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【Paper】

Emission Spectra of Metal-CO_2 Flames

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Abstract

Spectroscopic measurements were made on lithium and magnesium flames with CO_2. Quantized emissions from metal atoms and metal oxide molecules and continuum emissions from condensed metal oxides were visible in the flames. The features of the spectra indicated that lithium and magnesium could burn in the vapor phase in CO_2.

Introduction

Earlier, the author proposed a CO_2-breathing engine using metals as fuel in carbon dioxide rich planet atmospheres without oxygen such as those of Mars and Venus[1]. The attractive metals for this engine are lithium and magnesium, because of their high heats of reaction with CO_2[1] and their easier ignitability[2]. In the present study, emission spectra of lithium and magnesium flames with CO_2 were observed to help the understanding of combustion processes of the metals in CO_2.

Experimental Apparatus

Figure 1 shows a schematic of the experimental apparatus used in this study. A combustion chamber had a horizontally mounted resistance heater with a depression at the center, an axially symmetric converging nozzle, and quartz windows to allow photographic and emission spectrum observations. CO_2 gas issued from the nozzle with an exit diameter of 30 mm into a spherical part of the chamber (106mm in diameter). Its nozzle exit velocity was kept constant at 0.5m/s. The CO_2 gas impinged on a sample holder to produce a stagnation flow over it. The holder had a depression (10mm in diameter, 3mm in depth) in which a metal sample was just fitted through an exchangeable receptacle, made of very thin molybdenum or stainless steel to avoid reactions between the holder and the metals. Lithium and magnesium used in this study have the purities of 99.0% and 99.9%, respectively. All of the experiments were carried out at the atmospheric pressure. The sample was heated through the sample holder by the heater, made of molybdenum which does not react appreciably with CO_2, in an inert gas at first. When the sample tempereture became uniform at a predetermined value, the sample was ignited by exposing the sample to the CO_2 stream. The apparatus and procedure are outlined in detail in Ref. 2.

Spectroscopic observations were made with a grating spectroscope (Jasco CT-25c), having a dispersion of about 3.2nm/mm, via a quartz fiber light guide. Emission spectra were photographed on 35 mm Kodak 103 a-E films, which was sensitive over the wavelength range from 250 to 675nm[3]. Spectral lines

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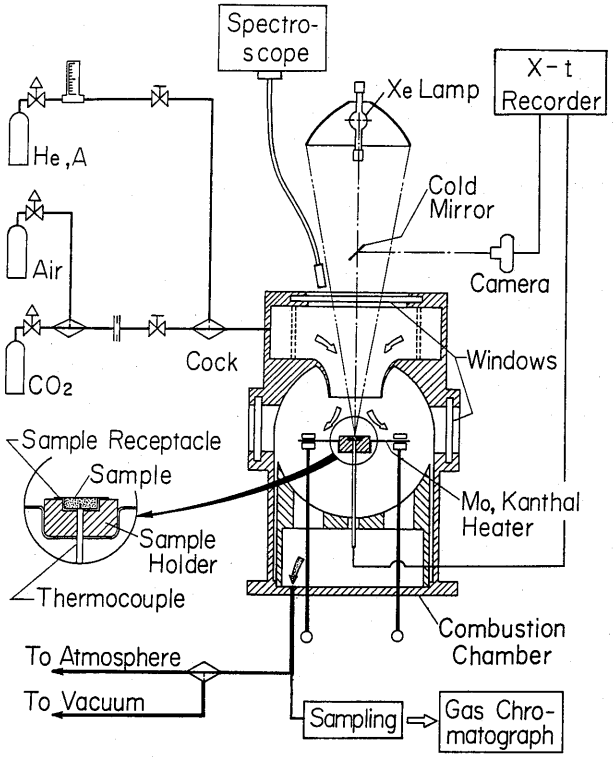

Fig. 1 Schematic of experimental apparatus.

and bands were identified with the help of tables in the references[4),5)].

