

accuracy. The fact that the atmospheric absorption in the red is much less than that in the blue is obviously also an advantage. Readings taken over a period of a minute have an average deviation of about one second. Somewhat greater sensitivity could undoubtedly be attained by raising the cell voltage. However, until the need arises, this will not be done since it would involve some risk of spoiling an excellent photo-cell.

The point of maximum sensitivity for equal spectral energy is near 8000 Å. After the light from an A0 (white) star has penetrated the atmosphere, been reflected from a mirror and passed through several glass surfaces, about 55 per cent of the total effective energy is of longer wave-length than 6800 Å. For a K0 (yellow) star this ratio is about 75 per cent. When a filter is used which cuts off the energy at approximately 7800 Å, the total effective energy of a white star is reduced by about 80 per cent while that of a red star is reduced by approximately 64 per cent.

Actual observations have shown that the photoelectric current is at least very nearly proportional to the incident light intensity over a range of magnitudes extending from 3.0 to 6.5. The important point at present is that the same relative magnitudes are found for the same stars on different nights to within a high degree of accuracy.

I am very grateful to Dr. Schilt, then at Yale Observatory, now at Columbia University, for his many helpful suggestions and constant encouragement. The coöperation of the Bell Laboratories in general and of Dr. Prescott in particular made this work possible. The G-M Laboratories, Inc., in Chicago and the Westinghouse Laboratory in Pittsburgh also showed noteworthy spirit of coöperation.

THE ROTATIONAL STRUCTURE OF THE ULTRA-VIOLET ABSORPTION BANDS OF FORMALDEHYDE

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COMMUNICATION NO. 31 FROM THE ALFRED L. LOOMIS LABORATORY IN TUXEDO

Communicated March 28, 1932

We have photographed the ultra-violet absorption bands of formaldehyde in the third order of the 40 ft. spectrograph of the Loomis Laboratory at Tuxedo³ with a dispersion of about 0.4 Å per mm. The bands are practically completely resolved, and the lines are very sharp. Until now we have measured and studied the bands at 3520, 3430 and 3390 Å. Although not all details of the analysis have been completed yet, we think that the results obtained so far are of sufficient interest to justify their publication. Some of the minor details may require modification

afterward. We are confident, however, that the main results are essentially correct.

Victor Henri, who did most of the pioneer work in this field, and Schou⁴ attempted also a rotational analysis of the formaldehyde bands. Our results do not confirm their analysis. This is not surprising, as instruments of much lower resolving power were used by Henri and Schou with which they obtained about 100 lines in every band whereas we were able to measure more than 500 in a single band.

All the bands show quite striking regularities at both ends, which become evident even with a casual inspection. In the center many lines overlap even with our resolution, and accordingly the analysis is much more difficult and uncertain there. It is complicated there, furthermore, by the fact that the lines do not follow any simple formula as they do at the ends of the band. The structure of the bands 3520 and 3390 is identical and can in first approximation be regarded as a \perp band⁵ originating from a symmetrical top molecule. This is due to the fact that the moment of inertia about the CO axis is very small and accordingly the two moments of inertia about the axes perpendicular to the CO axis are almost the same. The only bands of this type known so far are some incompletely resolved infra-red bands.⁶ The main difference between our bands and those infra-red bands (apart from the fact that they are completely resolved in our case) is the fact that the moments of inertia in the upper and lower states are different which causes successive lines in the various branches to be no more equidistant, and is responsible for the occurrence of typical band heads.

In this communication only those properties of the bands which can be understood with this simple symmetrical top model will be discussed. The deviations which manifest themselves according to theory and observations mainly in the center of the bands will be treated in a subsequent paper.

The rotational energy of a symmetrical top is given by

$$\frac{h^2}{8\pi^2 A} J(J + 1) + \frac{h^2}{8\pi^2} \left(\frac{1}{C} - \frac{1}{A} \right) K^2,$$

in which C and A are the moments of inertia about the axis of symmetry and about an axis perpendicular to the axis of symmetry. If we denote, as in diatomic molecules, transitions (in *emission*) in which the total angular momentum J changes by -1 , 0 , 1 as P -, Q - and R -branches and denote transitions of the component K of the angular momentum about the axis of symmetry by an analogous small letter in front of the P , Q , R we must expect the following branches for a transition in which the electric moment is perpendicular to the axis of symmetry

pP and rR	both strong; they are the only branches for high values of K
pQ and rQ	strong for small values of K
pR and rP	weak and only present for small values of K .

