The Absorption of Methane at Low Temperature in the 0.84 μm Region*

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This is a report summarizing the progress of ground based studies in support of astronomical observations of the absorption of methane in the atmosphere of Jupiter.

On the basis of the room temperature absorption spectra of methane obtained over the region 11,000-12,000 cm^{-1} by this laboratory, Dr. Nathaniel Carleton of Harvard and the Smithsonian Observatory suggested more detailed observation at different temperatures of the region between 11,900 and 11,920 cm^{-1}. This region appears to be the most favorable in terms of Jupiter spectra with regard to the intensity of the absorption and the possibility of observing single lines. However, nowhere in the entire 11,000-12,000 cm^{-1} region surveyed is the spectrum as ideal as one would like in terms of the presence of obviously unblended single sharp lines.

Initially, this project called for observations in the laboratory at dry ice temperature and above. However, early runs made by packing the cell in dry ice, while yielding temperatures of -60°C, did not show any absorption features which were appreciably temperature sensitive. Accordingly, the cell was redesigned to allow cooling by means of liquid nitrogen and its vapor. What follows summarizes the measurements made and the results obtained at temperatures between 23°C and -150°C.

Apparatus and Procedure

The absorption cell was of the White-type with a base length of 5 meters. The sample tube was enclosed by a concentric pipe to form a cooling jacket with the entire apparatus covered with a 6 inch layer of styrofoam. Cooling was accomplished by forcing liquid nitrogen into the jacket from two 100 liter Dewars until the minimum desired temperature was reached. The cell was then allowed to stabilize and data were taken as it slowly warmed. Condensation on the windows was avoided by use of an evacuated section of thin wall stainless tubing with a room temperature window at one end and a cold window at the other end in contact with the sample. Figure 1 is a sketch of the cell arrangement.

The simple design of the cell did not permit operation while continuously cooling as this produced temperature gradients which resulted in both turbulence in the methane sample and shifts in the adjustable White cell mirrors. Shifts in the mirrors were also a problem as the cell warmed, but over short regions of the spectrum reasonably constant signal levels and uniform temperature could be maintained.

Temperatures were monitored by a series of five thermocouple junctions distributed along the inside of the sample cell.

The spectra were obtained with the Florida State University 3 m focal length instrument operated double pass in the third order of a 20 cm, 400 ruling/mmn grating blazed at 37°. The source was a 650 watt quartz- iodine projection lamp. An RCA C31034 photo-multiplier served as the detector.

Results

After survey runs at -140°C were made in the region between 11,900 and 11,950 cm^{-1}, efforts were concentrated on two features. The first was a group of four lines in which the highest frequency line (which will be referred to as A) at 11,919.15 cm^{-1} appeared to decrease in intensity at low temperature relative to the others in the group. The second feature was a very weak absorption at 11,912.40 cm^{-1}

(henceforth referred at as B) which showed a considerable increase in intensity as cooling progressed.

To obtain further information as to whether the features chosen contained single lines, the spectra were digitized and deconvoluted at room temperature by use of the method developed in this laboratory by Jansson. Figure 2 shows A and B before and after deconvolution. As a result of the relatively high sample pressure of 30 cm Hg required to develop these lines, deconvoluted line widths at half intensity are on the order of 0.10 cm^{-1}. This while the features chosen do appear to contain single lines, the blending of lines of spacing less than 0.10 cm^{-1} is a possibility.

Figure 3 shows the appearance of A and B as observed at room temperature (23°C) and at -150°C. The measured equivalent widths of these features are listed in Table I along with the conditions of observation. These equivalent widths, to a good approximation, fall in the linear region of the curve of growth since the observed absorptance never exceeded 10%. The same sample was used for all results in Table I so as to maintain a constant density of molecules in the absorbing path.

From Table I it is seen that A does not decrease in intensity with cooling as was hoped. It appears that no absorption feature of any appreciable intensity in this region has this property. It is quite likely that at the low level of absorption present, the lines of appreciable intensity that are observed involve moderate values of the angular momentum quantum number J. These lines will be least temperature sensitive and only very weak features such as B will show large temperature dependence. Also, with features as weak as B initially, it would be very difficult to follow accurately any loss in intensity with cooling.

