Atomic Weight – Love it or Leave it

N E HOLDEN

Brookhaven National Laboratory, Upton, New York 11973, USA, Chairman of the IUPAC Commission on Atomic Weights and Isotopic Abundances

I Introduction. The definition of "atomic weight" has been under intense discussion in recent years for a number of reasons. In the early nineteenth century, scientists considered the atomic weight of an element to be a constant of nature. Aston's discovery of isotopes[1] and Thode's work on the variation in nature of boron's isotopic composition and its atomic weight[2] have made scientists realize that atomic weights are not "constants of nature." As methods and techniques for detecting variations in isotopic composition improved, and the observed variation in composition became comparable to or larger than the experimental uncertainties, restrictions were included on the atomic weight values to indicate under what conditions these values applied. These restrictions made the choice of an atomic weight value more difficult for some elements.

In addition to this problem, the International Committee on Nomenclature and Symbols (IDCNS) of the International Union of Pure and Applied Chemistry (IUPAC) has been urging that the term "atomic weight" be discarded since it is not a weight and is, in fact, dimensionless. These two difficulties have been discussed at length over the past decade. The International Commission on Atomic Weights and Isotopic Abundances (ICAW) has proposed[3] and IUPAC has approved a new definition (see Section III) to improve this situation with regard to the problem of a variable atomic weight.

The following discussion treats the background of the second difficulty in more detail and investigates the possibilities of resolving it.

II History. Early work on combining weights led Dalton to his atomic hypothesis and the first table of relative atomic weights of the elements. Since substances combine in simple numerical ratios of atoms, the relative masses of the reacting atoms could be deduced from the observed ratios of combined weights. At that time, the extremely small magnitude of the mass of a nuclide (-22×10^{-24} to -4×10^{-22} grams) was beyond measurement capabilities. A century later, Aston's mass spectrograph enabled scientists to determine mass ratios by physical means. The discovery of the isotopes of oxygen in 1929 by Giauque and Johnston[4] led to a situation in which physicists use a scale with $^{16}O = 16$, while chemists used an elemental oxygen = 16 scale. Further complications followed when the isotopic composition of oxygen was found to be variable in nature.

After agreement by physicists and chemists, a new scale with $^{12}C = 12$ was chosen and a new table of atomic weights was prepared in 1961.[5] At the same time, the ICAW proposed to change the name "atomic weight" to "relative atomic mass." However, the Commission on the Nomenclature of Inorganic Chemistry of IUPAC reported to the Inorganic Chemistry Division that "atomic weight" should be retained (see Section IV). Twenty years later, the ICAW is now the strong proponent of no change in the name "atomic weight."

III A New Definition. The presently IUPAC approved definition of atomic weight (mean relative atomic mass) of an element from a specified source is "the ratio of the average mass per atom of the element to ½ of the mass of an atom of ^{12}C." There are a number of remarks on this definition:

1 An atomic weight can be defined for any sample.
2 Atomic weights are evaluated for atoms in their electronic and nuclear ground states.
3 The "average mass per atom" in a specified source is the total mass of the element divided by the total number of atoms of that element.
4 Dated Tables of Standard Atomic Weights published by the ICAW refer to its best knowledge of the elements in natural terrestrial sources.

This present definition has resulted from discussions held for over a decade to solve the problem of the variation of the atomic weight and isotopic composition. With this problem finally removed, discussion is now shifting to the name of the quantity presently defined as "atomic weight."

This new definition was accepted by IUPAC and by the International Union of Pure and Applied Physics (IUPAP). Most recently, IUPAP changed the name "atomic weight" to "relative atomic mass" with the identical definition. This change was based on the apparent misinformation that IUPAC had taken a similar action at the IUPAC General Assembly at Davos, Switzerland in September 1979.

IV Proposed Name Change. There has been mounting pressure to replace the term "atomic weight" because it is not a weight, and other groups use a similar definition for the term "relative atomic mass". Mass is a more fundamental property of matter than weight. However, this distinction is less significant when you refer to relative, not absolute, quantities and the numbers are dimensionless, as pointed out by the IDCNS.

