DETERMINATION OF THE IONIZATION ENERGY OF THE METASTABLE 2 $^1S_0$ STATE OF ^{4}He THROUGH RYDBERG-SERIES EXTRAPOLATION

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Helium, as one of the simplest few-electron atoms, is well suited to test fundamental interactions and QED calculations with a high precision. Its importance is underlined by recent advances in the determination of particle properties such as the α-particle charge radius[a]. Yet, the most accurate theoretical[b,c] and experimental[d,e] data on the ionization energies of the low-lying electronic states show a significant discrepancy of more than 2 σ (about 3 MHz). We report on the determination of the ionization energy of the metastable 2 $^1S_0$ state of helium through Rydberg-series extrapolation with a relative uncertainty of 5×10^{-11} through the determination of 20 different np $\leftarrow$ 2 $^1S_0$ transition frequencies in the range of n from 24 to 102, yielding quantum-defect parameters for the np Rydberg states. A one-photon excitation scheme was employed, using the frequency-doubled output of a narrowband cw laser source (312 nm), calibrated to a frequency comb referenced to a GPS-disciplined Rb clock. The major sources of systematic uncertainties are minimized by (i) carrying out the experiment in a doubly skimmed, pulsed supersonic beam of metastable ^{4}He atoms to minimize the Doppler broadening, (ii) compensating electric stray fields to below 0.7 mV/cm, and (iii) cancelling the first-order Doppler shift by monitoring two Doppler components resulting from two counter-propagating laser beams. The effects of residual stray electric fields are included as DC-Stark shifts in the analysis. Our new value of the ionization energy of the 2 $^1S_0$ state of ^{4}He, with an absolute uncertainty better than 50 kHz, represents an improvement by a factor of about five in precision. It also allows for a purely experimental determination of the ionization energies of several other low-lying electronic states of ^{4}He, which were previously only accurately known through combination of measured and theoretical energy intervals.

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