## Letters to the Editor.

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### The Nebulium Spectrum.

IN an interesting note by C. T. Elvey (NATURE, **121**, p. 12, Jan. 7, 1928) a calculation has been given of the "density necessary to produce the nebulium spectrum," the example considered being the nebulosity originating in the new star Nova Aquilæ, 1918. The outburst of this star was observed early in June 1918; by October a bright nebulous envelope had appeared around the star; it continued to spread as long as the star was under spectroscopic observation (August 1926). The outward flying gases had an average velocity of some 2000 km./sec. The $N_1$ and $N_2$ lines (5007 A. and 4959 A.) were recognised in the spectrum about 19 days after the outburst. At that time the density of the envelope would be of about $10^{-17}$ grams/c.c. In the first years of the existence of the envelope the light of the gas consisted mainly of the nebulium lines $N_1$ and $N_2$; in 1926, however, these were extremely faint, and most of the light came from the Balmer lines of hydrogen and 4686 A. $He^+$ (E. Hubble and J. C. Duncan, *Astrophys. J.*, **66**, p. 60; 1927; and Plate IV.). Nine other novæ give similar density, $10^{-19}$ to $10^{-20}$ grams/c.c., that is, about 50 molecules/c.c.

This constancy was taken as indicating that "there is a limiting density above which the conditions are unfavourable for the production of the nebular spectrum" ($10^{-17}$ grams/c.c.). This corresponds to some millions of H atoms/c.c., the free path being of the order of hundreds of kilometres. Forbidden lines, however, have been actually obtained at higher pressures, and without denying that the density is of great importance, it seems to us that another factor has been unduly neglected: the temperature. It is evident that the expansion of the star was accompanied by changes in temperature or at least by changes in the composition of the spreading matter. It is generally recognised at present that the light observed in nebulæ is in some way caused by neighbouring stars (in the diffuse galactic nebulæ) or where the luminosity is arranged around a brighter nucleus (planetary nebulæ) by the light from the central star. The nebulous material must be in a physical state sensitive to stellar radiation and close enough for the density of radiation to be effective.

An attempt has been made (Zanstra, *Astrophys. J.*, **65**, p. 50; 1927) to show that the light emitted by the diffuse nebulæ is, in the case of the Balmer lines, at least, due to the recombination of positive ions and electrons. The total number $p_n$ of electrons which is captured by the $n$th level of the H atom is, according to Kramers, about

$$p_n = \frac{\dfrac{1}{n+Cn^3}}{\sum\limits_{n=1}^{\infty}\dfrac{1}{n+Cn^3}} \text{ where } C = \frac{\frac{1}{2}mv^2}{W_1}$$

($W_1$ the ionising energy of the first excited level, $m$ and $v$ the mass and the velocity respectively of the electron). If $\frac{1}{2}mv^2$ of the electron is comparable with $W_1$, an appreciable fraction of electrons will be captured by the first levels. Although the Balmer series and the associated continuum have been observed in many nebulæ, it is by no means clear how recombination phenomena can account for the majority of these clouds. The density of the gas itself is usually smaller than the concentration of charges obtainable in the positive column of a (rare) gas discharge, and in this case recombination is negligible.

Any theory of nebulæ emission has to account for the wide differences in the spectra of nebulæ. In this respect Hubble's results as to the type of stars associated with the gaseous matter are important (*Astrophys. J.*, **56**, pp. 162 and 400; 1922). The light emitted by the nebulæ is very often different from the spectra of these centres. There is, however, a close correspondence in that nebulæ giving bright lines are always connected with stars of earlier than B1 type, whereas when later types are involved the nebular spectrum is continuous, with or without dark absorption lines. B1 type stars correspond to a temperature of about 20,000°.

The typical nebular lines $N_1$ and $N_2$, the forbidden lines between the low-lying metastable levels of $O^{++}$, are as a rule much stronger in the planetaries than in the diffuse nebulæ. In the diffuse case $H_\beta$ is about as strong as $N_1$, in the planetaries the ratio is $N_1 : N_2 : H_\beta = 10 : 3 : 1$. The strengthening of the nebulium lines in the planetaries is not accompanied by a corresponding increase of the continuous spectrum of the nuclei in this region; but the maximum of the continuous nuclear spectrum is shifted to the violet as compared with that of the stars associated with diffuse nebulæ. Thus the planetary nuclei have an extraordinary intensity in the ultra-violet, the maximum being certainly at a wave-length less than 3300 A. There are now two points to which we should like to direct attention. The first is that the energy to excite the nebulium lines would be very small if the material (oxygen) were already in an ionised state, so that the connexion between strong ultra-violet spectra and nebulium lines is difficult to understand on that basis. The second point is that the lines are essentially emission lines and have as yet no importance in absorption spectra. Both facts lead to the conclusion that the oxygen which is responsible for the nebular lines cannot be in an ionised state, but must be present as a molecule or molecular ion. As a molecular ion it ought to show absorption bands situated in the visible spectrum.

That forbidden lines between low metastable states of an atom may be expected from dissociating molecules was first pointed out by the authors in a paper published more than half a year ago (*Proc. Roy. Can. Soc.*, vol. 21, p. 27; 1927: cf. the discussion of the low metastable levels of $I_2$). We should like to add that not only the emission of forbidden lines must occur, but also their absorption. In the case of mercury vapour, for example, the heat of dissociation of the molecules is low; under the conditions of the experiment it is of the order of the energy of the faster molecules, so that a large number of molecules break up into atoms, while other atoms recombine to maintain the equilibrium. So long as in this process one mercury atom remains under the influence of the field of its companion of late, it may absorb forbidden lines. That forbidden lines are absorbed has indeed been strikingly demonstrated by Lord Rayleigh (*Proc. Roy. Soc.*, vol. 117, p. 294; 1927).

These relations will be more closely analysed in connexion with other work; their importance for our knowledge of the constitution of stars is evident.

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