# Quenching of Metastable Hydrogen by Helium*

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Measurements of collisional quenching of metastable hydrogen by helium in the thermal region ($v \simeq 5\times10^{-3}$ a.u.) have been made. The resulting cross section $\sigma_Q \simeq 8\times10^{-15}$ cm$^2$ per atom is 20–25% larger than the theoretical results obtained by Byron and Gersten using a pseudopotential method.

The study of the quenching of hydrogen in the metastable 2$S$ state by helium is of considerable importance in that the measured cross sections can be compared with results calculated from first principles. Previous studies of H(2$S$)-He(1$S$) collisions have been confined to energies $\gtrsim 300$ eV.[1,2] Comparison of the experimental results in the keV region with an eikonal calculation using an effective potential of the polarization type resulted in a possibly fortuitous agreement since later calculations indicate that exchange effects are of considerable importance.[1,3] It is likely, however, that the inclusion of a large number of final states is necessary to explain the results in the keV region.

Byron and Gersten[3] have recently carried out detailed calculations of the quenching cross sections in the energy range below approximately 250 eV considering only 2$S$-2$P$ transitions in H. Using a pseudopotential method they find reasonable agreement with the experimental results at the lowest energies (~300 eV) obtained in the previous work.[1] As expected, the 2$S$-2$P$ cross section lies below the experimental results since other transitions should be taking place at these energies.

Experimental studies in the thermal region ($v \simeq 10^{-3}$ a.u.) should provide a rigorous check on these calculations since the quenching of H(2$S$) in this region should arise only from 2$S$-2$P$ transitions. We report here the results of a measurement of the H(2$S$)-He(1$S$) quenching cross sections in the thermal region.

The cross sections were obtained from measurements of the attenuation of an H(2$S$) beam in passing through a helium target cell. The use of the attenuation technique permits determinations of the absolute cross sections without a knowledge of the absolute detector efficiency. A ground-state atomic hydrogen beam was produced by partial thermal dissociation of $H_2$ in a tungsten oven ($T \simeq 2800$°K). This beam was crossfired with an electron beam of $\simeq 14$ eV. A Channeltron multiplier was used to detect the resulting metastable H and $H_2$. A dc quench region ($\simeq 150$ V/cm) which selectively removes H(2$S$) from the beam permitted subtraction of the metastable molecular component. The electron gun was pulsed (pulse width $\simeq 5$ $\mu$sec) to permit use of time-of-flight techniques. The target chamber was a simple gas cell with a circular entrance aperture and interchangeable exit apertures. The pressure of the He in the scattering chamber was determined with a capacitance manometer. Detailed measurements were made to determine that elastic scattering of the H(2$S$) was negligible.

The resulting cross section $\sigma_Q$ is shown in Fig. 1 as a function of the H(2$S$) velocity. The indicated error bars include corrections for the velocity of the target atoms, for the finite electron-gun pulse width, and for the effective length of the scattering cell. Also shown are the theoretical results[3] obtained (1) from replacement of the He atom with a Breit-Fermi pseudopotential and (2) from a perturbation-theory method. As can be seen, our results are 20–25% larger than the theoretical result obtained using the pseudopotential method.

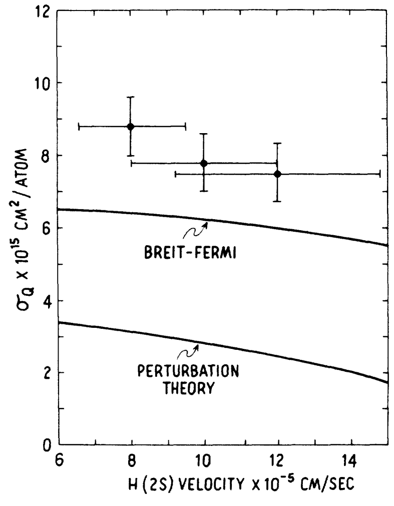

FIG. 1. The quenching cross section for H(2$S$)-He(1$S$) collisions in the thermal region.

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# Observation of a Quadratic Term in the hfs Pressure Shift for Muonium and a New Precise Value for Muonium $\Delta\nu$*

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New measurements of $\Delta\nu$ for muonium in argon at low pressures and at very weak magnetic field provide the first observation for muonium of a quadratic term in the hfs pressure shift and lead to a new precise value for the hfs interval in muonium, $\Delta\nu = 4463.311(12)$ MHz.

Measurement of the hyperfine structure interval $\Delta\nu$ in the ground state of muonium ($\mu^+e^-$) with the highest possible accuracy is of great importance for muon electrodynamics and for a precise determination of the fine-structure constant $\alpha$.[1-3] An important factor which influences the accuracy of the determination of $\Delta\nu$ is the hfs pressure shift caused by collisions of muonium with atoms of the inert stopping gas in which muonium is formed. These collisions are, of course, of interest in their own right; in particular, for muonium the effects of three-body collisions can be studied and the dependence of the collisions on the hydrogen isotope (since muonium can be considered an isotope of hydrogen) is also studied.

The measurements reported in this Letter involve several important improvements in the observation of the transition $(F,M_F)=(1,\pm 1)\rightarrow(0,0)$ at a magnetic field of 0.010 G.[4,5] An improved arrangement of the scintillation-counter system and a larger microwave cavity led to an improved ratio of signal to background at low stopping-gas pressure. Use of a 45-MHz digitron and a PDP-8 computer led to valuable time-dependent data and good monitoring of experimental parameters.[6]

A resonance curve obtained with argon gas at 10 atm is shown in Fig. 1. The experimental signal is the percentage increase in decay positron counts observed during a time interval of 0.1 to 5.6 $\mu$sec following a stopped-muon signal when the microwave power is on. The experimental points are fitted by a Lorentzian curve:

$$S(\nu)=\frac{A(\delta\nu)^2}{(\delta\nu)^2+4(\nu-\nu_0)^2} \tag{1}$$

in which $\nu$ is the microwave frequency, and $A$ and $\nu_0$ are parameters obtained from the fit. The linewidth (full width at half-maximum) $\delta\nu$ of 520 kHz is due to microwave power broadening of the natural linewidth (145 kHz) and agrees with the width expected from microwave power measurements in the cavity and the line-shape theory.[7] The maximum signal is consistent with the measured background counts and with our previous observations.

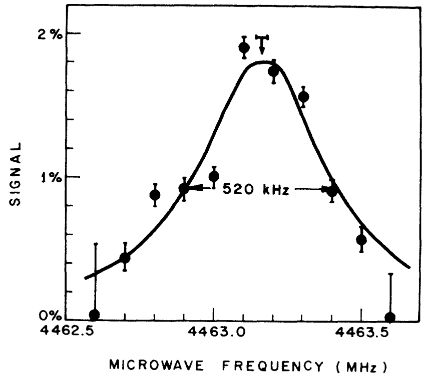

FIG. 1. Muonium resonance curve for the transition $(F,M_F)=(1,\pm1)\rightarrow(0,0)$ at a very weak magnetic field, 0.010 G, in a 10-atm argon stopping gas. The 1-standard-deviation error bars are due to counting statistics. The solid curve is a least-squares fit by a Lorentzian with the center at 4463.159 ±0.016 MHz.