LETTERS TO THE EDITOR

ASTROPHYSICS

Identification of Solar Coronal Emission Lines

THE coronal emission lines are produced by highly ionized atoms undergoing forbidden transitions from metastable levels¹. In an attempt to identify further lines we have examined the level separation 3P_2 — 3P_1 in the excited four-electron configuration $1s^2 2s 2p$. Fig. 1 shows the level structure near the ground-state.

Fig. 1

The 3P_2 state has no allowed downward transitions to the ground-state, and should give rise to emission lines through a magnetic dipole transition to 3P_1 , as indicated by the arrow. For A XV, K XVI and Ca XVII these lines fall in the visible or near visible region of the spectrum. The 3P_1 and 1P_1 levels de-excite predominantly by electric dipole transitions to the ground-state and will not give rise to visible radiation for these elements. The 3P_0 level de-excites by two-photon emission to the ground-state and cannot give an emission line in the visible.

We have obtained the level separations for the iso-electronic sequence, as an expansion in Z , the nuclear charge, using the perturbation methods of Layzer². A full account of the calculations for the configurations $1s^2$, $1s^2 2s$, $1s^2 2p$, and $1s^2 2s 2p$, which include the first and second relativistic corrections to first-order perturbation theory, will be published soon. We have also included the radiative corrections, and have estimated the effect of 1P_1 on 3P_1 , in intermediate coupling. It is not practicable to calculate the second and higher orders of perturbation theory; but we know their Z dependence, and have estimated their effect by obtaining the best polynomial to fit the experimental data³ for $Z = 4-12$.

The results, for the observable region of the spectrum, are given in Table 1, together with already identified lines, due to the same elements in slightly lower stages of ionization. One would expect adjacent stages of ionization of the same element to have comparable populations.

Table 1. THE CORONAL LINES

Wave-length	Spectrum	Transition predicted	T.P. sec ⁻¹	E.P. (eV)	I.P. (eV)
47,736 ± 14	Cl XIV	$1s^2 2s 2p \ ^3P_2 - ^3P_1$	28	26.8	647
5,926 ± 11	A XV	$1s^2 2s 2p \ ^3P_2 - ^3P_1$	62	28.5	745
4,608 ± 10	K XVI	$1s^2 2s 2p \ ^3P_2 - ^3P_1$	127	30.3	849
6,329 ± 8	Ca XVII	$1s^2 2s 2p \ ^3P_2 - ^3P_1$	251	32.1	960
Observed					
4,412	A XIV	$1s^2 2s^2 2p \ ^2P - ^2P^{\frac{1}{2}}$	108	2.84	687
6,777	K XIV	$1s^2 2s^2 2p \ ^2P - ^2P^{\frac{1}{2}}$	39	3	717
5,446	Ca XV	$1s^2 2s^2 2p \ ^2P - ^2P^{\frac{1}{2}}$	74	3	820
5,694		$1s^2 2s^2 2p \ ^2P - ^2P^{\frac{1}{2}}$	95	2.18	

In fact only one of our predictions, A XV λ 5926, has been observed⁴ and this is a very weak line. The absence of the other lines is probably to be explained by the high excitation potentials required. For the previously observed lines the excited level is in the ground-configuration, and may be radiatively excited, but our excited configuration could only be produced by electron impact and is less probable. Nevertheless, in view of the strength of the Ca XV lines in coronal condensations, one may hope to verify our Ca XVII prediction when more sensitive observations become available.

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¹ For a review see Edlén, B., *Mon. Not. Roy. Astro. Soc.*, **105**, 323 (1945). More recent identifications are given in *Intern. Astro. Union Symp.*, 16, Clouderoft, 1961, *The Solar Corona*, edit. by Evans, J. W., 286 (1963).

² Layzer, D., *Ann. Phys. (New York)*, **8**, 271 (1959); **17**, 177 (1962).

³ Moore, C. E., *Atomic Energy Levels*, Nat. Bur. Stand. Circ., 467 (1949). Bockasten, K., Hallin, R., and Hughes, T. P., *Proc. Phys. Soc.*, **81**, 522 (1963).

⁴ Aly, M. K., *Astrophys. J.*, **122**, 438 (1955). Aly, M. K., in the Clouderoft Symp. (ref. 1), 285.

A Theoretical Domain for Flare Stars in the H-R Diagram

It has been suggested several times¹ that the flare activity observed in flash and UV Ceti stars is of a nature similar to that of solar flares. In this communication I shall adhere to this point of view, which, together with present ideas about the Helmholtz-Kelvin phases of stellar evolution, will permit us to understand, in a simple manner, a number of observations regarding flares in stars.

Flares in the Sun are a result of magnetic activity, and if we adopt Parker's² theory of the Sun's magnetic field, we see that its activity comes from the interplay between the convective motions in the outer layers and the differential rotation. In a more general context, the importance of the convection zone has been stressed by Schatzman³ in his theory on the surface activity in stars and their loss of angular momentum. Thus stars that are wholly convective (or nearly so) and that have rapid rotations (as is the case of premain sequence stars⁴) should show violent and very frequent flares (the shorter the period of rotation the more frequent the flares⁵).

In the treatment of the premain sequence stars by Henyey, Le Levier and Lové⁵, there was no room for a