

usually called the Principal series of helium and parhelium (viz., the series beginning with the line 20,587 for parhelium and 10,834 for helium) do not really correspond to the combination $(1, s) - (m, p)$ but to the combination $(2, s) - (m, p)$. The $(1, s)$ term for helium is still unknown, and the series $(1, s) - (m, p)$ lie far down in the ultraviolet.²⁰ Hence, according to our theory, none of the lines belonging to the combinations $(2, s) - (m, p)$, $(2, p) - (m, d)$ can be absorbed by a layer of helium gas.

But if by heating or some other means we can convert a good proportion to the states $(2, s)$ or $(2, p)$, then and then only can these lines appear as absorption-lines. But at a pressure of 10^{-1} atm. helium becomes incandescent, i.e., emits the lines $(1, s) - (m, p)$, and absorbs the lines $(2, p) - (m, d)$ at probably not less than $10,000^\circ$ or $12,000^\circ\text{K}$, i.e. only in stars of the B-Class.

But instead of a high temperature we may think of other

²⁰It is quite possible that some of the $(1, s) - (m, p)$ lines for helium and parhelium may be identical with the lines discovered by Lyman in the ultra-violet, and some with the lines discovered by Richardson and Bazzoni in the region of 300 to 400 A.U. by the photo-electric method (vide Richardson and Bazzoni, *Phil. Mag.*, 1918).

means. The spark produces mechanically the very same conditions which can be realized at very high temperatures. This is exactly what Paschen²¹ has done. He found that the lines of the combination $(2, s) - (m, p)$ for helium and parhelium cannot be absorbed by an ordinary layer of the helium gas. But when a spark is sent through the absorbing layer the lines are strongly absorbed, the absorbed energy being again re-emitted in all directions.

The paper thus suggests more problems than it attempts to solve. A critical examination and further development of the hypothesis advanced here requires an overhauling of the whole data on the line-radiation of gases—such as are contained in Kayser's *Handbuch der Spektroskopie* and further works. But this programme requires much more time and more extensive study, both practical and theoretical.

University College of Science, Calcutta.
May 25, 1920.

²¹Paschen, *Ann. d. Physik*, Vol. xlv. p. 625 (1914).

16. THE ATOMIC RADIUS AND THE IONISATION POTENTIAL

(*Nature*, 107, 682, 1921)

Prof. Eve's interesting contribution to *Nature* of June 30, p. 552, on the relation between the ionisation potential and the atomic radius induces me to publish certain similar ideas of mine on the same subject to which I referred some time ago before the Royal Society in some remarks on Prof. Rankine's paper "On the Proximity of Atoms in Gaseous Molecules" (Proc. Roy. Soc., February, 1921). I did not publish the results, because I desired to wait for further data. These ideas may be stated as follows:—

According to the Rutherford-Bohr model of the atom, by the radius of the atom is meant the distance from the nucleus of the outermost electron, i.e. the electron the quantum vibrations of which cause the radiation of the arc lines of the atom. Sommerfeld has shown that in the normal (unexcited) state the orbit is characterised by the azimuthal quantum-number unity and the radial quantum-number zero. This orbit is circular, but to calculate its radius we must know what is the field of force exerted by the central nucleus and the remaining $(n-1)$ electrons upon the

vibrating electron. This is at present an insoluble problem, but Mr. S. N. Basu (*Phil. Mag.*, November, 1920) has shown that we can at least arrive at a qualitative explanation of Rydberg's laws of spectral regularity by assuming the attracting system to be equivalent to a net central charge unity, with a doublet of strength L . On the bases of this theory, if a_w is the radius of the monoquantic orbit, it is easy to show that

$$\frac{e^2}{2a_w} = -\text{energy of the vibrating electron.}$$

$$= h(1s) \text{ where } (1s) = \text{convergence frequency of the principal series of the element in absolute measure.}$$

$$= eV_w, V_w = \text{ionisation potential in } e.s. \text{ units.}$$

For the H-atom we have, according to Bohr's theory,

$$a_H = \frac{h^3}{4\pi^2 e^2 m} \quad (a_H = \text{radius of the electron in the normal state})$$

$$= 0.532 \times 10^{-8} \text{ cm,}$$

and

$\frac{e^2}{2a_H} = e(13.54 \text{ volts})$. Therefore for an element x with an ionisation potential of V_x we have

$$a_x = \frac{(0.532 \times 13.56)}{V_x} \times 10^{-8} \text{ cm.}$$

Thus the atomic radius varies inversely as the ionisation potential.

