Concerning the Carbon Dioxide Content of the Atmosphere of the Planet Venus

Recent work at the Mount Wilson Observatory on the infrared spectrum of Venus[1] disclosed three absorption bands with centers at 11,496.5 cm^{-1}, 12,672.4 cm^{-1}, and 12,774.7 cm^{-1}. From the major interval between neighboring fine-structure lines the moment of inertia of the absorbing molecule was computed to be 70.5×10^{-40} gram cm^2, and the atmospheric constituent responsible for the spectrum was therefore assumed to be carbon dioxide. This claim was fully substantiated by subsequent theoretical work[2] in which it was shown that the carbon dioxide molecule does indeed possess three rotation-vibration bands precisely coincident with the planetary ones both in position and detailed structure. In the latter investigation, the bands were identified in terms of the fundamental frequencies of the molecule as

$$5\nu_3=11{,}496.5+0.769\mathrm{N}-0.0153\mathrm{N}^2$$

$$5\nu_3+\left\{\begin{matrix}\nu_1\\2\nu_2\end{matrix}\right\}=\left\{\begin{matrix}12{,}672.5+0.769\mathrm{N}-0.0153\mathrm{N}^2\\12{,}774.7+0.769\mathrm{N}-0.0156\mathrm{N}^2,\end{matrix}\right.$$

where the two combination bands form a group because of the resonance degeneracy $[\nu_1\cong2\nu_2]$ inherent in the molecule.[3]

It is evidently of considerable importance to ascertain the quantity of carbon dioxide present in the absorbing layers of the Venus atmosphere. The most satisfactory method by which to achieve this end is to determine the quantity of the gas required for the detection of the bands $5\nu_3$ and $5\nu_3+\begin{pmatrix}\nu_1\\2\nu_2\end{pmatrix}$ in the laboratory. Adams and Dunham were unable to detect these bands in the solar spectrum shortly before sunset, at which time it is estimated there exists in the earth's atmosphere a CO_2 path length of at least thirty meter-atmospheres. Nor were the bands found to be present in a spectrum taken with forty meters of CO_2 gas at three atmospheres pressure.[1]

We have recently succeeded in photographing the band $5\nu_3$ by using an absorption cell forty-five meters in length charged with forty-seven atmospheres of gas. The spectra were taken with a glass prism Hilger E–I; and although they show a well-defined envelope structure for $5\nu_3$ at 11,496 cm^{-1}, they evince no trace of the bands $5\nu_3+\begin{pmatrix}\nu_1\\2\nu_2\end{pmatrix}$. This is entirely in accord with the experiments[4] on ν_3 and $\nu_3+\begin{pmatrix}\nu_1\\2\nu_2\end{pmatrix}$ which show that the path length necessary for the detection of $(2n+1)\nu_3$ is of a lower order of magnitude than that required for the observation of $(2n+1)\nu_3+\begin{pmatrix}\nu_1\\2\nu_2\end{pmatrix}$.

The lower limit of an estimate on the CO_2 content of the absorbing strata of Venus is apparently two mile—atmospheres whereas the amount actually present in these layers is very probably several times greater. Accordingly there is more than 10^{15} tons of CO_2 present in the upper strata; and this is, presumably, just a very small fraction of the total CO_2 content of the entire atmosphere.

In the upper strata alone, Venus possesses 10^4 times as much CO_2 as is present in the entire atmosphere of the earth.

ARTHUR ADEL
V. M. SLIPHER

University of Michigan
and Lowell Observatory,
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[1] Adams and Dunham, Pub. A.S.P. **44**, 243 (1932).
[2] Adel and Dennison, Phys. Rev. **43**, 716; **44**, 99 (1933).
[3] Due to the fact that the oxygen nucleus has zero spin, half the fine-structure lines of CO_2 are missing in these bands. The above formulae represent the observed positions of the lines when N takes on the values 1, 3, 5, ... R-branch; and −2, −4, −6, ... P-branch.
[4] Martin and Barker, Phys. Rev. **41**, 291 (1932).

On the Identification of the Methane Bands in the Solar Spectra of the Major Planets

Recent analysis of the absorption spectra of the major planets (Jupiter, Saturn, Uranus and Neptune) has shown that they consist almost wholly of rotation-vibration bands of methane. The classification of thirty-four of these planetary CH_4 bands in terms of the four fundamental frequencies of vibration of the molecule (inactive: $\nu_1=2915$ cm^{-1}, $\nu_2=1520$ cm^{-1}) (active: $\nu_3=3014$ cm^{-1}, $\nu_4=1304$ cm^{-1}) is tabulated in Table I.

TABLE I.

Location ($\mu\mu$)	Identification	Planets in whose spectra the bands have thus far been located *J*	*S*	*U*	*N*
886	$4\nu_3$	*			
725	$5\nu_3$	*	*		
619	$6\nu_3$	*	*	*	*
543	$7\nu_3$	*	*	*	*
486	$8\nu_3$			*	*
441	$9\nu_3$				*
980	$8\nu_4$	*			
874	$9\nu_4$	*			
788	$10\nu_4$	*			
720	$11\nu_4$	*	*		
662	$12\nu_4$			*	*
614	$13\nu_4$			*	*
566	$14\nu_4$			*	*
534	$15\nu_4$				*
502	$16\nu_4$				*
861	$3\nu_3+\nu_1$	*			
702	$4\nu_3+\nu_1$	*	*	*	*
595	$5\nu_3+\nu_1$		*	*	*
521	$6\nu_3+\nu_1$				*
987	$3\nu_3+\nu_2$	*			
782	$4\nu_3+\nu_2$	*	*		
656	$5\nu_3+\nu_2$			*	*
568	$6\nu_3+\nu_2$			*	*
504	$7\nu_3+\nu_2$				*
1009	$3\nu_3+\nu_4$	*			
798	$4\nu_3+\nu_4$	*			
668	$5\nu_3+\nu_4$	*	*	*	*
576	$6\nu_3+\nu_4$	*	*	*	*
509	$7\nu_3+\nu_4$			*	*
(459–560)	$8\nu_3+\nu_4$				*
643	$10\nu_4+\nu_3$			*	*
597	$11\nu_4+\nu_3$			*	*
557	$12\nu_4+\nu_3$			*	*
523	$13\nu_4+\nu_3$				*

The spectra of ethane, ethylene and acetylene have been carefully examined. There appears to be no detectable amount of these low boiling point hydrocarbons in the upper strata of the giant planets.