All these branches have been found. They show the following characteristics which fix their nature and allow an unambiguous assignment of quantum numbers.

1. At the violet end of the bands there is a very easily recognizable sequence of about seven R -branches, each of which contains about 15 lines. The spacing of equivalent lines is very nearly the same in all branches and they follow with great precision a Deslandres formula, both the lines in one branch and equivalent lines in the different branches.

2. If all these R -branches are compared with the one lying most to the red, it is seen that in the second one the first line is missing, in the third the first and second lines, etc., until the seventh where the first six lines are missing. This shows that the successive R -branches must be rR branches, i.e., due to successive $K + 1 \rightarrow K$ transitions. As always $J \geq K$ there must be one more line at the beginning missing for every higher value of K in accordance with what is found.

3. In the red end of the band a few branches can also easily be recognized and shown to be P -branches.

4. If the pP branches belonging to the rR branches mentioned in (1) and (2) are calculated they coincide almost exactly with the empirical P branches mentioned in (3). The number of missing lines increases also here by one if K is increased by one.

5. The correctness of this conclusion is proved by the combination relations which are satisfied within the limits of the errors of measurement. These combination relations allow the separation of the rotational differences of the initial and final electronic state and permit an unambiguous assignment of quantum numbers both for J and K .

6. The value of the moments of inertia calculated from the bands 3520 and 3390 which arise from the transitions from two successive vibrational states ($v = 0$ and $v = 1$) of the upper electronic level to the normal state of the molecule are

	A·10 ⁴⁰	B·10 ⁴⁰	C·10 ⁴⁰
Normal state	24.58	21.63	2.951
Upper state $v = 0$	27.98	24.81	3.176
$v = 1$	28.13	24.94	3.190

These values probably will undergo slight modifications, when the influence of the assymetry of the molecule on the structure of the bands is more rigorously taken into account.

From these values it follows that in the normal state of the formaldehyde molecule the distance between the two hydrogen nuclei is 1.88 Å. If it is assumed that the CH distance is the same as in other molecules, e.g., CH namely, 1.1 Å, the angle between the two CH bonds becomes about 120° and the CO distance 1.21 Å. This value is slightly larger than in the normal CO molecule where it is 1.15 Å. If the angle between the two CH bands is assumed to be the tetrahedron angle (110°) the CH distance is 1.15 Å and the CO distance 1.19 Å. If these values are confirmed by the more rigorous calculations, it would mean that the bonds in formaldehyde are slightly weakened.

7. It appears that the intensity of successive rR -branches is alternately

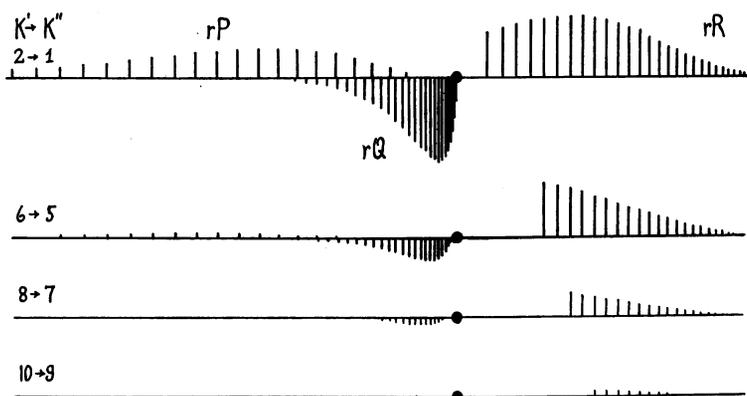


FIGURE 1

Intensities in the absorption bands of formaldehyde at room temperature. The spacing of the lines is chosen arbitrarily so as to bring out the intensity relations most clearly. In the *ultra-violet* absorption bands the lines converge much more strongly, so that the head of the R -branches is reached for low values of J . In the *infra-red* absorption bands the lines converge very little, so that all the lines of the Q -branches practically fall on top of each other. The dots denote the origins of the individual sub-bands.

strong and weak, and that the transitions from an even K of the excited electronic state to an odd K of the lower state are the strong ones. Such behavior must be expected, if the rotation occurs about the CO axis of the CH_2O molecule. Then only the two hydrogen atoms contribute to the moment of inertia and the same kind of intensity alternations must occur as in the hydrogen molecule. The observed intensities are consistent with the expected ratio 3:1.