Table I

Feature	Temperature	Pressure	Path	Equivalent Width
A	23°C	29.45 cmHg	100 m	0.47×10^{-2} cm^{-1}
A	-150°C	12.9 cm Hg	100 m	0.47×10^{-2} cm^{-1}
B	23°C	29.45cm Hg	100 m	0.35×10^{-2} cm^{-1}
B	-150°C	12.9 cm Hg	100 m	1.20×10^{-2} cm^{-1}

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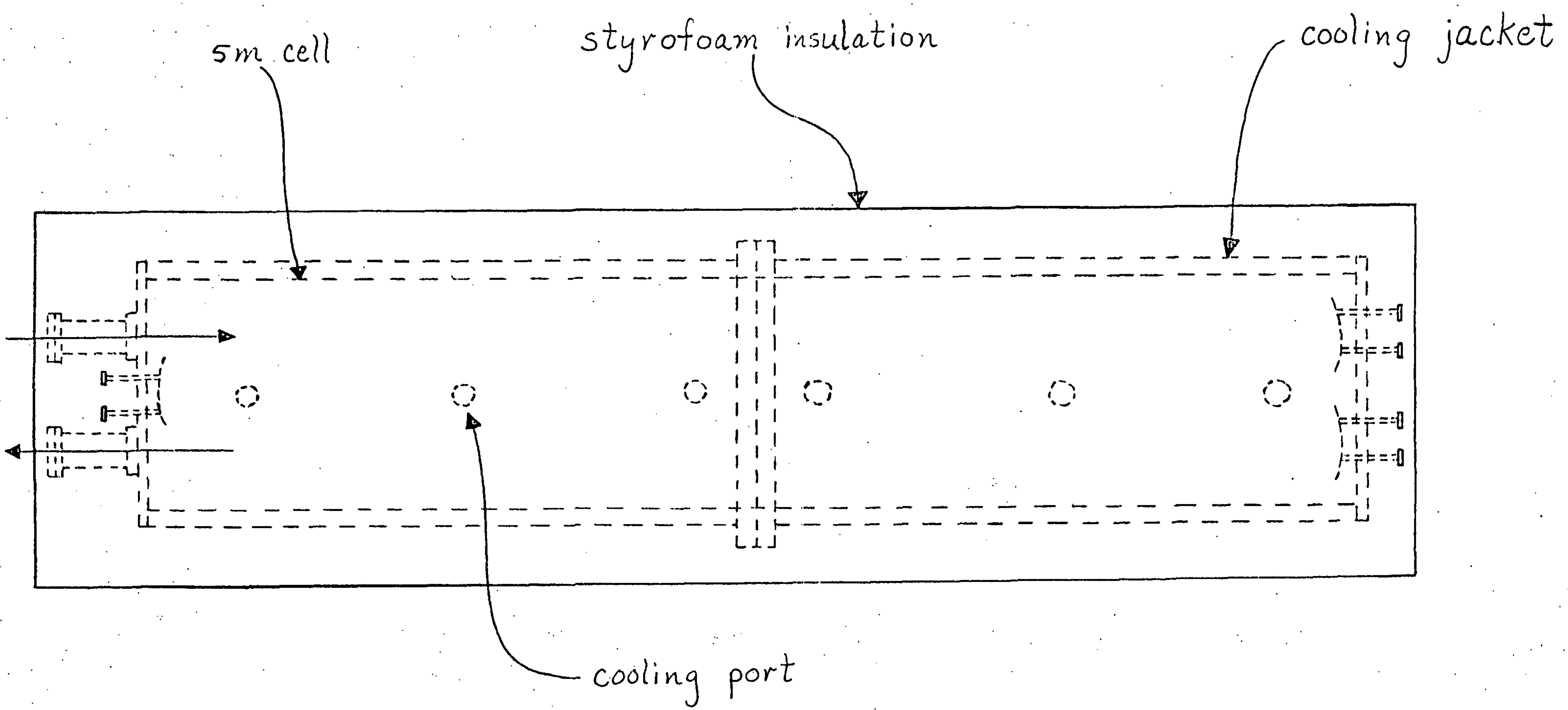

