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A Summary of the Symposium on Interstellar Lines at the Yerkes Observatory, on June 30, 1941

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In many fields of modern science it is useful to bring together from time to time specialists who are interested in a definite problem and who are able to discuss it from different angles. This is evidenced by the remarkable results of some recent astrophysical conferences in which practical and theoretical astronomers met with a number of physicists. A striking example is the one-day conference on interstellar lines which took place at the Yerkes Observatory on June 30, 1941, at the suggestion of Dr. O. Struve. Besides the Yerkes Observatory group, about twenty physicists actively took part in the symposium, especially Dr. R. S. Mulliken (Chicago), Dr. E. Teller (Washington), Dr. G. Herzberg (Saskatchewan), Dr. H. Beutler (Chicago), and Dr. C. A. Rieke (Chicago). The present report is a summary of the discussions and of the remarkably quick and important results which followed.

I. Dr. O. Struve opened the symposium by giving a general account of the present status of the problem of interstellar atomic lines. The evidence for the existence of interstellar gaseous matter results from the observation of sharp stationary absorption lines in the spectra of stars with variable radial velocities. This interpretation is supported by the fact that their intensities generally increase with the distance of the star and by the discovery of emission lines of *H* and [*O*II] in vast areas of the Milky Way. The first two columns of Table 1 contain the atomic lines heretofore observed and identified. In the third column are tabulated some ultimate lines which may be observed in the future.

TABLE 1

Absorption lines	Emission lines	Not yet found, but likely
NaI D_1 5896 D_1' 3303 D_2 5890 D_2' 3302	H_α, H_β, H_γ;	AlI 3944.01;
KI 7698.98	[*O*II] 3727;	ScII 3642.80;
CaI 4226.73	[*O*III] N_1, N_2;	SrII 4077.73, 4215.54;
CaII H and K	[NII] 6548; 6584.	BaII 4554.04, 4934.09.
TiII 3242; 3384; 3229; 3073.		
FeI 3719.95 ?		

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Once the existence of the interstellar matter has been established and the elements identified, many interesting questions arise as to the density of this matter, the relative abundances of the elements, and the physical conditions which prevail in interstellar space. It is clear that the answers to these questions are not independent. One of the determining factors as to the physical conditions is the radiation of the stars. But before reaching a given point P in the interstellar space it is obvious that the stellar radiation undergoes an absorption which depends upon the density of the interstellar matter, its composition and the type of aggregates which it forms. As usual in physical science, this problem has been solved by successive approximations. For stars radiating like black bodies, the most complete study of this problem has been carried out by Dunham. It consists in evaluating, by extrapolation of the conditions observed from the earth and by taking into account the general interstellar absorption, the number of quanta of frequency ν present in a cubic centimeter at the point P considered. For many problems, such as those of ionization and dissociation, it is then convenient to resolve this actual distribution of radiative energy into a certain number of black-body curves of different temperature T_n, which are affected by factors of dilution δ_n. In interstellar space, because of the very low density (dynamical considerations yield an upper limit of the order of 3.10^{-24} gr./cm^3) the main process of transformation of radiative energy into kinetic energy is provided by the ionization of the atoms. Electrons liberated by black-body radiation of temperature T_n will have a temperature αT_n where α is somewhere between $\frac{1}{3}$ and $\frac{2}{3}$. If they are liberated simultaneously by radiations of different temperatures T_n, they will level off their mean kinetic energies by collisions and take a mean temperature T^o in which the higher αT_n will be favored. An accurate evaluation of T^o is not so important because the determining factor in the problems which we shall have to consider is always the radiative temperature. The first of these problems is that of the ionization in interstellar space. In presence of black-body radiation of temperature T_n diluted by a factor δ_n a number of theoretical investigations have shown that the numbers of atoms M_r and M_{r+1} in the r^{th} and $(r+1)^{th}$ states of ionization of statistical weights u_r and u_{r+1} are related by the equation

