October 23 Mole Day (https://www.moleday.org) — a reference to an approximate value for Avogadro's constant, 6.02×10^{23}, which defines the number of particles in one mole (mol) of substance[1].

For most young scientists encountering chemistry for the first time, moles come pretty much straight after being introduced to the principles of stoichiometry and the law of conservation of mass, where the total mass of the reactants equals the total mass of the products. For those of us that did not go on to become accomplished chemists, this probably stirs traumatic memories of endless exercises attempting to convert grams to moles, while keeping in mind the conceptual difference between the mass of a substance and the amount of substance (the ratio of which is the molar mass, of course) — and somehow not losing track of stoichiometric ratios in the chemical reactions themselves.

An impending change to the definition of the mole might help us clear up this molar confusion. It is perhaps surprising to recall that the mole is an SI base unit, in the same category as the second, metre, ampere, kelvin, kilogram and candela. Currently, its definition links it to the kilogram, by defining it as the amount of substance of a system that contains as many elementary entities (atoms, molecules, ions, electrons…) as there are atoms in 0.012 kilograms of carbon-12 (pictured). This number is expressed by the Avogadro constant, which has a (for now still experimentally determined) value of $6.02214076 \times 10^{23}$ mol^{-1} (refs [1,2]).

As part of the proposed redefinition of the SI units in terms of fundamental constants[3], the ampere, kilogram, kelvin and mole will be redefined by choosing exact numerical values for the elementary electric charge, and the Planck, Boltzmann and Avogadro constants, respectively (the second, metre and candela are already defined by physical constants). In the case of the mole, the proposed definition is[4]:

> "The mole, symbol mol, is the SI unit of amount of substance. One mole contains exactly $6.02214076 \times 10^{23}$ 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."

A formal vote scheduled to be held on 16 November 2018 at the 26th General Conference on Weights and Measures (CGPM) in Versailles, France, is expected to approve this proposal and, alongside the revised definitions for the ampere, kilogram and kelvin, it is likely to come into force on 20 May 2019 — an event that will be marked as World Metrology Day[3].

Credit: Andrew Lambert Photography/Science Photo Library

One consequence of this change is that it severs the link with the dalton (Da, also known as the unified atomic mass unit, u), which is currently also defined in terms of the mass of the ^{12}C atom (so that the mass of a ^{12}C atom is exactly 12 dalton). Though not categorized as an SI unit, the dalton is accepted within the SI system and used fairly widely — for example, when comparing mass on an atomic or molecular scale.

Whereas the current definition of the mole also means that the number of daltons in a gram is exactly the numerical value of the Avogadro number (that is, N_A u = 0.001 kg mol^{-1}), its new definition will result in this no longer being true. Proposals to address this discrepancy have been put forward[5], but they would necessarily decouple the dalton from the carbon-12 reference mass. We must await the outcome of the discussions at the CGPM to find out how this will get resolved. ❐

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