![PHYS.ORG]

The 'new' kilogram is approaching: Avogadro constant determined with enriched silicon-28

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The high-purity silicon sphere of the Avogadro experiment reflects a copy of the international kilogram prototype - the last embodiment of a unit via a physical body. The sphere, in contrast, stands for the definition on the basis of atomic properties or fundamental constants. Credit: PTB

A milestone in the international Avogadro project coordinated by the Physikalisch-Technische Bundesanstalt (PTB) has been reached: With the aid of a single crystal of highly enriched 28Si, the Avogadro constant has now been measured as exactly as never before with a relative overall uncertainty of 3 • 10^{-8}. Within the scope of the redefinition of the kilogram, the value NA = 6.02214078(18) • 1023 mol^{-1} permits the currently most exact realization of this unit. The results have been published in the most recent edition of the journal *Physical Review Letters*.

The crucial phase of the long-term Avogadro project - which is coordinated by PTB - started in 2003: In that year, several national metrology institutes launched - together with the Bureau International des Poids et Mesures (BIPM) and in cooperation with Russian research institutes - the ambitious project of having approximately 5 kg of highly enriched ^{28}Si (99.99 %) be manufactured as a single crystal, of measuring the Avogadro constant with it and of achieving - by the year 2010 - a measurement uncertainty of approx. $2 \cdot 10^{-8}$. Meanwhile, the first measurements have been completed on the two 1 kg spheres of ^{28}Si - which had been polished in Australia - and their density, lattice parameter and surface quality have been determined.

The single steps: After an extensive check of the crystal perfection, the influence of the crystal lattice defects was assessed. Then, the lattice parameter was determined at the Italian metrology institute (INRIM) by means of an X-ray interferometer, and confirmed by comparison measurements with a natural Si crystal at the American NIST. At BIPM, NMIJ (Japan) and PTB, the masses of the two silicon spheres were linked up in vacuum to the international mass standards. In the respective Working Groups of NMIJ, NMI-A (Australia) and PTB, the sphere volume was measured optically - with excellent agreement - by means of interferometers with different beam geometries. The surface layer (basically composed of silicon dioxide) was spectroscopied with electron radiation, X-ray radiation and synchrotron radiation in accordance with different procedures, analyzed and taken into account for the determination of the silicon density. The unexpectedly high metallic contamination of the sphere surfaces with copper and nickel silicides which occurred during the polishing process was measured, and its influence on the results of the sphere volume and of the sphere mass was assessed. This resulted in a higher measurement uncertainty.

What was decisive for the success achieved - i.e. a relative overall measurement uncertainty of $3 \cdot 10^{-8}$ - was the development of a new mass-spectrometric method for the determination of the molar mass at PTB.

The result is a milestone on the way towards a successful realization of the new kilogram definition on the basis of fundamental constants whose values have been fixed. At present, the agreement of this value with other realizations of the kilogram is not good enough to change the existing definition of the mass unit. The present state of the Avogadro project is, however, so promising that - on the basis of new measurements with improved sphere interferometers - the measurement uncertainty of $2 \cdot 10^{-8}$ demanded by the Consultative Committee for the Mass (CCM) will in the near future be achieved on contamination-free spheres and will probably even be undercut.

More information: Andreas, B.; Azuma, Y.; Bartl, G.; Becker, P.; Bettin, H.; Borys, M.; Busch, I.; Gray, M. et al. (2011), "An accurate determination of the Avogadro constant by counting the atoms in a 28Si crystal", *Phys. Rev. Lett.* 106 (3): 030801 (4 pages), doi:10.1103/PhysRevLett.106.030801

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