$$\log\,(M_{r+1}/M_r)_n = -5040X_r/T_n + 3/2\log T_n + \log\,(2u_{r+1}/u_r) - \log N_e + 1/2\log\,(T^o/T_n) + \log\delta_n + 15.38, \quad (1)$$

where X_r is the ionization potential of the atom in the r^{th} state and N_e is the electronic density. For a composite radiation, such as that considered previously, we have

$$(M_{r+1}/M_r) = \sum_n (M_{r+1}/M_r)_n \quad (2)$$

However, in establishing these formulae two aspects of the problem have been neglected. First of all, the ionization always takes place from the ground state of the atoms while the recombination can happen to any

of the excited states. If a_g and a_t represent the recombination coefficients toward the ground state and toward the totality of the states (normal and excited) we have to multiply M_{r+1}/M_r by a_g/a_t (Bates, Massey). On the other hand, when traveling through space, the radiation not only undergoes a general absorption and dilution but a part of it is used to maintain the equilibrium of ionization all along its path. For a very abundant element this can lead to important and interesting effects which have been worked out in detail by B. Strömgren.

To derive the abundance of an element from the observed intensity of one of its absorption lines, we must know the oscillator strength f of the line, the curve of growth for interstellar space (or a region of it) and the electron density, so that by equation (1) we could compute the fraction of atoms in the state considered. In the early investigations of this problem, one had simply supposed that the intensity of the line was proportional to $M_x f$ if M_x is the number of atoms in the state considered, and one had adopted a very low value of the electron density $N_e \sim 10^{-3}/cm^3$. This led to an abundance of *Na* in interstellar space equal to some 300 times the corresponding abundance of *Ca,* while on the earth and in the stellar atmospheres they are of the same order. Eddington questioned the first of these assumptions and applied considerations previously developed by Struve, Elvey, and Unsöld in order to show that the differential galactic rotation could remove this difficulty by bringing the points representative of the lines of *Ca*II and *Na*I on the flattest part of the curve of growth. But if this theory were correct, important effects of distance and longitude would appear which have never been observed. Furthermore, an investigation by O. C. Wilson and P. W. Merrill has shown that there are many nearby stars for which the ratio of the intensities of the lines of the doublet D of *Na* is approximately equal to 2 and, since $f_2/f_1 = 2$, this proves that, at least for these stars, the intensities of the lines vary as $(M \cdot f)$. On the other hand, recent observations by Dunham of lines of *Ca*I, *Ti*II, and *K*I have shown that the degree of ionization in interstellar space must be much lower than previously assumed. All this suggested that the value of N_e adopted was too low. To settle this point, good observational curves of growth and observations of the intensities of lines of the same atom in two different states of ionization were needed. The curves of growth can be derived from the observations of the ratio of the intensities of the components of the D lines of *Na* in stars at different distances (Wilson and Merrill) or of the observations of the intensities of the D and D′ lines of *Na* in the same star (Dunham).

Using the intensities of the lines of *Ca*I and *Ca*II given by Dunham and the curve of growth of Wilson and Merrill, O. Struve by application of equation (1) found $N_e = 30$ el./cm³. Using his own curve of growth, Dunham found $N_e = 14.4$ el./cm³ if one neglects the general absorption, and $N_e = 7.3$ el./cm³ if one takes it into account. If one considers these values of N_e as reliable it is now very easy to determine

the abundances of the different atoms of which we observe lines. The results of this determination are shown in Table 2. One can see, in particular, that the ratio *Na/Ca* is now reduced to 10, instead of 300. If one takes into account the Bates-Massey correction for *Ca*, one obtains $N_e = 2.7$ el./cm³. But this would not increase the ratio *Na/Ca* since according to Strömgren the Bates-Massey correction would still be greater for *Na* than for *Ca*. To account for the large electron density obtained in this way, it was natural to think of hydrogen and one can see from Table 2 that an abundance of *H* in good agreement with other astrophysical evidence is required for this purpose.

