A big step towards the redefinition of the kelvin

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Metrologists are measurement artists who are very precise – in the case of the Boltzmann constant up to the sixth decimal place. Whoever is able to determine it very exactly will cause a small revolution in the field of worldwide temperature measurement: The temperature unit will then no longer be based - as hitherto - on a chemico-physical material property, i.e. the triple point of water, but on an unchangeable fundamental constant. Scientists of the Physikalisch-Technische Bundesanstalt (PTB) have now succeeded in re-determining the Boltzmann constant. Although the uncertainty of the result is not yet sufficient for a redefinition of the kelvin, it furnishes proof that the procedure selected by PTB is basically a suitable one. The physicists expect that in the next two years they will be able to reduce the uncertainty to such an extent that a redefinition of the kelvin will be possible. These results have been recently published in the scientific journal *Metrologia*.

Today's temperature definition bears some problems as up to now, the properties of a substance - the triple point of water - have been used which is the basis for the definition of the temperature unit "kelvin". However, water does not always equal water - different effects can influence the triple point temperature. A special problem is the dependence on the isotopic composition and on the impurity concentrations. These values can easily vary when substances are contaminated or contain different isotopes – i.e. identical atoms with different atomic masses. For this reason, scientists want to define the kelvin via an unchangeable fundamental constant and to make it more reliable in this way. This is the basis for even more exact measurements which might in future be required in science and technology.

The Boltzmann constant k is such a fundamental constant. It allows conclusions regarding the thermal energy to be drawn from the mechanical energy of particles. Worldwide, a great number of research groups are working on the task to define the kelvin via a fundamental constant. European research institutions are cooperating in this field in several joint EU projects. Only if several groups obtain the same result with at least two independent methods will a "water-free" definition of the kelvin become possible. In the long term, scientists are trying to define all base units of the International System of Units (SI) with the aid of fundamental constants. In the case of the metre, this has, for example, already been done via the speed of light.

For the determination of the Boltzmann constant, which is required for the redefinition of the kelvin, many research groups are using acoustic gas thermometry which has also furnished the most exact values so far. PTB has followed an alternative, completely independent path to rule out systematic error sources and, thus, to place the redefinition on a solid basis: Here, Dielectric-Constant Gas Thermometry (DCGT) is used. The method is based on the density determination of the measuring gas "helium" by means of a capacitance measurement or, in other words: The researchers measure to what extent the gas changes the capacitance of a capacitor. From measurements performed at the triple point of water with different pressures in the measuring capacitor, the Boltzmann constant can be determined by means of fundamental relations.

This task makes extreme demands on metrology. Its realization was possible only with the aid of experts from industry and several other PTB working groups. Pressure measurement at 7 MPa must, for example, be carried out with piston gauges exact to one millionth, capacitance measurement even exact to one part in a billion. The required temperature stability is provided by a large bath thermostat which was manufactured and optimized in cooperation with the national metrology institute of Italy.

The developed set-up now allows DCGT measurements to be carried out at the triple point of water and furnishes a value for k of 1.380655•10-23 J/K. With an uncertainty of 8 ppm it demonstrates that DCGT is suitable for a determination of the Boltzmann constant at the highest level. However, until the uncertainty of 2 ppm aimed at is reached, some difficulties will have to be overcome. The scientists of PTB expect that this will be possible within the next two years and that then, the way for the redefinition of the kelvin will be cleared. if/ptb

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