FIGURE 1. SCHEMATIC OF ABSORPTION CELL

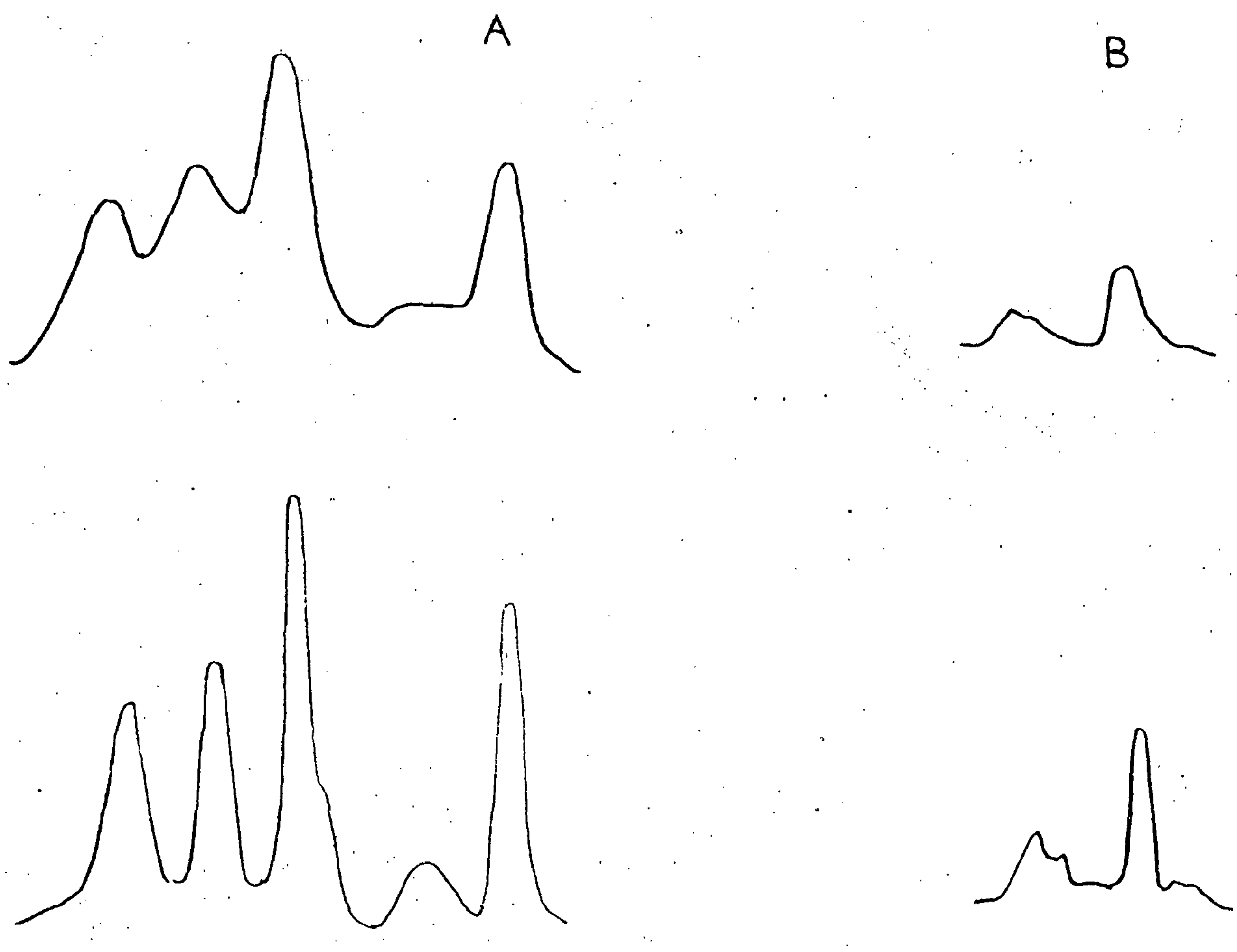

FIGURE 2. FEATURES A AND B BEFORE (UPPER TRACES) AND AFTER DECONVOLUTION (LOWER TRACES).