TABLE 2

	Log. N/cm³			
Element	O. Struve	Dunham	Sun	Nebulae
Electrons	0.2	1		
Hydrogen	0.2	1	0	0
Oxygen	—3		—1.5	—2
Sodium	—6	—4	—3.3	—4
Potassium		—5	—3.7	—5
Calcium	—7	—5	—3.8	—4
Titanium		—7	—5.3	—4
CH		—6		
CN		—6		

Because of the great relative abundance of *H*, the correction of Strömgren, referred to previously, will be important. To take it into account we have to multiply the values of M_{H^+}/M_H by a factor τ_ν where

$$\tau_\nu = \int_0^s \sigma_\nu M_H \, ds$$

where σ_ν is the coefficient of absorption per atom, of radiation of frequency greater than the limit ν_L of the Lyman series, and s is the distance traveled by the radiation from the hot star or group of hot stars considered to the point P where we study the ionization of *H*. Because of this exponential factor, the regions where *H* is ionized will be rather sharply limited, the outside regions containing no quanta of ν greater than ν_L. In the H^+ regions the Balmer lines will appear in emission.

The identification of these regions with the bright regions with emissions lines of *H* and [*O*II] discovered by Struve and Elvey is well supported by the facts that these regions are particularly rich in hot *O*-stars and that their radius is of the same order as computed from the theory of Strömgren. Furthermore, from the observed intensities of the emission lines of *H*, it is possible to compute M_H, and Strömgren found $M_H = 3$/cm³, which is in very good agreement with the values of N_e and M_H derived previously from *Ca*I/*Ca*II, when one takes the Bates-Massey correction into account.

Struve showed that the presence of the emission lines of [*O*II] in the same regions and of [*O*III] in their central parts also agrees with Strömgren's theory. Struve also explained why one does not observe

emission lines of *Na*I and *Ca*II, or absorption lines of *H*. The abundance of *O* given in Table 2 has been derived from the intensity of the emission line λ 3727 of [*O*II].

Moreover, as a result of Strömgren's theory, N_e outside the regions where *H* is ionized will be very low—in fact of the order of 10^{-3}/cm³ which had been adopted previously. Since this is incompatible with the intensities of the observed absorption lines, we must conclude that these lines originate mainly in the regions of H^+.

Finally, certain observations of interstellar lines indicate that interstellar space is far from being homogeneous from the point of view of the repartition of matter as well as from the point of view of the distribution of the physical conditions, and one of the most urgent tasks is the study of this heterogeneity. We can also remark that we have always supposed that the stars radiate like black bodies and that the more direct determination of N_e rests on the ratio of the intensities of the lines of *Ca*I and *Ca*II, the first being very weak and difficult to measure.

II. Dr. P. Swings then discussed the lines of molecular origin. We have already been accustomed by the observed atomic lines to consider that the excitation in interstellar space is very low; for instance, we observe only lines originating from the ground level $^4F_{3/2}$ of Ti^+, although the excitation potential of $^4F_{5/2}$ is only of the order of 0.012 volt. This explains why the only features definitely attributed to molecules are sharp lines, although the first reference to interstellar molecules was made by Russell in 1935 in trying to identify several rather diffuse lines discovered by Merrill.

Swings and Rosenfeld in 1937 tentatively identified λ 4300.3 as being due to *CH* ($A^2\Delta \leftarrow X^2\Pi$). This was strongly confirmed in June, 1940, when Adams found in the spectrum of ζ Ophiuchi, λλ3886.32, 3878.7, and 3890.15 [transitions (0.0) in the electronic system $^2\Sigma \leftarrow {}^2\Pi$ of *CH*, starting from the lowest rotational level]. Other sharp molecular lines have been identified, namely R(0) and R(1) in the transition (0.0) of

TABLE 3

Characteristics	λ	ν (cm⁻¹)	Δν	Remarks
Sharp lines	4232.58	23619.6		
			1640.3	
	3957.72	25259.9		According to Adams these three lines are connected.
			1432.5	
	3745.33	26692.4		McKellar suggested that this is R(0) of (9,0) in $^1\Sigma \leftarrow {}^1\Sigma$, NaH.
	3579.04	27932.5		
	3934.3	25410.3		
Broad lines (width ~ 3A)	5780.55			
	5797.13			Band of solid *O* at λ 5796
	6202.99			
	6269.99			
	6283.91			
	6613.9			
Very broad line (width ~ 40A)	4427	22582		

CN ($^2\Sigma \leftarrow {}^2\Sigma$) at λλ 3874.61 and 3874.02 (the difference in rotational energy is only of the order of 0.00042 volt). One can also expect to find λ3357.8 of *NH* and λ3078.4 of *OH*. The interstellar lines which are still unidentified are given in Table 3.

