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NEON ABSORPTION LINES IN STELLAR SPECTRA

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The great strength and general occurrence of the "forbidden" emission lines of Ne III and Ne IV in the spectra of nebulae and novae[1] is suggestive of a high cosmic abundance for this supposedly rare gas. It appears extremely unlikely that neon should be plentiful only in these classes of celestial objects or that it should be produced in the process of nova activity. The absorption lines of this atom should appear in normal stellar spectra.

The atom of Ne I[2] has an ionization potential of 21.5 volts. Its resonance lines lie in the far ultra-violet and the only astrophysically observable lines, which lie in the region λλ 5400–7200, have excitation potentials of 16.6 volts. The atom of Ne II[3], ionization potential 40.8 volts, has observable lines in the λ 3700 region, but the excitation potentials are about 27 volts. The visible spectra of higher stages of ionization are still unknown.

Applying the ionization theory as developed by Fowler and Milne,[4] we find that the lines of Ne I and Ne II should come to maximum in stars of respective surface temperatures 12,500° and 22,000°, i.e., near spectral classes B8 and B0. Russell[5] has shown that the elementary theory ought to give a fairly satisfactory representation for temperatures of this magnitude.

A search for the lines of Ne I was made on panchromatic plates taken by Menzel with the three-prism visual spectrograph attached to the 36-inch refractor at Lick Observatory. The strongest line of Ne I, at λ 6402.24, appears to be present as a very faint line in the spectrum of β Orionis (B8p). It is far weaker than the neighboring pair λλ 6347 and 6371 of Si II, which are the most intense lines in the region to the red of λ 5875 He, not excepting Hα. The presence of λ 6402 has been confirmed on three plates and the agreement in wave-length is satisfactory. The line had been measured by Menzel several years ago, when the possibility of attributing it to neon had not been considered. We cannot rule out, however, on the evidence of a single line, the chance that it may be due to some

MULTIPLET	IQ	WAVE-LENGTH LABORATORY	INT. LAB.	WAVE-LENGTH AND INT. STELLAR MARSHALL	STRUVE	IDENT.	
$3s^4P-3p^4P^0$	2½–1½	3664.09	9	4.15 (2)[a]			
				4.18 (1)[c]			
	2½–2½	3694.22	10	4.28 (4)[a]			
				4.26 (1)[c]			
				4.18 (2)[d]			
	1½–½	3709.64	7	9.79 (3)[a]		OIII	9.52 (2)
				9.53 (1)[d]			
	1½–1½	3734.94	7	4.33		H	4.370
	½–½	3751.26	5	0.16		H	0.154
	1½–2½	3766.29	8	0.67		H	0.632
	½–1½	3777.16	8	7.22 (3)[a]		OII	7.60 (4)
				7.33 (2)[e]			
				7.11 (2)[d]			
				7.24 (1)[c]			
$3s^2P-3p^2D^0$	1½–2½	3643.89	5	3.74 (2)[a]			
	1½–2½	3713.09	10	2.98 (4)[a]		OII	2.75 (7)
				2.83 (4)[d]		H	1.973
				2.79 (7)[c]		OIII	2.48 (2)
	½–1½	3727.08	9	7.27 (6)[a]		OII	7.33 (8)
				7.21 (4)[e]			
				7.35 (7)[d]			
				7.38 (6)[c]			
$3p^2P^0-3d^2D$	1½–1½	3800.02	5				
	½–1½	3818.44	6	8.27 (1)[a]			
	1½–2½	3829.77	7	9.93 (1)[c]		NII	9.80 (3)
$3d^4D-4f^4D^0$§	3½–3½	4219.76	6	0.08 (2)[b]	0.07 (1)[a]		
					9.64 (3)[c]		
	2½–2½	4231.60	4		1.70 (2)[b]		
					2.04 (2)[d]		
	1½–2½	4250.68	4	0.60 (2)[b]	0.10 (1)[a]		
					0.82 (1)[b]		
$3d^4F-4f^4G^0$§	3½–4½	4391.94	7	2.03 (2)[b]	1.96 (2)[a]		
					1.96 (3)[b]		
					1.96 (2)[d]		
	2½–3½	4409.30	7	9.15 (2)[b]	9.27 (3)[b]		
					9.32 (1)[d]		
$3d^4F-4f^4F^0$§	1½–2½	4369.77	5			OII	9.28
	3½–3½	4379.50	6	9.14		NIII	9.103 (10)
						OIII	9.55 (3)

[a] 10 Lacertae (O9)
[b] τ Scorpii (B0)
[c] β Cephei (B1)
[d] β Can Maj (B1)
[e] κ Cassiop (B0)
§ Incomplete multiplet

other element. The line could not be found in the spectra of α Canis Majoris, α Virginis, α Leonis or η Ursae Majoris, plates of which were also available.

The lines of Ne II were sought for in spectra obtained by Marshall with the single-prism spectrograph attached to the $37^1/_2$-inch reflector at the Observatory of the University of Michigan. The spectra were measured previous to the present investigation and the lines were merely looked up in the list already prepared. 10 Lacertae (O9) appeared to be the most promising star, because of the large number and sharpness of its lines. A spectrum of κ Cassiopeiae was available, but the lines in this object were much fuzzier and more difficult to see. Two lists of lines by Struve[6] and by Struve and Dunham[7] were also employed. In the table (p. 880) is presented the astrophysical evidence for the occurrence of Ne II in the spectrum of 10 Lacertae.

The respective columns contain the multiplet designations, inner quantum numbers, laboratory wave-lengths and intensities, the stellar wave-lengths and intensities for the various observers and possible identifications other than Ne II. With the exception of λ 3766.29, which may be masked by the neighboring line $H\iota$ (stellar intensity 8), all of the lines of the two strongest multiplets are present or accounted for. Several are masked by overlying lines of H or O II. It is interesting to note that λ 3694.22 was the strongest previously unidentified line in the near ultra-violet spectral region of these stars.[8] The stronger lines of several less intense multiplets are probably present. The presence of neon appears to be definitely established. The lines of F II appear to be absent.

Ne II and O II atoms have excitation and ionization potentials of the same order of magnitude. This fact, coupled with the observed similar intensities of the lines, suggests that the two elements have approximately equal abundances. This is roughly substantiated by the intensities of the O III and Ne III forbidden lines in nebulae and novae. Two of the "noble" gases, He and Ne, thus have high abundances in the universe. Cosmically speaking, the term "rare gases" for these elements is a misnomer.

[1] Boyce, Menzel and Payne, these PROCEEDINGS, **19**, 581 (1933).

[2] C. E. Moore, *A Multiplet Table of Astrophysical Interest*, Princeton Observatory (1933).

[3] *Ibid.*, cf. also de Bruin and Bakker, *ZS für Phys.*, **69**, 19 (1931).

[4] Fowler and Milne, *Mon. Not. R. A. S.*, **83**, 403 (1923).

[5] *Astroph. Jour.*, in press.

[6] Struve, *Ibid.*, **74**, 225 (1931).

[7] Struve and Dunham, *Ibid.*, **77**, 321 (1933).

[8] Cf. Marshall, *Ibid.*, **76**, 317 (1932).