nor any other spark-line was excited. The arc-line $\lambda=4703$ (1P—4D) was either not excited at all or excited very feebly.

The ionization potential of magnesium is 7·65 volts, and thus active nitrogen would just suffice to ionize magnesium. Active nitrogen passed over Ca, Ba, or Sr, would excite, besides their arc spectrum, also the spark spectrum.

(4) Hydrogen and the inert gases have no other influence on active nitrogen except a mere dilution of the glow. This is in accordance with the fact that the minimum excitation potential of these gases is much higher than the maximum energy which can be transferred by active energy.

On the other hand, when helium is activated by an electric discharge, it is capable of storing a large amount of energy ($e=20{\cdot}4$ volts) and hence would be found to be an extremely active substance. This view is supported by an interesting observation of Lord Rayleigh[14] in a recent paper, who found that activated helium on coming into contact with N_2-gas (unexcited) excites the afterglow. If the present view is correct, it would excite not only the positive bands but also the line-spectrum due to N. This point ought to be further investigated.

We now come to the most formidable difficulty confronting the above explanation, viz., chemically pure nitrogen shows no afterglow at all. This matter forms the subject matter of a very interesting paper by Lord Rayleigh in vol. xci. of the P. R. S. London. Following experiments by Tiede and Domcke, who found that chemically pure nitrogen, prepared by heating barium and potassium azide, and carefully freed from all impurities, shows no afterglow at all, Lord Rayleigh showed that nitrogen purified by prolonged standing over the liquid alloy of Na and K gave an afterglow, which was however very faint. On introducing small impurities of oxygen, or almost any easily excitable gas (1 in 1000 parts), the glow was restored to full brilliancy. This observation has also been confirmed by recent experiments of Pirani[15], who claims for his nitrogen a purity of 5×10^{-5} per cent. Pirani finds that perfectly pure N_2 shows no luminescence at all, though admixture of electronegative gases like O_2, H_2O, I_2 in concentration of $1{\cdot}5\times10^{-3}$ give a maximum after-luminescence. Large admixtures, say from 6 to 8×10^{-3}, choke the luminescence. In all these experiments, the authors seemed to have looked only for the after-luminescence of the chemically pure gas as a test of activity. They did not evidently apply the chemical tests. This point is of some importance, because the afterglow is simply the sign of the return of the molecule from the higher quantum states to one of the intermediate unstable states; it does not indicate the reversion to the normal state. Hence, if under certain conditions the intermediate orbits (*i.e.* final orbits of the afterglow band) be not stable, these will not be emitted at all, though the gas will exhibit all the chemical and spectral activity recorded by Lord Rayleigh.

It seems to be a general phenomenon that the activated atom, when left to itself, has always a tendency to fall to the lowest quantum state, without stopping at the intermediate stages. Hence only the primary bands would be emitted. This is confirmed by an interesting investigation of Wood[16], who finds that in his discharge-tubes, Balmer lines of H (for which the final orbit is an unstable orbit) are always rendered very brilliant if H_2O vapour is present as an impurity. The subject is, however, well worth further investigation.

Our explanation of the absence of afterglow in active nitrogen, if true, would mean that nitrogen may be loaded to an energy of about 8·5 volts without being luminous, and therefore will still possess all other properties associated with active nitrogen.

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[14] Lord Rayleigh, Proc. Roy. Soc. Lond. vol. cii. p. 454.

[15] Pirani, 'Chemical Abstracts,' 1923, ii. p. 157.

[16] Wood, Phil. Mag. xlii. p. 729.

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26. THE PRESSURE IN THE REVERSING LAYER OF STARS AND ORIGIN OF CONTINUOUS RADIATION FROM THE SUN

(*Nature*, **114**, 155, 1924)

There seems to be at present a wide divergence of views regarding the magnitude of pressure in the "reversing layers" of stars. While earlier investigators assigned to it a pressure of one to ten atmospheres, on the basis of pressure shift of lines to the red, these experiments do not appear to carry much weight at present. Fowler and Milne (Monthly Notices R.A.S., vol. 83, p. 415, 1923) actually assign to it a pressure of the order of 10^{-3} to 10^{-4} atmospheres.

The following speculations will show that probably an accurate method of determining the pressure may be developed from the limit of series absorption of elements in the Fraunhofer spectrum. To introduce the subject, let us start with the well-known fact that in the Fraunhofer spectrum of the sun the Balmer series of H absorption lines abruptly terminate at Hζ, while in the flash spectrum no less than 35 Balmer lines are found. Here the ionisation theory does not help us, for all Balmer lines require the same H atom (in the diquantic state) for absorption. We are therefore confronted with the fact that as continuous radiation pours through the H(2) atoms, pulses which lift the electron up to the 8th quantum orbit are freely absorbed, but pulses which would lift the electron to the higher orbits somehow fail to be absorbed in spite of the presence of suitable absorption centres. Something prevents the development of the H-orbits beyond certain limits.