We may be certain that the sharp features are not atomic lines. On the other hand, none of the neutral diatomic molecules now known has absorption lines starting from the lowest rotational level which agree with them. However, a molecular origin is certain and it seems that the study of ionized diatomic molecules such as CH^+, NH^+, NO^+, CN^+, C_2^+ would be particularly interesting. The polyatomic molecules also supply a wide field of nearly unexplored possibilities. In any case, we can try to find whether any clue as to the identification of the lines of Table 3 can be derived from the lines themselves. If, as Adams has suggested, the first three sharp lines of Table 3 are connected and if we classify them as the first lines of a progression in v′, we easily derive the values of the parameters in the expression of the vibrational energy referred to the ground state as zero

$$E_{v'} = av' - bv'^2$$

Then, from $dE_{v'}/dv'$, we get some idea of the limiting v′ and finally of the heat of dissociation D′ of the molecule in its upper electronic state (D′ ~ 1 volt). Consequently we can be certain that the potential energy curve of the upper state is shallow.

The broad lines could be considered as having a molecular origin if the molecules have very shallow potential curves, or if they were released by dissociation of more complicated molecules or solid particles, the products of this dissociation keeping some rotational energy and the transitions toward lower levels being strongly forbidden. One could also consider the case where the transitions between two rotational levels are so weak that the processes of populating of the upper level exceed the processes of emission. There is also the possibility of attributing them to solid particles. In this respect, the strong correlation existing between the intensities of these broad lines and the color excess, generally connected with the existence of small solid particles, is a favorable argument. Only molecular crystals or amorphous metals could exhibit such narrow bands since in ionic or metallic crystals the strong interactions between the neighboring particles will, even at the very low temperatures of interstellar space, give rise to much broader features. We could expect interstellar crystals of light elements, such as solid oxygen, ice, CO_2, etc., and one may notice that solid oxygen has an absorption band at λ 5795.7 (V. Henri) and that one of the broad features of Merrill is at λ 5796.9. But, unfortunately, the knowledge of the optical properties of these states of matter is very limited and until considerable progress in this field has been made, no conclusion can be reached.

Now we can review very rapidly the difficulties and questions which

arise from the existence of interstellar diatomic molecules. First of all, the two components of the expected molecule must approach each other to a distance of the order of say 10^{-8} cm. For *C* and *H*, if we take a kinetic temperature of the order of 10,000 degrees, there will be such a collision, per cm^3, every 10^5 years. But in order that a molecule be effectively formed, the excess kinetic energy of the colliding particles must be removed from them during the small time τ of their collision. Generally, this is realized by means of a third particle. But it is easy to see that because of the very low density of interstellar matter such three-body encounters will be extremly rare. For *CH*, supposing that the third particle is an *H* atom, one finds that in a cubic centimeter such an encounter will take place every 10^{24} years, which is incompatible with the cosmic time scale.

