Spectroscopy of low-volatility compounds supercooled in the boundary layer of a supersonic stream

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The spectrum of monomer molecules of a low-volatility compound supercooled to 40°K in a supersonic stream has been obtained for the first time. An investigation was made of the electronic absorption spectrum of indium monochloride vapor entering into a helium stream through the porous wall of a wedge-shaped evaporation cell.

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Recently published communications report the determination of the spectra of a number of gases as well as the products of dimerization and polymerization of alkali metals, supercooled in a supersonic stream to temperatures on the order of several dozen degrees Kelvin.[1–3] This new method promises to yield interesting results in molecular spectroscopy, and also in gasdynamics, in the study of relaxation processes, etc. However, the spectra of monomeric molecules of low-volatility compounds supercooled in supersonic streams have never been obtained before.

Mal'tsev and the present author have shown[4] that in the investigation of low-volatility compounds a special role is played by the method used to introduce the vapor into the stream. It was proposed to introduce the vapor into the supersonic section of a stream of a cold inert gas, say through a porous surface of an oven (evaporation cell) parallel to the stream. This method is most promising from the point of view of the depth of supercooling, minimal condensation, minimum vapor pressure, and minimum of consumed material. This paper reports preliminary results of an experiment aimed at realizing this supercooling method.

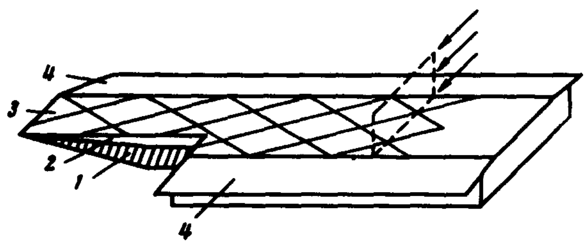


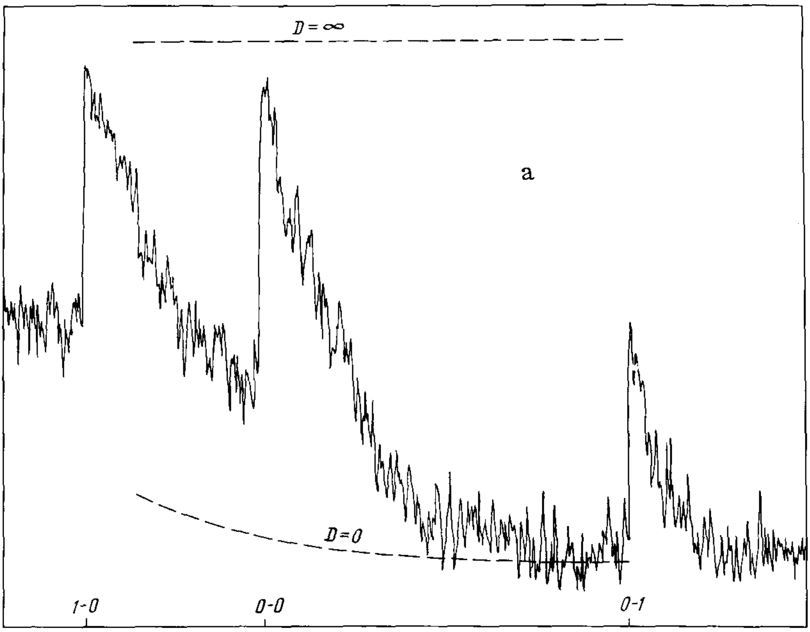
FIG. 1. Wedge-shaped evaporation cell. The nose part is shown in section: 1—housing, 2—cavity for evaporated material, 3—heater (the porous part is cross hatched), 4—"winglets." The dashed lines show the cross section through the boundary layer, projected on the spectrograph slit, and the three arrows indicate the direction of the light.

The experiment was performed in the helium-filled wind tunnel of the N. E. Zhukovskiĭ Central Aerohydrodynamic Institute. The initial helium pressure was 50 atm, and the temperature 300 °K. In the working part of the tube the Mach number was 19.5, the static pressure 0.2 Torr, and the static temperature 2.4 °K. The investigated material was evaporated from a wedge-shaped cell (Fig. 1). The upper plane of the cell was a platinum-foil heater 0.1 mm thick, having 2000 holes of 0.15—0.20 mm diameter on a 50×20 mm area. The investigated material (granulated) is spread under the heater. On the sides of the cell are "winglets" heated to the same temperature. They prevent cold gas from flowing from the zone behind the shock discontinuity under the cell into the zone above the cell. Light from an ISSh-500 flash lamp was focused into the boundary layer of the stream above the heater, and the image of the boundary layer was projected onto the slit of an STÉ-1 spectrograph. This yielded the absorption spectrum, in which sections with different heights corresponded to different sublayers of the boundary layer. The investigated material was indium monochloride (InCl). It has an intense band spectrum in the 266—270 nm region,[5] and is evaporated almost completely in the form of a monomer,[6,7] and is convenient to work with. The tunnel startup time was 0.6 sec. The heater was turned on together with the tunnel starter, and 0.5 sec later the flash lamp was turned on and the heater was simultaneously turned off. By that time the heater temperature could reach 1000 °C, but enough vapor entered the boundary layer even at 500 °C. The experiment is described in detail in[8].

Some experimental conditions were not optimal. Thus, an oblique shock discontinuity was produced over the upper plane of the cell (apparently because the leading edge was not sharp enough), and the static temperature increased behind this shock. In addition, operation conditions called for the use of large-grain photographic material and of a spectrograph slit three times wider than normal, and this affected adversely the spectral and spatial resolutions. The results must therefore be regarded as preliminary.

