Proc. Indian natn. Sci. Acad., **46**, A, No. 5, 1980, pp. 456–459.

I. PHYSICS

Instrumentation

STUDIES IN A SHOCK TUBE FOR RECORDING OF OPTICAL SPECTRUM

S. K. KANOO *and* S. JOIS

Department of Physics, Gauhati University, Gauhati 781 014, Assam

(Communicated by S. D. Chatterjee, F. N. A.)

(*Received 6 August 1979; after revision 19 March 1980*)

A 5 cm diameter diaphragm type shock tube is described with a view to study the emitted radiation. Some modifications have been made to increase the light output which is essential for successful recording of spectrum. CN and C_2 spectra were obtained by the shock wave technique. H_2 is used as a driver gas for obtaining a shock in Ar, with a driver pressure of under 3.5 atm. The energy transfer during the shock wave is 3.2 eV which corresponds to a pressure ratio of about 290.

Keywords : Shock Tube; Shock Wave; Diaphragm; Bands Spectra; Energy Transfer Process.

INTRODUCTION

THE apparatus used for producing shock waves in the present study is described. The high pressure chamber is filled with H_2 at higher pressure. The gas is ignited by heating coil operated by 230 volts a.c. Some improvements have been achieved involving shock speed, intensity, and diaphragm breaking technique, which have helped successful recording of spectra.

EXPERIMENTAL ARRANGEMENT

The schematic experimental arrangement is shown in Fig. 1. The shock tube has been constructed using galvanised iron pipe, 180cm long, 5cm in diameter, with a wall thickness of 2mm. The pipe was cut into two unequal parts. The driver section was 45cm long, the test section 135cm long. The plate on the longer section had a glass window of 2.5cm diameter and 2mm thickness to transmit optical radiation. In the initial experiments thin polythene of 10 × 10cm size and thickness 0.01cm were used as diaphragms. Both the chambers were evacuated. Hydrogen gas at one atmosphere pressure was initially used as driver gas in the high pressure section. The test section was filled with commercial argon gas at a pressure of 10mm Hg.

The diaphragm could be broken due to pressure difference between both sides. A shock wave was generated and the wave front penetrated into the argon atmosphere. Atoms and molecules present in the temperature zone were excited energetically and emitted their characteristic radiation which could be seen as a light flash. However, these flashes were initially very feeble, so the spectra could not be recorded easily. Later on, experiments were conducted with thicker diaphragms and the red

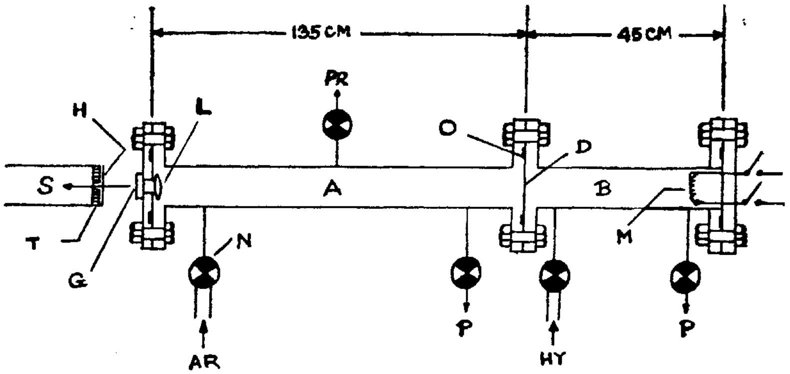

FIG. 1. Layout for photographing the emission spectrum behind a shock front. *B* : driver section; *M* : heating coil connected to 230 volts a. c. main; *P* : pump; *HY* : hydrogen; O : 'O' ring; *A* : shock tube; *L* : lens, *PR* : pressure gauge; *N* : needle valve; *AR* : argon; *G* : glass window : *H* : Hartmann diaphragm; *T* : spectrograph slit; *S* : spectrograph.

part of the visible spectrum could be recorded on a 400 ASA (120 size) panchromatic ORWO strip using a wider slit.

MODIFICATIONS

Lapworth (1959) has pointed out the difficulty in recording weak radiation. He overcame this difficulty by placing a flat obstacle in the tube spanning the working section and focussing the upstream face of this on to the spectrograph slit. But the present method of using a lens of 0.5cm thickness inside the tube next to the glass window appears to be simpler and easier for construction.