The excess kinetic energy could be carried away by an electron, the molecule being formed in an ionized state, but, the difference between the potential of ionization and the heat of dissociation being generally large, this means that only those collisions where the particles have large kinetic energies could be useful. Furthermore, even when the energy requirements are fulfilled the probability of this process is still small and probably we can also disregard it. Finally, the excess energy can be emitted in the form of radiation. If the two atoms approach each other their energy varying along the potential curve of an excited state of the molecule, in general, one at least of the atoms is in an excited state and since we have seen that the excitation is extremely low in interstellar space we can be sure that this case will not be very frequent. In general, if the two atoms are in their ground states their energy during the collision will follow the potential curve of the ground state of the molecule. The excess energy can be emitted in the form of a vibrational quantum. Although the probability of pure vibrational transition is small, this last process will probably be in general the most efficient. However, for certain molecules like *CH*, which possess an excited state dissociating in normal atoms, the probability of an electronic transition being larger than the probability of a pure vibrational transition, the case where the energy of the two approaching atoms follows the potential curve of this excited state, will be more effective. According to the first process, homonuclear molecules will be practically nonexisting (only quadrupolar transitions) and this has perhaps a physical meaning since we have never been able to find C_2 in interstellar space. Once the process of dissociation and formation are known one can obtain the dissociation formula by equating the total number of molecules formed per second and cubic centimeter to the total number dissociated. Unfortunately, there is no good quantum mechanical computation of the coefficient of continuous absorption from the ground state and from the whole set of possible excited states for molecules (this would enable us to apply the Bates-Massey correction) so that an exact derivation of this formula is not now possible.

If one uses the ordinary dissociation formula relative to thermodynamical equilibrium multiplied by the factor of dilution δ and $\sqrt{T/T^o}$ (Swings-Rosenfeld) one finds, for instance for *CH*, using the abundances of *C* and *H* given by Struve,

$$N_{CH} \sim 10^{-10}/cm^3$$

while Dunham has derived from his observations

$$N_{CH} \sim 2.1 \cdot 10^{-6}/cm^3.$$

For *CN* (N_{CN} observed $\sim 10^{-6}/cm^3$) the discrepancy is still more marked. Of course, the observed values of *CH* and *CN* depend upon the adopted values of the oscillator strengths for these molecules. Dunham derived them from laboratory experiments and the values found: $f_{CH} = 0.060$, $f_{CN} = 0.075$, depend very much upon the heat of dissociation adopted for *CH* and *CN* ($D_{CH} = 3.47$ volts, $D_{CN} = 7.1$ volts) and upon the difficult evaluation of the carbon pressure in the graphite tube used. Thus, the observed abundance of *CH* and *CN* cannot be considered as definitive. However, there is no doubt that agreement between computed and observed values of *CH* and *CN* cannot be reached by modifications of the observed values only and it would be very interesting to have a good derivation of the exact theoretical formula under interstellar conditions which certainly differ very much from those of thermodynamical equilibrium. Finally, we must consider the consequences of Strömgren's theory. Since in general the heats of dissociation are small compared to the ionization potential of *H*, the division of interstellar space in regions of *H* and regions of H^+ will not affect the dissociation equilibrium of the molecules. But it can affect their ionization. This last problem of the repartition of the ionized molecules in interstellar space is complicated by the fact that we must consider also the direct formation of ionized molecules from one neutral and one ionized atom.

III. In the following discussion, Dr. Herzberg drew attention to the fact that the value of D_{CN} equal to 7.1 volts adopted by Dunham is probably too large and that he would rather suggest a D_{CN} of the order of 5.9 volts. This will increase f_{CN} and consequently decrease the observed abundance of *CN*. The opinion of Dr. Teller was that in this way, one could at best reduce the abundance of *CN* to something like $\frac{1}{5}$ of the abundance of *CH* and that more probably for some reason (perhaps predissociation) *CH* is very easily dissociated; this could explain why it is not much more abundant than *CN*. Dr. Teller also made some remarks on the populations of the rotational levels. One always supposes—and the identifications support it—that the rotation is very little excited in interstellar space. But for *CH* the population (or the mean life-time which, in first approximation, can be considered proportional to ν^{-3}, ν being the frequency of the emission line originating from the level considered) on a rotational level must be 10^9 times greater than on an electronic level ($\nu_{el}/\nu_{rot} \sim 1000$). For N_2, for instance, it would

be still greater—of the order of 10^{12} times—and furthermore N_2 being a homonuclear molecule we should still have to multiply this number by the ratio of the probability of the emission of dipolar radiation to that of the emission of quadrupolar radiation, which will bring the life-time on a rotational level of N_2 to a value equal to 10^{26} times the life-time on one of its electronic levels. If we adopt for the latter, 10^{-8} sec., this would give a life-time on a rotational level of the order of 10^{10} or 10^{11} years. This is of the same order as the cosmic time scale and consequently for homonuclear molecules other rotational levels than the lowest could be represented in interstellar space and such molecules could perhaps give rise to the broad lines observed.

