SHOCK TUBE SYMPOSIUM THE PHYSICS OF FLUIDS SUPPLEMENT I, 1969

Shock-Tube Measurements of van der Waals Broadened Silicon Lines

RICHARD A. DAY*
Harvard College Observatory, Cambridge, Massachusetts

The widths of van der Waals broadened Si I spectral lines were measured by using a conventional shock tube and a scanning Fabry–Perot interferometer. The experiments have been performed by using argon as the perturbing gas in the reflected region of the shock wave at a temperature of about 5500°K and over a pressure range of 2–10 atm. The temperature was determined by a line reversal technique; the pressure was measured using a quartz transducer. The scanning Fabry–Perot was driven by a piezoelectric crystal operating at its resonant frequency (10.5 kc/sec); the line profiles were detected photoelectrically and displayed on an oscilloscope for photographing and analyzing. A set of calculated curves was used to obtain the contribution of the pressure broadening to the widths of the spectral lines. The experimental widths thus determined are within a factor of two of the results obtained from theory.

I. INTRODUCTION

The shock tube is an excellent spectroscopic light source for studies of atomic and molecular properties of interest to astrophysicists. In the temperature region of 5000–8000°K and carrier gas densities of the order of 10^{18} cm^{-3} to 5×10^{19} cm^{-3}, observation times of the order of several hundred microseconds are available for the studies of line profiles. This paper describes an experiment devised to measure damping constants (half-widths) of spectral lines.

In the shock tube under the above-stated conditions electron densities will range from about 5×10^{14} to 5×10^{16} cm^{-3}. Whether a spectral line is broadened by electron impacts or by collisions with neutral perturbers depends on the detailed structure of the atom, but typically when the ionization of a gas is less than 1%, the spectral lines emitted from energy levels lying lower in the atom, that is, where the level spacing is large, will more likely be broadened by neutral perturbers, especially if one of the levels is an s state. Spectral lines emitted from higher-lying levels are more apt to be broadened by electron impacts.

As a prelude to the study of Stark (electron) broadening processes in a shock tube, the present experiment was performed to assess the reliability of the van der Waals theory as given by Griem.[1] Since the theory as quoted in *Plasma Spectroscopy* is an adiabatic theory, this experiment, which is performed at relatively high temperatures, provides a rough measure of the importance of inelastic processes in van der Waals broadening.

II. EXPERIMENTAL APPARATUS AND PROCEDURE

The experimental equipment was a diaphragm type shock tube used with hydrogen as the driver gas. The test gas argon with a 0.1% admixture of $SiHCl_3$. Typical diaphragm breaking pressures were in the range of 60–600 lbs and the corresponding pressures of the test gas were in the range of 15–120 Torr. These conditions gave a reasonably constant temperature (between 5500 and 7000°K) and densities of neutral particles between 2×10^{18} and $\sim 4 \times 10^{19}$ cm^{-3}. The temperature range of about 25% was not significant for the measurement of van der Waals broadening since the predicted temperature dependence is slow, proportional to $T^{3/10}$.

The various measurements were made in the flow region behind the reflected shock wave; about 100 μsec were allowed for the shock wave to equilibrate judged from the time behavior of the intensity of a spectral line. Then, the temperature of the gas was measured spectroscopically by means of a line reversal technique. If the shocked gas is assumed to be in local thermal equilibrium,[2] the temperature can be determined by measuring the emissivity of the gas and the intensity emitted in a given spectral range.

The total pressure of the gas was measured with a quartz transducer. Then, by using the measured temperature and pressure and the known percentage composition of the gas, all of the properties of the gas can be calculated, i.e., densities of atoms, molecules, and electrons.

---

* Present address: Department of Physics, University of Oklahoma, Norman, Oklahoma.

[1] H. R. Griem, *Plasma Spectroscopy* (McGraw-Hill Book Company, New York, 1964).

[2] W. R. S. Garton, W. H. Parkinson, and E. M. Reeves, Proc. Phys. Soc. (London) 88, 771 (1966).