Redefining Temperature: Spectroscopic Determination of the Boltzmann Constant

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In 2005, the Bureau International des Poids et Mesures (BIPM) recommended that the world work towards redefining all the SI base units in terms of fundamental constants or atomic properties. A target date of 2011 has been established by the BIPM to assign a fixed, exact value to Boltzmann's constant, kB, and to redefine the kelvin in terms of this fundamental parameter. To minimise any problems with such a redefinition, the BIPM has mandated that k_B be re-measured by several different methods. We have developed a spectroscopic technique based on accurate measurements of the Doppler-broadened spectrum of atomic rubidium (Rb) transitions at infra-red frequencies. The D2 transition between the 52S1/2 and 52P3/2 levels was probed using a tunable laser diode and non-linear regression was then performed on the spectrum to extract the 1/e-halfwidth associated with Doppler broadening. We implemented frequency and intensity stabilization servo systems on the probe laser and utilized a combination of saturation absorption spectroscopy and a Fabry-Perot cavity to obtain an accurate measurement of the optical frequency. We also found that existing models relating the incident light intensity to the absorption shape were insufficiently accurate and therefore developed a new theory to augment the traditional rate equation formalism. These efforts resulted in preliminary measurements of k_B at 294 K with a relative deviation from the CODATA value of 6×10^{-3}. Primary thermometry above room temperature has also been trialed. Proposals for possible future improvements to the technique will also be discussed.