New and Last Measurement of the Boltzmann Constant k by Acoustic Thermometry of Helium-4 Gas

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The SI unit of temperature will soon be redefined in terms of a fixed value of the Boltzmann constant k derived from an ensemble of measurements worldwide. We report on the best ever and definitive determination of k using acoustic thermometry of helium-4 gas in a 3 I volume quasi-spherical resonator at LNE. The method is based on the accurate determination of acoustic and microwave resonances to measure the speed of sound at different pressures. We find for the universal gas constant R=8.3144614 (50) J·mol⁻¹·K⁻¹. Using the current best available value of the Avogadro constant, we obtain $k=1.38064878(83)\times10^{-23}$ J·K⁻¹ with $u(k)/k = 0.60\times10^{-6}$, where the uncertainty u is one standard uncertainty corresponding to a 68 % confidence level. This value is consistent with our previous determinations and with that of the 2017 CODATA adjustment of the fundamental constants (Mohr et al., Metrologia Accepted Manuscript online 10 November 2017) within the standard uncertainties. The principle of the experiment is as follows. A gas-filled quasi-spherical resonator (QSR) is maintained in a thermostat at a known temperature (here T_{TPW} =273.16 K or within a few millikelvin of it, with measurements corrected for the small difference by a temperature ratio, other terms being sufficiently constant at the required level of accuracy). Acoustic resonance measurements are performed at different pressures of helium gas while the radii of the QSR are measured using microwave resonance. Great care is taken to avoid impurities in the test gas: a gas purifying system supplies a continuous flow of pure helium to the resonator to remove outgassing impurities. The amount of the only impurity that cannot be removed by purification, ³He, is determined by mass spectrometry of samples from the same bottle as that used for the experiment.