Dr. Beutler thought also that this possibility should be studied carefully and the more so since one of the other possibilities advocated (amorphous metals) does not seem to him well founded and that, in any case, the laboratory work in this field is very far from being satisfactory. Dr. Teller and Dr. Beutler then discussed the possibility indicated by Dr. Swings that the molecules are formed in interstellar space on the ground level of the molecules with emission of the excess kinetic energy in the form of a quantum. If one considers for instance CH, one can take for the cross-section of C, $\sigma = 10^{-15}$ cm^2 and, since the duration of the collision is of the order of 10^{-13} seconds and since, in the mean, a time of the order of 10^{-7} second elapses before a quantum of vibration can be emitted, the probability of this process taking place during the collision is of the order of 10^{-6}. Consequently, the effective cross-section of C for the capture of an atom of H can be taken equal to $\sigma^* = 10^{-21}$ cm^2. If the kinetic temperature is taken to be equal to 10,000°, the mean velocity of an atom of C will be of the order of 5×10^5 cm/sec., and consequently, using the value of σ^* derived above, such an atom will undergo a successful collision with an H atom every 2×10^7 years. This time is still a small fraction of the cosmic time scale and this process can be efficient in interstellar space.

Dr. R. S. Mulliken then read a communication on polyatomic molecules. Following Adams the lines λλ 3745.33, 3957.72, 4232.58 seem to be related to each other, λ 4232 being the strongest. Their attribution to CH_2 is not excluded if one identifies λ 4232 as being due to the transition (without vibration) $^1A_1 - {}^1B_1$ predicted for this molecule. In that case λ 3958 and λ 3745 would correspond to transitions toward states with one quantum of vibration ν_2 and ν_1, respectively, the frequencies of these modes being 1640.3 and 3072.8 cm^{-1}. The latter is close to that for symmetrical CH_2 vibration in compound molecules (*e.g.* C_2H_4) and although the relative values of these frequencies look a little strange (usually ν_2/ν_1 is somewhat below rather than above ½) they are not impossible. For CH_2 one and only one transition is predicted in the visible and ultraviolet as is easily verified from the electronic configurations of the normal and the two lowest singlet and triplet excited states

N: $1s^2\ (a_1)^2\ (b_2)^2\ (a_1)^2$, $^1A_1$
A: $1s^2\ (a_1)^2\ (b_2)^2\ (a_1)\ (b_1)$, $^3B_1$, $^1B_1$
B: $1s^2\ (a_1)^2\ (b_2)\ (a_1)^2\ (b_1)$, $^3A_2$, $^1A_2$

From the forms of the orbitals (wave-functions) called b_1 and (the second) a_1, it is expected that the transition to the $^1B_1$ should have a fairly large f value. Transitions to the other states should be weaker by large factors (transition to the $^1A_2$ is forbidden by the electronic selection rules, but in polyatomic molecules weak transitions are still possible in such cases). From valence theory, it is certain that the molecule CH_2 should be triangular with apex-angle in the range 100° — 120°. It is then certain that the (second) orbital a_1 should be the most easily excited and an excitation energy from a_1 to b_1 of 3 volts (agreeting with λ 4232) is entirely reasonable. On the other hand, the changes in electronic structure by the electronic transition from $^1A_1$ to $^1B_1$ may be expected to produce a moderate weakening of the bond strengths and lengthening of the bonds, and more or less change in the angular equilibrium. This is in harmony with the observation of the strong λ 4232 and the weaker λλ 3745 and 3958. Additional weaker lines at shorter wave-lengths are also possible.