The next step is naturally to identify this agency with the congestion in the reversing layer due to high concentration of particles. In order that the *n*th-orbit may be developed, the electron should be capable of passing to an average distance of $0{\cdot}532\times10^{-8}\times n^2$ cm. from the nucleus. But if within this distance it comes under the influence of a second nucleus, or another electron, there can be no free development of the orbit: the electron will become either free, or attach itself to another nucleus. Hence for rays shorter than Hζ, the H(2) atoms in the particular layers treated will lose their power of picking up the pulses corresponding to the Balmer series, but will exercise a sort of general, though much enfeebled, absorption on all radiation beyond Hζ, somewhat after the manner of X-ray absorption. This part will be freely emitted only by higher layers, where the pressure has fallen to sufficiently low values; in other words, if the solar atmosphere were composed of H(2) atoms only, part of the continuous spectrum beyond Hζ would originate from somewhat higher levels than the redder part of the spectrum.

The idea helps us to get a clearer view of the origin of continuous radiation from the sun. For what has been said of H(2), absorption is a general phenomenon, and can be extended to all other elements. In fact a scrutiny of the Fraunhofer spectrum shows that quantum orbits higher than the 5th or the 6th (total quantum number) are rarely developed. The examples given in the following table illustrate the point[1].

Element.	Last Series-line in the Fraunhofer Spectrum.	Corresponding Wave Number of final Orbit.
H	Hε, $\nu=N\left\{\frac{1}{2^2}-\frac{1}{7^2}\right\}$	2238
	Hζ, $\nu=N\left\{\frac{1}{2^2}-\frac{1}{8^2}\right\}$	1714
Na	$2p_1-6d$, $\lambda=4668{\cdot}60$	3062
	$2p_1-6s$, $\lambda=4751{\cdot}89$	3437
Mg	2P—6D, $\lambda=4351{\cdot}94$	3649
Ca	2P—4D, $\lambda=5188{\cdot}85$	6385
	2P—5S, $\lambda=4847{\cdot}29$	5028

For every one of these elements conclusions similar to that in the case of hydrogen hold. Thus, since the higher members of the series lines are in the ultra-violet, there will be cumulative continuous absorption on the short wave-length side. Hence, as a rule long waves will come from deeper layers, short waves from higher layers. How satisfactorily this view accounts for the distribution of energy in the solar spectrum will be evident from the following passage: "Both the observed curves of distribution of energy in the solar spectrum (by Wilsing and Abbot) agree in having a much more pronounced peak than the black body curve, in being depressed below the latter in the violet (*the drop of intensity on the violet side of the maximum being very sudden*), and in coinciding with the black body in the extreme infra-red" (Milne, Phil. Trans., A, vol. 223, p. 218).

Thus for different rays we have different photospheres, but the distances separating the extreme photospheres probably do not differ by so much as 100 km. The photospheres and the reversing layers thus get very much mixed up. Owing to the rapid density gradient of luminous matter (except probably in the case of such atoms as are maintained by selective radiation pressure) the luminosity of the concentric layers round the sun decreases very rapidly. For example, it is well known that if, when obtaining the Fraunhofer spectrum, exposures of longer duration than 1/100 sec. are given, there is no contrast, all dark lines becoming bright. But to obtain the spectrum of layers about 100 km. from the disc during total solar eclipses, exposures of 4 to 10 sec. are required. This shows that the so-called dark lines of the Fraunhofer spectrum are intrinsically 100-1000 times more luminous than the bright lines of the flash. Hence when we expose for the Fraunhofer spectrum, the time of exposure is too short for the chromosphere, which does not, therefore, contribute anything to the resulting photograph. In other words, Fraunhofer absorption is caused by layers close to the disc, the higher chromosphere contributing nothing to the process.

These ideas may be extended to stars. According to a rough calculation, if *n* is the quantum number corresponding to the last absorption line of the Balmer series in a star, $n \propto \left(\frac{T}{P}\right)^{\frac{1}{6}}$. I have been able to collect the data for three A-type stars, α Cygni (ab. mag. —4·5), α Lyrae (ab. mag. +0·6), α Canis Majoris (ab. mag. +0·9). In α Cygni, 24 Balmer lines are developed, in Vega 17 (up to Hρ), and in Sirius 13. Now α Cygni is a typical giant star, Sirius is a typical dwarf, and Vega lies between them. It is generally admitted that the pressure in the reversing layer of giants is much lower than in dwarfs, and hence the great development

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[1] See Russell, *Astrophysical Journal*, vol. 55, p. 130. According to some authors, Hε is the last absorption-line of the Balmer series. It is always difficult to trace the last line, as it is usually very faint.

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)

(*Mon. Not. Roy. Astro. Soc.*, **85**, 977, 1925)

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^+ $-6{\cdot}1$, 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 $24{\cdot}28-6{\cdot}29=17{\cdot}99$ 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 $24{\cdot}3+7$ 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

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