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Precision Atomic Mass Measurements of Light Ions[1]

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The atomic masses of the proton, deuteron, triton and helion (nuclei of hydrogen, deuterium, tritium and helium-3) are regarded as fundamental constants impacting wide areas of physics. In particular, a high-precision value for the difference in mass between tritium and helium-3 is needed for testing systematics in the ongoing KATRIN neutrino mass experiment, while the mass ratio of the deuteron to proton is important for interpreting the results of recent, high-precision laser and terahertz spectroscopy of the HD^+ molecular ion. This leads to an improved electron-proton mass ratio and limits on a hypothetical Angstrom-scale nucleon-nucleon force. At FSU we measure precision mass ratios by simultaneously trapping the two ions in a Penning trap. Our measurements of mass-3 ions, besides providing an important datum for KATRIN, revealed significant errors in the previously accepted masses of p, d and h. They also provided an experimental demonstration of metastable, high-J, K rotational levels in the H_3^+ ion. Recently we have been able to place two ions in a coupled magnetron orbit and measure their cyclotron frequencies simultaneously, suppressing the effect of variation in the magnetic field several orders of magnitude. Using this technique with a deuteron and a H_2^+ ion we have been able to resolve molecular vibrational energy, and partly resolve rotational energy, as mass changes of the H_2^+. This resulted in the first light-ion mass ratio with an uncertainty 5 x 10^{-12}, a value for m_d/m_p at 5 x 10^{-12}, and an atomic mass of the proton at 10^{-11}.

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