The atomic radii calculated according to this formula are, in general, smaller than the atomic radii calculated either from crystal data (Bragg) or from the kinetic theory of gases (Rankine and others). They are shown in the appended table for the sake of comparison.

The values of V_x for copper, silver, and gold have been calculated from Hick's value of the (1S) term for these elements. That for manganese has been similarly calculated from Mr. Catalan's value of (1S) for manganese (not yet published). For these data I wish here to record my indebtedness to Prof. Fowler and Mr. Catalan. The sources for the other values are quite well known.

21 Cromwell Road,
London, July 13.

Element	I.P.	Atomic Radius		Viscosity data
		From I.P. $a \times 10^8$	Crystal measures $b \times 10^8$	
H	13.54	0.530	—	—
He	25.40	0.28	—	1.08
Ne	22.80	0.33	0.65	1.01
(Horton, <i>Phil. Mag.</i> , May, 1921)				
Li	5.40	1.34	1.50	—
Na	5.11	1.41	1.77	—
K	4.32	1.67	2.07	—
Rb	4.16	1.73	2.25	—
Cs	3.88	1.86	2.37	—
—				
Cu	7.63	0.94	1.37	—
Ag	7.50	0.95	1.77	—
Au	8.63	0.83	—	—
—				
Mg	7.61	0.95	1.42	—
Ca	6.09	1.18	1.70	—
Sr	5.67	1.27	1.95	—
Ba	5.19	1.39	2.10	—
—				
Zn	9.35	0.77	1.32	—
Cd	8.95	0.81	1.60	—
Hg	10.38	0.69	—	—
—				
Tl	7.30	0.90	2.25	—
Mn	7.38	0.98	1.47	—

17. ON A PHYSICAL THEORY OF STELLAR SPECTRA

(*Proc. Roy. Soc. Lond.*, A99, 135, 1921)

(Communicated by Prof. A. Fowler, F.R.S. Received January 18, 1921).

1. Introduction.

The present paper embodies an attempt towards a physical explanation of the ordered gradation in the spectra of stars—a subject in which pioneering work was done by the late Sir Norman Lockyer, but which was worked up with systematic thoroughness at the Harvard College Observatory, under the lead of the late Prof. E. C. Pickering and Miss A. J. Cannon.¹ During this interval the spectra of more than 100,000 stars have been photographed, classified, and published with full details in the Henry Draper Memorial Catalogue. The most noteworthy facts which have been brought to light from these monumental studies have thus been summarised by H. N. Russell.²

“The spectra of the stars show remarkably few radical differences in type. More than 99 per cent. of them fall into one or the other of the six great groups which during the classic work of the Harvard College Observatory were recognised as of fundamental importance, and received as

designations, by the process of the survival of the fittest, the rather arbitrary letters B, A, F, G, K, M. That there should be so few types is noteworthy, but much more remarkable is the fact that they form a continuous series. Every degree of gradation between the typical spectra denoted by B and A may be found in different stars, and the same is true to the end of the series, a fact recognised in the familiar decimal classification, in which B5A, for example, denotes a spectrum half-way between the typical examples B and A. The series is not merely continuous, it is linear. There exists slight difference between the spectra of different stars of the same spectral class, such as A₀, but these relate to minor details. Almost all the stars of the small outstanding minority fall into three other classes (or rather four), denoted by the letters P, O, N, R. Of these, O undoubtedly precedes B at the head of the series, while R and N, which grade one into the other, come probably at its other end, though in this case the transition stages are not clearly worked out.”

Russell is of opinion that the principal differences in the stellar spectra arise in the main from variations in a single

¹Harvard, 'Annals', vol. 28, Parts I and II; vols. 56, 76, and 91.

²'Nature,' vol. 93, pp. 227, 252, 281.