The observation of a single absorption line for each vibrational transition is exactly what is required for such a molecule as CH_2 in its lowest rotational state and the lowest excited rotational level should be about one third as high as in the case of CH and so should hardly give appreciable absorption in interstellar space.

The allowed electronic transition from

$$(s)^2\ (\pi)^4\ [\sigma],\ ^2A_1 \text{ to } (s)^2\ (\pi)^3\ [\sigma]^2\ ^2E$$

in CH_3, which probably has a moderate f value, should give a line in the visible or near ultraviolet. But actually the excited state ^2E must split into two non-degenerate states of a less symmetrical molecule (C_s symmetry) and this would give in cold absorption two lines of nearly equal intensity some distance apart (the additional doubling due to the spin will be negligibly small). One or more additional pairs due to excitation of vibration may also be found.

Finally, some other molecules which could have lines in the observable spectral region are

$$NH_2, OH_2^+, NH_2^+, NH_3^+, NH^+, CH^+, CN^+, C_2^+, OH^+, \text{etc.}$$

(NO^+ would absorb only in the vacuum ultraviolet.) Of all these, only an OH^+ spectrum has as yet been observed. For all the orders, predictions (similar to the above) can be made. Of course, if polyatomic molecules are definitely ruled out by the dissociation formula in interstellar space, then most of these molecules lose their interest and especially CH_2 and the considerations of it developed above.

After Dr. Mulliken's communication, Dr. Herzberg, Dr. Beutler, and Dr. Swings once more discussed the possibility of attributing the three lines of Adams to a diatomic molecule which, as Dr. Swings

pointed out, must then have an excited state with a very shallow potential curve. As a result of their discussion, considerable interest attaches to CH^+ which on account of its electronic similarity with BH, should satisfy this condition.

Dr. C. A. Rieke then presented an account of the theoretical computations of the oscillator strengths which she has obtained for the transitions

$$^2\Delta \leftarrow {}^2\Pi \text{ of } CH$$
$$^3\Pi \leftarrow {}^3\Sigma \text{ of } NH$$
$$\text{and } ^2\Sigma \leftarrow {}^2\Pi \text{ of } OH$$

She has obtained $f_{CH} = 0.010$ and $f_{OH} = 0.0004$. As the experimental value of f_{OH} is of the order of 0.0008, it is possible that the corresponding correction for the computed f_{CH} would bring its value more closely to the value $f_{CH} = 0.06$ adopted by Dunham. For NH, the f value turns out to be intermediate between f_{CH} and f_{OH}.

Addendum

The hopes aroused during the meeting in regard to CH^+ have been completely confirmed since then by an investigation of the spectrum of a discharge through helium to which a trace of C_6H_6 had been added, carried out by Dr. Herzberg and Dr. A. E. Douglas in their laboratory. They found bands with heads at λλ 4225.3, 3954.0, and 3743.4 A consisting of three singlet branches—P, Q, R—of a $^1\Pi - {}^1\Sigma$ transition. The R (0) lines of these transitions are at λλ 4232.57, 3957.71, and 3745.30, and agree perfectly with the three interstellar lines of Adams. On the other hand, the rotational constant B''_0 of the molecule is equal to 14.0 cm^{-1} which is very nearly that of CH (14.189), and indicates that, in any case, the emitter is a hydride molecule belonging to the second period of the periodic system. But among the possible hydrides, CH^+ alone can possess a system $^1\Pi - {}^1\Sigma$ (analogous with the isoelectronic molecule BH). Thus, we can be certain that the interstellar lines at λλ 4232.58, 3957.72, and 3745.33 are due to CH^+.

This is very important from an astrophysical point of view since we now know relatively strong interstellar lines due to the same molecule in its neutral and ionized states. We have already seen that this was badly needed since in the other case (Ca and Ca^+) the line of Ca was very weak and difficult to measure. If we had good values of the oscillator strength for these molecular lines and of the ionization potential of CH, we could derive a new and reliable value of N_e; a comparison between the distributions of CH and CH^+ molecules in space should also be considered.

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