of Balmer lines in α Cygnus can be easily understood. Sirius also shows more Balmer lines than the sun, and this is to be ascribed to the joint action of higher temperature and lower pressure in its atmosphere.

For an exact estimation of the pressure from such data we must wait for further theoretical and experimental work. Much of the idea contained in this communication is to be found in papers by Fowler (*Phil. Mag.*, vol. 45, p. 20), Urey (*Astro. Journ.*, Jan. 1924), Wright (NATURE, vol. 109), Becker (*Zs. f. Physik*, vol. 18, p. 335).

27. IONISATION IN STELLAR ATMOSPHERES AND STERIC FACTOR

(a reply to Mr. M. C. Johnson)

In a paper entitled "Cumulative Ionisation in Stellar Atmospheres,"[1] Mr. Martin C. Johnson has criticised certain views of the present writer regarding the so-called "steric factor." On going through the matter in detail, I find that his criticisms cannot be upheld. I shall take his criticisms one by one.

Objection 1 (in. Mr. Johnson's words):

"The principal difficulty in Saha's theory of the steric factor is that it applies to all forms of ionisation equally due to radiation, thermal energy, and applied field energy; it should, therefore, lead to all experimental values of ionisation potentials being lower than the values deduced from convergence frequencies of spectra in the case of most' elements. The tabulations of data (*e.g.* Foote and Mohler) show no such discrepancies that could be interpreted as more than naturally distributed errors."

In the electrical experiments on ionisation potential the vapour is bombarded by electrons subjected to a gradually increasing voltage, and the current voltage curve plotted (after due precautions). The particular voltage at which a sudden increase occurs in the current is taken as the ionisation potential. Whatever the steric factor may be, the vapour cannot be ionised, and no sudden kick will occur in the curve as long as the E.M.F. impressed on the electrons do not reach the required value, *i.e.* the ionisation potential. For an element having a large steric factor the current at this point may be larger, but the position of the kick will remain unchanged.

Hence there is no reason why the electrical experiments should give a lower value of the ionisation potential for elements with large steric factors.

Objection 2:

"Saha gives the steric factor large for C and small for Mg. The I.P. of Mg is 7·65; for C it is quoted by Professor Fowler as from 7 to 8 volts, on a suggestion due to Saunders. On the theory of the steric factor, C^+ should appear at a lower temperature than Mg^+ in a stellar sequence; but whereas Mg^+ appears in Go stars, C^+ does not appear till B6 or B8."

Even assuming that C has the same I.P. as Mg, which appears to me rather doubtful, it appears that Mr. Johnson has overlooked another point of great importance. Mg^+ is detected in stellar spectra by the line $\lambda=4481$, which corresponds to the combination $(3d-4f)$. Now, in order that an Mg^+ atom may absorb this line, it must be brought from the 1S stage to 3d stage, which means an additional potential of 9 volts (15·02, I.P. of Mg^+ —6·1, the voltage corresponding to 3d term of Mg^+, which according to Fowler, is 49776). But in the corresponding case C^+, the element is detected by the line $\lambda=4267$, which, according to Fowler, belongs to $3d-mf$ combination. In order that C^+ may be enabled to absorb this line, it must be brought from the normal state of C^+ to the 3d stage. According to the figures given by Fowler this corresponds to a potential of $24·28-6·29=17·99$ volts. This is just double the corresponding excitation voltage of Mg^+. Thus this objection of Mr. Johnson seems to be quite invalid.

Objection 3:

"Again, N, an element with a high steric factor, according to Saha, persists as absorption lines of the neutral atom as far as stars of the class Oe5, with the maximum at B2, C^+ having a maximum at the same place in the stellar sequence and beginning and persisting similarly. Now the I.P. of N is variously estimated at from 17 to 30 volts, in any case less than the second I.P. of C^+, which is given by Professor Fowler as 24·3+7 or 8 volts. But on Saha's theory the steric factor reducing the effective ionisation for N is greater than for C, *i.e.* N should be more easily ionised even if the ionisation potentials were the same."

Probably Mr. Johnson has the line $\lambda=3995$ in mind

[1] M. N., **84**, 516, 1924,

which, up to this time, was attributed to neutral nitrogen. But in my paper (*Phil. Mag.*, **44,** 1138, 1922) I pointed out that since these groups of lines do not occur in classes cooler than Ao, they are most probably due to N^+.