Figure 2 show microphotographs of the spectrum, obtained at a heater temperature 1100 °K. Microphotographs a, b, and c correspond to three sublayers of the boundary layer: directly in contact with the heater, the middle one, and the outer one. It is seen how the supercooling narrows down the rotational structure and, in particular, eliminates the mutual overlap of the 1—0 and 0—0 bands. In addition, owing to the decrease of the population of the $v''=1$ vibrational level, the integrated intensity of the 0—1 band decreases more rapidly than for the 0—0 and 1—0 bands, and consequently there is time also for vibrational relaxation to take place. An estimate of the temperature, obtained by determining the intensity distribution of the 0—0 band rotational structure, yielded 870, 200, and 40 °K respectively for microphotographs a, b, and c. The temperature was estimated by comparison with a synthetic spectrum,[9] and also (for 520—1230 °K) by comparison with the absorption spectrum of vapor heated in the quartz cell.

The concentration of the InCl molecules in the hot sublayer is 10^{13}—10^{14} cm^{-3}, and is lower by one order of magnitude in the cold sublayer. It is interesting to note that according to the equation for the vapor pressure of InCl,[6] under equilibrium conditions the InCl molecule concentration at 40 °K is $\sim 10^{-110}$ cm^{-3}.



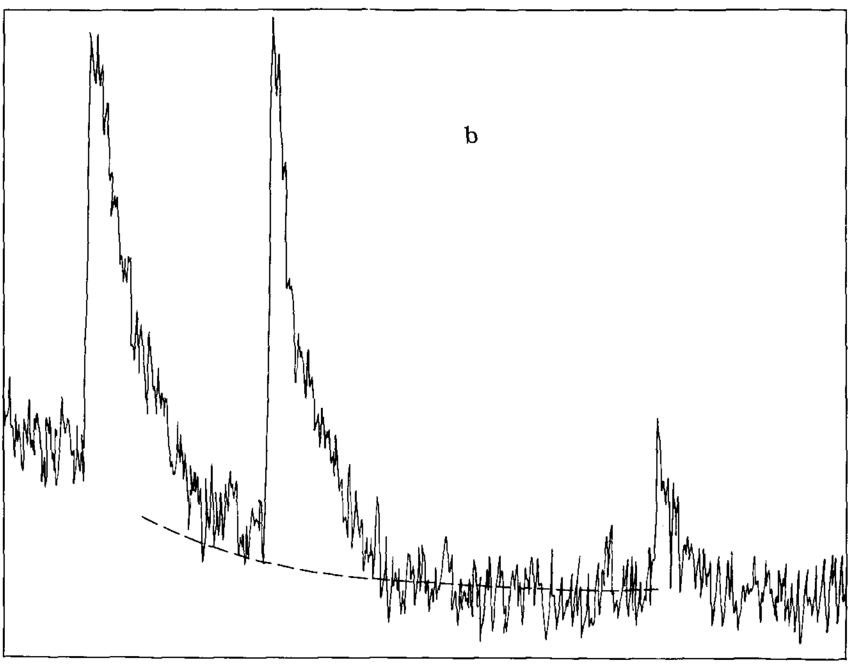


FIG. 2. *(continued)*

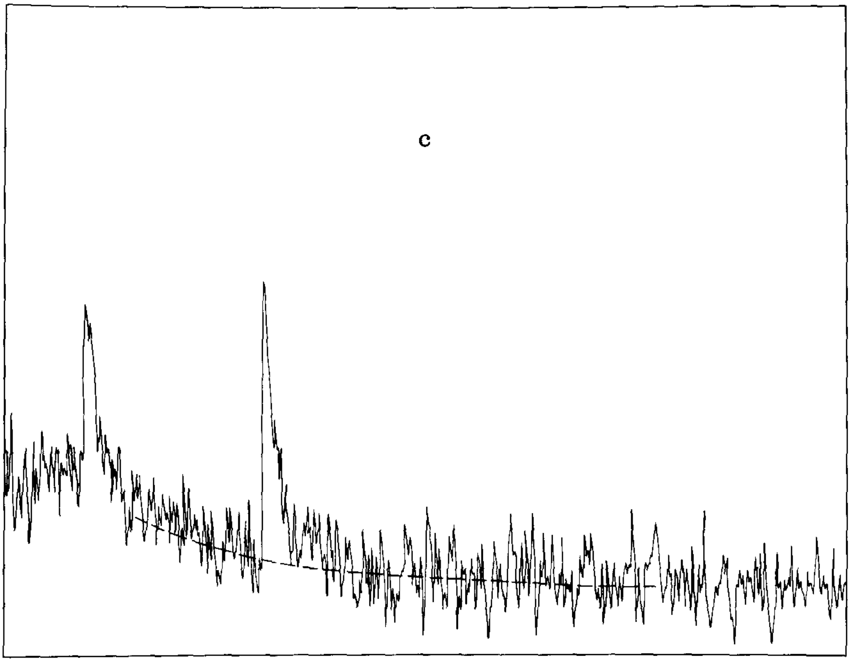


FIG. 2. Microphotographs of three absorption bands of InCl, corresponding to hot (a), medium (b), and cold (c) sublayers of the boundary layer. The dashed curves show the levels with optical densities $D=0$ and $D=\infty$.

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