The name "atomic weight" refers back to a time when atomic masses could only be determined by procedures that involved weighing, i.e., observing a mass reacting to the attraction of the earth's gravitational field. The relative value is, of course, the same since at any one location the acceleration due to gravity would be the same for the mass of the element and of the standard.

The Commission on the Nomenclature of Inorganic Chemistry had dismissed the request for a change to "relative atomic mass" some twenty years ago with the argument "from dimensional considerations it is quite irrelevant whether the term "atomic weight" is retained or whether it is replaced by the term "relative atomic mass." Since the former is a well-established term with a definite meaning which has been used by chemists for a long time without giving rise to any confusion, the Commission on Nomenclature recommends that "atomic weight" be retained inasmuch as the other alternative might be confused with the atomic mass of a single isotopic species. If it is felt, however, that the term "atomic weight" should be abandoned for some reason, then it should be replaced by a term which indicates that it is actually a pure number.

Peiser[6] has pointed out the "atomic weight" is firmly established in usage by the vast majority of chemists; and to force a change should be for some reason other than pressures from persons (mostly not chemists) who illogically proclaim that it is an incorrect expression. There is no rule in practice or by consensus that any definition of the meaning of a noun modified by an adjective must have the dimensions of the noun. For example, a specific weight is not a weight, dipole moment is not a moment, resolving power is not a power, electromotive force is not a force and relative atomic mass is not a mass.

If a strong reason is presented for change, the substitute term should be unambiguous and relatively simple. Relative Atomic Mass and Atomic Mass are now used unambiguously by physicists for the mass of a single atom of an individual nuclide. It is ambiguous and confusing to use the same term to mean a mixture of isotopic nuclides of a particular composition characterizing an element. The "Atomic Mass Table" of Wapstra and coworkers,[7] which is

presently used by the ICAW in preparation of its atomic weight table, is given in unified atomic mass units. Scientists would confuse this "Atomic Mass Table" prepared with the encouragement of the IUPAP SUNAMCO Commission (C2 and C13) with an IUPAC "Atomic Mass Table." The situation would become even more confusing if the Atomic Weights Commission should also change its name to Atomic Mass Commission as has been suggested.

Wolfe[8] has recently commented that the process of "weighing" with any kind of balance, as distinguished from a spring scale, determines the mass of any object by comparing it with a standard mass, called a weight. He suggests that "gravity force" might be a better name than "weight" for technical use in physics, because of the rather general use of the term "weight" to mean mass.

Roth[9] has pointed out that in spite of possible confusion between the concept of weight and mass, he has never had a student who misused the term atomic weight.

Murphy[10] noted that in some new chemistry texts, the term weight has been systematically eliminated throughout. The only reference to a weight is now uniquely in the term "atomic weight," which should minimize any possible confusion.

V Conclusion. My conclusion from the above discussion is that the term "atomic weight" is generally understood by users and should not be changed at the present time. Atomic weight has been used for almost two hundred years and there appears to be no confusion on the part of users. No strong or compelling reasons have yet been presented for making a change. The alternative most often suggested, "relative atomic mass," would cause orders of magnitude more confusion than presently exists. The ICAW is a conservative group whose procedure has always been to make no change unless the reasons are compelling and that the change should be an obvious improvement of the present situation. Serious consideration for a change is not given unless these conditions are met.

I would be surprised if the ICAW were to treat the change in the name "atomic weight" in a manner different from their above standard procedures.

To paraphrase "Humpty Dumpty" from Lewis Carroll's "Through the Looking Glass,"[11] when atomic weight is used it means just what the ICAW chooses it to mean — neither more, nor less. As long as one defines what one means by atomic weight and uses it in a consistent fashion there should be no problem.

In conclusion, quoting Humpty Dumpty, "The question is, which is to be master" — the words or the ICAW? I think that this summarizes the situation at present.

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