Frequency Shift of the Zero-Field Hyperfine Splitting of Cs^{133} Produced by Various Buffer Gases

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(Received June 27, 1958)

The pressure shift, caused by collisions with various noble gases in the zero-field ground-state hyperfine interaction of Cs^{133}, has been measured by an optical transmission, microwave saturation method. A pressure shift to higher frequency was found in the case of the lighter gases, hydrogen, helium, nitrogen, and neon (+1900, +1600, +930, +650 cps/mm Hg) while a pressure shift to lower frequency was found in the case of the heavier gases, argon, krypton, and xenon (−250, −1300, −2400 cps/mm Hg).

INVESTIGATIONS of the frequency shift produced by argon and neon buffer gases in the zero-field hyperfine splitting of Na^{23} have been previously reported.[1] This note gives the results of similar experiments performed with Cs^{133}.

The experimental apparatus is essentially the same as the one previously described for sodium. Cesium, in a spherical glass cell about 1 inch in diameter, was maintained at a temperature of 30°C. Spectroscopically pure buffer gases were used, ranging in pressure from 1 mm to 15 mm Hg. Resonant light from a standard cesium lamp was used for optical pumping and optical detection of the (4.0) to (3.0) microwave hyperfine transition. The microwave frequency was obtained from an *X*-band klystron phase-locked to a stable crystal oscillator, and measured with an electronic counter monitored with station *WWV* with a short-term accuracy of 1 part in 10^8 to 1 part in 10^7.

The value of the hyperfine splitting of cesium in the ground state was found to be 9192.632×10^6 cps ±500 cps in agreement with the value obtained by atomic beam measurements.[2] A shift in the hyperfine frequency which is proportional to the pressure of the buffer gas has been observed for various kinds of gases (Fig. 1). A pressure shift to higher frequency was found in the case of the lighter gases, hydrogen, helium, nitrogen, and neon (+1900, +1600, +930, +650 cps/mm Hg) while a pressure shift to lower frequency was found in the case of the heavier gases, argon, krypton, and xenon (−250, −1300, −2400 cps/mm Hg).

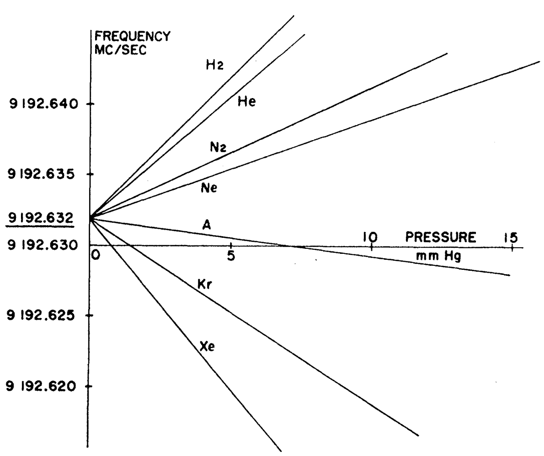

FIG. 1. Pressure shift of zero-field hyperfine splitting of Cs^{133}.

These results suggest pressure shifts for the hyperfine transition quite similar to optical pressure shifts,[3] although the order of magnitude is quite different. In a mixture of buffer gases, the pressure shift δ is approximately equal to $\delta=\sum_i \delta_i p_i$, where δ_i is the pressure shift of a pure gas and p_i the partial pressure of the gas in the mixture ($\sum_i p_i=1$). For example, the following mixtures gave very little pressure shift: A 75%−Ne 25%; A 85%−He 15%; A 70%−N_2 30%.

In these experiments the line width of the resonance frequency was broadened by power saturation and frequency modulation. When extrapolated to zero field and zero modulation, the line width was of the order of 100 to 125 cps and was independent of the pressure or the nature of the buffer gas within the range of our measurements (from 1 to 15 mm Hg). The line width in this range of pressure may be due to the combined effects of a residual Doppler broadening which decreases with pressure of the buffer gas and a statistical collision broadening effect which increases with pressure. The signal strength is half again as strong for the pair of buffer gases Ne and A which produce the least pressure shift as for the pair Kr and He. The strength for Xe is very poor. This suggests that those gases which produce the greatest pressure shift also produce the greatest mixing and disorientation in the excited states.

ACKNOWLEDGMENTS

We are grateful to Dr. P. L. Bender and E. C. Beaty of the National Bureau of Standards for a helpful discussion of our results.

* A division of International Telephone and Telegraph Corporation.

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