Successive pP (and also rQ , etc.) branches show the same behavior.

8. In looking for the rQ , pQ , rP and pR branches it is necessary to take into account the intensities of these branches. If the moments of inertia are known, the intensities of all the lines in a band can be cal-

culated. We did this with the values given above and found an excellent agreement with the observed intensities. In figure 1 intensities of the P , Q and R -branches are given for several $K + 1 \rightarrow K$ transitions. For small values of K the intensity relations are the same as in bands of diatomic molecules (e.g., the $2 \rightarrow 1$ sub-band has the same intensities as a $\Delta \rightarrow \Pi$ band of a diatomic molecule). With increasing K the rP -branches become so weak that they are beyond the possibility of observation. The rQ branches also disappear for high values of K and then only the rR -branches are left. For the $K - 1 \rightarrow K$ transitions analogous relations hold.

These theoretically expected intensity relations are exactly those observed in the bands. In addition to this, as mentioned under 7, all lines coming from a level with an odd value of K are about three times as weak as compared with those coming from a level with an even K .

9. The moments of inertia of the initial state increase with increasing vibrational quantum number. That is also the case for diatomic molecules. This fact is important for the identification of the nuclear vibration. But we prefer postponing the discussion of this point for a subsequent paper. On photographs taken with a quartz spectrograph and long absorption tubes with formaldehyde under relatively high pressure, we found a number of new bands not noticed by previous observers. These seem rather essential for a discussion of the vibrational structure of the band system. But as the nature of the bands can be recognized with much more certainty, if the rotational structure is known, and as we hope to be able to analyze their fine structure this summer, we leave the matter until then.

10. The band at 3430 \AA shows in principal the same structure as the two other bands. The moments of inertia for the excited state are $A = 28.16$, $B = 24.99$, $C = 3.173 \cdot 10^{-40}$. The band is a little weaker than the other two and accordingly not so well developed. Also there seem to be quite distinct deviations from the simple quadratic formula which make especially the value of C less accurate than for the other two bands. Nevertheless, we can say that the values for A and B are about the same as those for the initial state of $\lambda 3520$ ($v = 0$), whereas the value for C is very nearly the same as that for the initial state of $\lambda 3390$ ($v = 1$). In the upper state of $\lambda 3420$ another vibration is excited, and it deforms the molecule in a way different from that of the vibration responsible for the initial state of the band at 3390 .

11. Henri and Schou gave a partial vibrational analysis of the band system which was corrected by Herzberg.⁷ According to Herzberg the lower state of the α band at 3700 is not the normal state of the molecule but has one vibrational quantum. We can confirm this by observations with the gas at 300°C . The α band is very much strengthened then

with respect to the other bands which shows that its lower state must lie somewhat above the ground level of the molecule.

In conclusion we wish to express our thanks to Mr. Alfred L. Loomis for his hospitality and the opportunity to use the facilities of his laboratory. We are also grateful to Mrs. Hilde Kistiakowsky for her help with the wave-length calculations.

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⁵ For nomenclature, etc., see, e.g., D. M. Dennison, *Rev. Modern Phys.*, **3**, 280 (1931).

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THE CILIATION OF THE OVIDUCTS OF REPTILES

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Communicated March 30, 1932

An examination of the oviducts of several species of reptiles has been made to determine the way in which these organs act in the transportation of sperms and eggs. In particular the cilia in these tubes have been studied. Parker (1928 a, b; 1930) found in the painted turtle, *Chrysemys picta* (Schneider), and in the pigeon, *Columba livia* Gmel., that though the cilia on the greater part of the wall of the oviduct beat toward the cloaca, some beat in the opposite direction. In these animals there is a band of pro-ovarian cilia which extends from the isthmus through the albumen-secreting portion of the duct to the infundibulum. The probable function of these cilia is to carry sperms up the duct to the point where fertilization takes place. I have tried to determine whether a similar condition occurs in other reptiles.

At the outset I examined the oviducts of *Chrysemys picta* and of the larger terrapin, *Pseudemys elegans* (Wied). In both of these species the pro-ovarian tract can be found with ease. Hence I can confirm Parker's statement for the condition in *Chrysemys* and add *Pseudemys* to the list of animals showing a pro-ovarian tract.

In the "horned toad," *Phrynosoma cornutum* (Harlan) the length of the albumen-secreting part of the duct is only about two centimeters, or less