This prediction has been verified by Fowler's[2] recent work on the spectrum of ionised nitrogen, and he has now definitely assigned $\lambda=3995$ and other associated lines to N^+. The I.P. of neutral nitrogen is still unknown, but recent work by Kiess[3] indicates that it is in the neighbourhood

of 12 volts. The I.P. of N^+ is also unknown, but Fowler estimates it to be about 24 volts, so that the excitation potential for the line $\lambda=3995$ is $12+24-8\cdot5=27\cdot5$ volts, while the corresponding quantity for the C^+ line $\lambda=4267$ is $7+24-6\cdot1=24\cdot9$ volts. Thus the nitrogen lines present not only no difficulty to the theory of steric factor, but they probably justify the theory. We must, however, wait till the I.P. of C, N, and N^+ are accurately determined.

Physics Department,
Allahabad University:
1925 *August* 14.

[2] Fowler, *Proc. Roy. Soc. Lond.*, **107** (1925).
[3] Kiess, *Journ. Am. Optical Society*, 1925 June.

28. INFLUENCE OF RADIATION ON IONISATION EQUILIBRIUM

Meghnad Saha and Ramani Kanta Sur

In considering ionisation equilibrium of the type $M \rightleftarrows M^+ + e - U$, the usual method adopted is to write down the entropies of M, M^+, and e from the quantum theory, and then the law of reaction isochore is obtained from the equation $S+S'-s=U/T$. In this way we obtain the law of ionisation equilibrium

$$\log \frac{x^2}{1-x^2} P = - \frac{U}{2\cdot3RT} + \frac{5}{2} \log T - 6\cdot5 \qquad .. \quad (1)$$

The system is regarded as unary (one-component), *i.e.* all the reacting electrons as well as M are derived from the ionisation of M, but when there is excess of electrons, the system is binary and the equilibrium is expressed by the form first given by H. N. Russell, namely,

$$\log \frac{x}{1-x} \cdot \frac{x'}{1+x'} P = - \frac{U}{2\cdot3RT} + \frac{5}{2} \log T - 6\cdot5 \qquad (2)$$

The process is regarded as an abrupt one, M-atoms passing directly under the influence of heat to the M^+-stage, without going through the intervening metastable states. Darwin and Fowler have attempted to include these intervening states by adding to the right-hand side of equation (1) a function $B(T)$. Prof. Russell has pointed out that neither equation (1) nor (2) can be regarded as final, because it fails to take account of the possible influence of radiation and excitation of higher states. We may introduce the matter in the following way. Suppose we have a mass of sodium-vapour in the solar chromosphere. Then the ionisation of sodium atoms is determined not only by the temperature of the chromosphere (say 5000°C), but also by the intensity of photospheric radiation of wave-length λ less than the wavelength

of the limit of the P series, passing through these sodium atoms. This radiation has a higher temperature than the local temperature; hence, as was first pointed out by Milne, we have no thermodynamic equilibrium in the solar chromosphere. The excited states are produced under the joint influence of temperature of the chromosphere and of the photospheric radiation passing through the chromosphere. To the same class belongs the absorption experiments of Wood and others, in which a column of sodium or other vapour is acted on by light of much greater intensity than what would be produced at the temperature of the absorbing gas. Here all the excited atoms, or ionised atoms, are produced by light only, and almost none are due to temperature.

The general problem has been thus attacked. In all photochemical reactions the equilibrium is determined by the intensity of light, and in treating these cases from the point of view of the phase rule, Smits expressed the opinion, without however giving his reason, that the ordinary Gibbs formula, $F=C+2-P$, must be replaced by $F=C+3-P$. We, however, arrive at the same result by assuming that the number of components has increased by one, the photochemically active light being regarded as a new and independent component. In other words, when a normal sodium-atom passes to the $2p$-stage by absorbing the $h\nu$-pulse of D-radiation, then either the excited atom of sodium or the pulse of light may be regarded as a new component, except when the D-light is derived from the effect of temperature prevailing in the gas. In the latter case, the system is a system of one component, as in the corresponding case of free electrons in equation (1).