IMPROVEMENT OF INTENSITY

It is imperative that stronger light would be necessary to get intense spectra. This could be achieved by increasing the shock speed which could be increased if the driver gas could be heated to a higher temperature. Various methods of transferring heat to the driver gas has been described by several authors (Resler *et al.*, 1952; Curzon & Phillips, 1971; and Phillips & Pugatschew, 1975).

In the present work, internal heating as suggested by Resler *et al.* (1952) was adopted. An electrical heating element in the form of a coil was fitted on a laminated 15 × 15 × 2.5cm perspex plate. The sealing metal plate on the driver section was removed and in its place the above perspex plate was bolted in position with an intervening 'O' ring of diameter 8cm. The coil when excited by 230 volts a.c. main, heats up the driver gas almost instantaneously. A very high pressure consequently develops, causing the rupture of the diaphragm.

CONTROLLED RUPTURE DIAPHRAGM

Imperfect rupture of the diaphragm was also one of the limitations of improving the shock speed. Following the suggestion put forward by Resler *et al.* (1952), two lines perpendicular to each other were scratched on the diaphragms with a sharp knife.

The point of intersection was made to coincide with the axis of the tube. Old X-ray films of different thickness and of size 10 × 10cm were used as diaphragms. The best results were obtained when the diaphragms of thickness 0.048cm were used.

RECORDING OF SPECTRA

After the above mentioned improvements, slit width of the order of 0.02–0.03mm were used to record the spectra. The shutter of the Hilger Spectrograph was kept open in a darkened room before setting off the shock.

The spectra recorded in this way were mainly line spectra. The line spectrum from an iron arc was also recorded for use as standard comparison spectrum. Later, analysis of the spectra from the shock tube was found to be the spectrum of iron. Iron spectrum was always present even when attempt were made to obtain the band spectra by introducing some vapour of organic and inorganic substances. Then a glass tube 130cm long with an outer diameter of 48mm was introduced inside the test section, avoiding the iron environment of the shock tube. Under this condition, the iron spectrum was completely removed and some band spectra C_2 and CN were recorded by using vapours of benzene (C_6H_6) and carbon tetrachloride (CCl_4) separately.

RESULTS AND DISCUSSIONS

Heating is brought about by collision between molecules of moving gas and the molecules of the target gas. If there are '*n*' collisions on the average in the shock front, the mean loss of energy per collision is (K. E.)/*n*. If the spacing of a typical spectral interval is $\leqslant$ (K. E.) /*n*, some of the energy loss is converted into internal energy. On the other hand, if the energy spacing is $\geqslant$ (K. E.)/*n*, the molecules will remain unexcited through the shock front (Hornig, 1957; and Gaydon, 1970). The CN bands arise due to the transition of $B^2\,\Sigma^+ - X^2\,\Sigma^+$. The *B* state lies about 25731cm^{-1} above the ground state (Herzberg, 1950). This corresponds to 3.2 eV. Similarly, C_2 bands arise due to the transition of $A\,{}^3\pi_g - X\,{}^3\pi_u$. The *A* state lies about 9306cm^{-1} above the ground state, (Herzberg, 1950). This corresponds to 2.4 eV. Now we can say, at least 3.2 eV of energy must have been supplied through the shock front to excite those bands.

ACKNOWLEDGMENTS

The authors would like to thank Professor B. Chaudhuri, Head of the Department of Physics, Gauhati University for providing them with laboratory facilities and Dr S. D. Chatterjee, Professor Emeritus, Jadavpur University for his valuable suggestions.

REFERENCES

Curzon, F. L., and Phillips, M. G. R. (1971) Low attenuation shock tube: driving mechanism and diaphragm characteristics. *Can. J. Phys.*, **49**, 1962.

Gaydon, A. G. (1970) Shock tubes. *Proc. R. Instn.*, (G. B.), **43**, 427.

Herzberg, G. (1950) *Molecular Spectra and Molecular Structure: I Diatomic Molecules.* Van Nostrand, New York.

Horing, D. F. (1957) Energy exchange in shock waves. *J. phys. Chem.*, **61**, 856.

Lapworth, K. C. (1959) Shock tube research at the National Physical Laboratory on the properties of gases at high temperature. Part II, preliminary spectrographic measurement. *Proc. Eleventh Symp. Coluston Res. Soc.*, p. 317.

Phillips, M. G. R., and Pugatschew, A. A. (1975) Improvement of shock speed in an electrothermal diaphragm shock tube. *J. Phys (E). Sci. Instrum.*, **8**, 913.

Resler, E. L., Lin, S. C., and Kantrowitz, A. (1952) The production of high temperature gases in shock tube. *J. appl. Phys.*, **23**, 1390.