PHYSICAL REVIEW LETTERS

VOLUME 6 APRIL 15, 1961 NUMBER 8

MEASUREMENT OF THE TEMPERATURE IN THE UPPER ATMOSPHERE TO 150 km IN A ROCKET EXPERIMENT

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(Received March 1, 1961)

The temperature of the upper atmosphere has been measured previously as high as 90 km by observing the speed of sound at high altitude in experiments in which grenades are released from rockets and exploded.[1-3] It may also be inferred from spectrographic observations of the airglow and the aurora to much greater altitudes.[4] We wish to report briefly the results of the temperature measurements between 100 km and 150 km by an experiment which involves the observation of sunlight resonantly scattered from sodium atoms in a cloud ejected from a rocket. The experiment was performed in the evening twilight of March 2, 1960, at Hammaguir (near Colomb-Bechar), Algeria, and employed a Veronique rocket which rose to 188 km and released 280 grams of sodium. The cloud was visible in the light of the scattered D lines and the altitude of various points accurately determined by triangulation. The temperature was measured by a variation on a technique developed for the airglow by Bricard and Kastler.[5] Photographs of selected portions of the cloud of known altitude were obtained repeatedly from a few moments after release of the sodium until the illumination by the sun was extinguished about half an hour later. These consisted of images formed side by side in light which passed through optical systems which were identical except for the presence of an absorption cell in one. This cell contained sodium vapor at a known temperature T_a and opacity τ. Densitometer measurements of corresponding points in the two photographs were made and the ratio of the intensities recorded at these points was obtained. For a single hyperfine component and an optically thin cloud the intensity measured without the absorption cell is proportional to

$$I_0 = \int \exp(-x^2)dx, \tag{1}$$

where

$$x^2 = Mc^2(\nu-\nu_0)^2/\nu_0^2RT, \tag{2}$$

since the line shape is purely Doppler. Here M is the atomic weight of sodium, T the temperature of the sodium cloud and hence of the atmosphere, R the gas constant per mole, and ν_0 the frequency at the center of the component. The intensity, for the same point in the cloud, measured through the cell is proportional to

$$I_a = \int \exp(-x^2)\ \exp[-\tau\ \exp(-ax^2)]dx, \tag{3}$$

where

$$D = T/T_a. \tag{4}$$

The ratio I_0/I_a is thus a function of T alone if T_a and τ are known and fixed. Complications arise because the cloud is not always optically thin, because the measured ratios are for the sum of all hyperfine components,[6] and because the cloud is in the shadow of the earth's own sodium layer during most of the experiment. This last produces a serious distortion of the spectrum but one which can be allowed for. The altitude and abundance of the earth's sodium were measured and the transmission function computed by meth-

Table I. Summary of results.

Altitude, km	Temperature in °K
100	215 ± 25
110	240 ± 30
120	275 ± 45
130	325^{+65}_{-50}
140	400^{+80}_{-70}
150	515^{+150}_{-115}

ods developed for the twilight flash.[7]

The results for the temperature given in Table I are in agreement with the values deduced by Hunten[4] from a consensus of spectroscopic observations on the airglow and the auroras but far below the values used in the ARDC (Air Research and Development Command) model atmosphere.[8]

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SPECIFIC HEAT OF LIQUID He^3 DOWN TO 0.054°K*

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(Received March 29, 1961)

The intriguing question of whether liquid He^3 may undergo a phase transition into a superfluid state has acquired new interest with the recent predictions of several investigators[1-3] that a transition into such a cooperative state should occur at a sufficiently low temperature. These theories based on the BCS model of superconductivity in metals predict a transition temperature as high as 0.08°K, this temperature depending sensitively on the effective mass m^* of the quasi-particles and on the single-particle potential used in the calculations. No evidence for such a phase transition above 0.03°K was found by Anderson, Hart, and Wheatley[4] in measurements of the coefficient of self-diffusion and nuclear susceptibility. However, in view of the lack of any firm theoretical predictions about the coefficient of self-diffusion near the phase transition, the indication that there exist relative angular momentum states favorable to a transition which would yield no change in susceptibility,[5] and because in the analogous case of superconductors a surprisingly small decrease in the electron spin susceptibility in the superconducting state has been found in superconducting Sn and Hg,[6-8] it would seem desirable to have other evidence before ruling out a phase transition in this region.

In going from the normal to the superfluid state a discontinuous increase in the specific heat of about a factor of two is predicted,[2] thus making the measurement of specific heat a particularly sensitive test for such a transition. Earlier specific heat measurements of Brewer, Daunt, and Sreedhar[9] extending down to 0.085°K showed no anomaly. In the measurements reported here the specific heat of liquid He^3 at saturated vapor pressure has been measured down to 0.054°K and a linear dependence on temperature was found below 0.09°K. A phase transition above 0.054°K would seem, therefore, to be excluded.

The He^3 used in this experiment has been purified by pumping back 2/3 of a given amount