

## Reactions/comments to the new definition of the mole

**Peter W. Atkins**—I have always been puzzled by the widespread view that the mole is a difficult subject. It has always seemed to me that many instructors tell their students that it is a sophisticated concept, and the students then wonder what all the fuss is about, suspecting that they have misunderstood it or have not appreciated its subtlety. The new definition cuts to the core of the meaning of 1 mole, and is therefore to be welcomed. Although there are subtleties in its determination, there can no longer be any excuse for misunderstanding its definition. How important it is, too, to distinguish the Avogadro number from the Avogadro constant.

The other aspect to be welcomed is the comment on the name 'amount of substance' with its emphasis on the word 'substance' as merely a place-holder for the entities under discussion. 'Amount of substance', it is widely accepted, is too much of a mouthful for daily use, and although they do not mention it, IUPAC is happy with the synonym 'chemical amount'. Even that, I think, is too long, and not a happy companion when the entities are photons or electrons. Happily, the authors are reluctant to proliferate new names, and I would like to think that one day the single word 'amount' will be the short, uncluttered name of what we measure in moles. We are moving towards that usage.

I suspect that the ungainly name 'amount of substance' and the widely used but regrettable colloquial expression 'number of moles' stem from the historical facts that the physical quantity is a late entry into our vocabulary (compared with mass, length, and time) and that only one unit (the mole) has ever been used to report its value. Thus, chemists have seen 'amount' and 'mole' as unambiguous synonyms and have not acquired the habit of distinguishing the fundamentally unit-free physical quantity from a specific choice of unit.

I do worry, though, about how we shall introduce the definition of the kilogram, as it changes from pointing to a lump of metal to a sophisticated definition that involves Planck's constant. I suspect that in introductory contexts we shall simply admit defeat and put in an appropriate footnote.

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**Bob Bucat**—In terms of the basic practice of chemistry, the proposed philosophical re-definition would change nothing. Pedagogically, I believe that the teaching and learning of the concept of chemical amount, and its unit (mole), will be considerably simplified.

What a simple definition for the mole, with the number of entities specified directly: One mole contains exactly  $6.022\,140\,76 \times 10^{23}$  elementary entities.

Conceptually, this is so much more easily understood than the previous mind-screwing definition, with its indirect specification of the number of entities in 1 mole: The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon-12.

Of course, students will rightly ask, "Why this strange number?" It seems not too difficult to accept the explanation that this number is chosen for convenience: it happens to be our best estimate of the number of carbon atoms in 0.012 kilogram of carbon-12. This provides us with a standard for measuring numbers of atoms/molecules/ions by measuring mass. [Please don't let me hear a professional chemist say "But it is essentially the same thing!"]. Indeed, it is but I am considering this, not from the point of view of a practising chemist, so much as from the novice school students struggling to come to grips with its meaning.]

How are we supposed to remember this number? Of course, we don't need to. For example, in considering the reaction between sodium and chlorine, the important concept is that one mole of solid sodium contains the same number of atoms as the number of molecules in one mole of chlorine gas (whatever that number is). Then we can let logic take over to do stoichiometric calculations, as is the case now.

In summary, I believe that the newly proposed definition will facilitate the pedagogy relevant to these concepts.

What is a little worrisome is the proposed definition (or explanation?) of chemical amount: The chemical amount,  $n$ , is a measure of the number of specified elementary entities. That sounds very much like it is a number: how else does one measure, but with a number? But it is not a number! I understand the complexity of wording the definition of this concept, but this proposed one will perhaps (or surely, in my view) create the conception of a chemical amount as a number—a conception that will be difficult to amend.

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