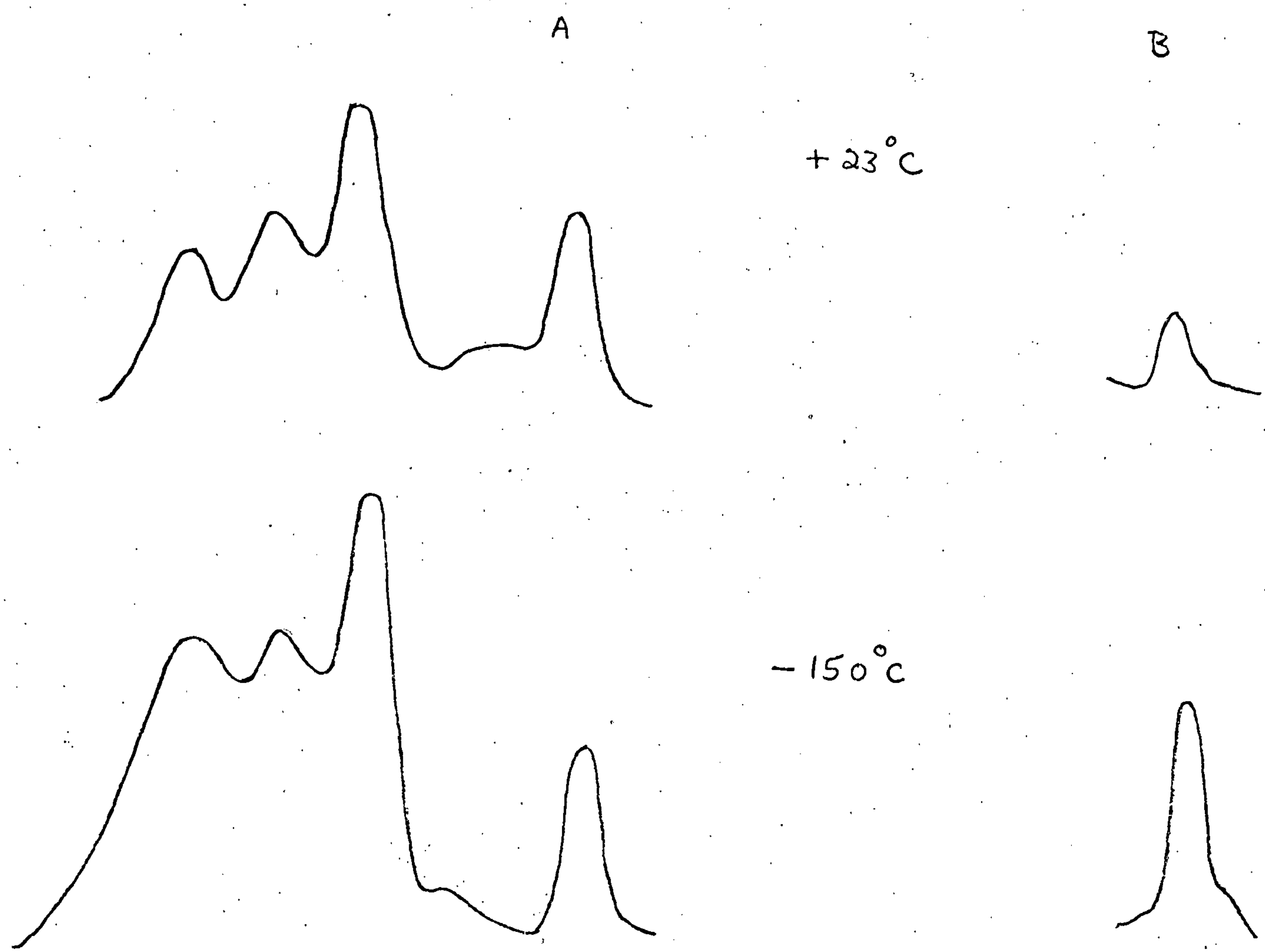

FIGURE 3. FEATURES A AND B OBSERVED AT +23°C AND -150°C.