Experimental Results

(1) Lithium

Lithium could ignite and burn in the CO_2 stream. Duration of flaming combustion of the sample was about two seconds, during which time only small quantities of white smoke were generated. After that, however, the sample continued to be heated red over a period of 20～30sec. A typical emission spectrum of the corresponding flame is shown in **Fig. 2**-(a). The principal features of interest were atomic lines of lithium and continuum emission. The following singlet lines of lithium could be identified in the spectra : 670.784nm (self-absorbed), 610.364nm (strong), 460.286nm (weak) and 323.261nm (weak). The presence of lithium lines indicates that the lithium sample burned in the gaseous phase. The continuum emission appeared in the red region. It was most likely the results of thermal radiation by the lithium oxide condensed in the flame. No band systems assigned to lithium oxide were observed in the experiments. From a comparison experiment using air as an oxidizer, the above features of emissions were found to be essentially the same as those in the air stream.

(2) Magnesium

Magnesium could ignited in the CO_2 stream. After ignition, the sample continued to burn with several incandescent flames and with a large amount of white smoke for a period of 30～40sec, during which the

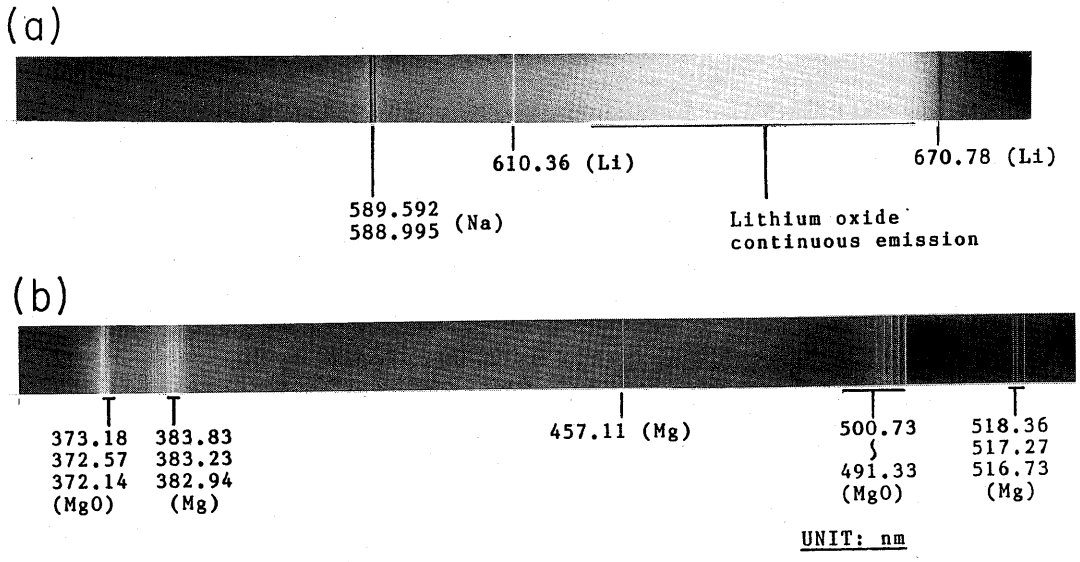

Fig. 2 Emission spectrum of metal-CO_2 flames with identified characteristic lines and bandheads: (a) lithium, (b) magnesium.

sample temperature remained 1000~1050°C close to the boiling point of Mg (1107°C). A typical emission spectrum of the corresponding flame is shown in **Fig. 2**-(b). The atomic lines of magnesium, the bands of MgO vapor and the continuum emission of condensed MgO were visible. The identified lines and bands were:

Mg singlets — 285.21 (self-resolved), 457.11nm
Mg triplets — 309.11, 309.30, 309.69nm (weak)
332.99, 333.22, 333.67 nm (weak)
382.94, 383.23, 383.83 nm (strong)
516.73, 517.27, 518.36 nm (strong)
MgO bands — 500.73nm (strong, 9 band heads)
372.14, 372.57, 373.18nm (strong band heads).

The prominent features of the spectra were in agreement with the observations of several other investigators[5~7] for Mg flames in oxidizing atmospheres. Consequently, the spectroscopic evidence shows that in the CO_2 stream the magnesium sample burned in gaseous phase.

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