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3 UNUSUAL RESONANCE LINES OF HIGHLY IONIZED ATOMS OF THE FIRST LONG PERIOD 6

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During an investigation of the spectra of highly ionized ions we have found weak lines that could not be referred to transitions between energy levels that are below the first ionization potential.

In general it is easy to recognize such lines when they appear in a region in which the expected spectrum is simple,[1] or in a region in which there is a large energy gap that is expected to be free of lines of any degree of ionization whatsoever. In our case the lines for a given element are in the energy gap lying above its ionization potential in the Na I isoelectronic sequence (I.S.). and below its first excited state in the Ne I I.S.. From Table 1 one can see that the ionization potential of an ion in the Na I I.S. is about 30% lower than the energy of the first excited level of an ion in the NeI I.S.. The Ne I spectrum is very simple, expecially the first excited configuration. Between this configuration and the ground state, two transitions are possible: $2s^2\ 2p^5\ 3s\ {}^3P^0_1 - 2s^2\ 2p^6\ {}^1S_0$ and $2s^2\ 2p^5\ 3s\ {}^1P^0_1 - 2s^2\ 2p^6\ {}^1S_0$, the former being of lower energy.

On our plates there appear weak lines of slightly lower energy than the above mentioned transitions (see Fig. 1). These lines cannot belong to the Ne I I.S. because their energy is lower than the first excited state, and of course, cannot belong to the F I I.S. (ground state: $2s^2\ 2p^5$). The non-resonance transitions of the Ne I I.S. appear at much higher

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ABSTRACT

Resonance lines originating from energy levels far above the ionization potential have been observed for highly ionized atoms from Ti to Cu. Two of the lines for each ion have been classified as the transitions $2s^2\ 2p^6\ 3s\ {}^2S_{1/2} - 2s^2\ 2p^5\ 3s^2\ {}^2P^0_{3/2,\ 1/2}$ of the Na I isoelectronic sequence. Wavelengths and energy tables are given and a typical spectrogram is presented.

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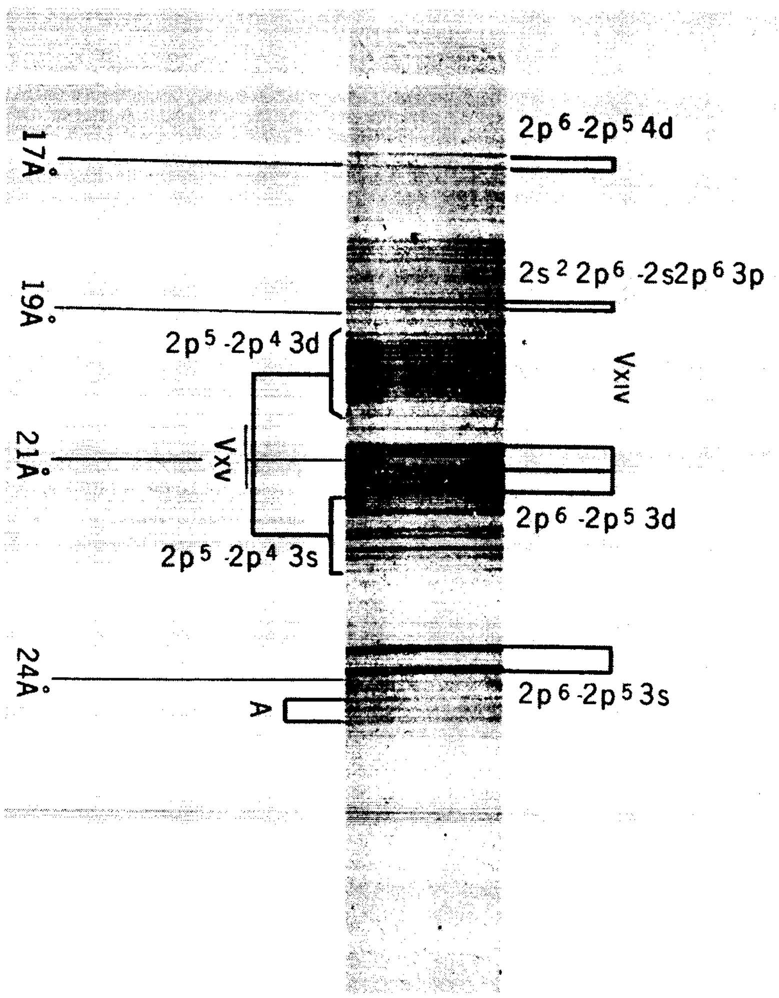

Figure 1. The Vanadium spectrogram reproduced above is a typical example of the $2s^2\,2p^r - 2s^2\,2p^{r-1}\,nl$ spectra in the highly ionized atoms of the first long period. The lines A arise from the transitions $2s^2\,2p^6\,3s - 2s^2\,2p^5\,3s^2$, while the weak lines in the same region belong to similar types of transitions $2s^2\,2p^6(NL) - 2s^2\,2p^5\,3s\,(NL)$, where NL is one or more electrons.

Table 1. Energies and energy differences in the $2s^2\ 2p^5\ 3s$ configuration of Ne I I.S. and the series limit $2s^2\ 2p^6\ {}^1S_0$ of the Na I I.S.

	Ne I Sequence			Na I Sequence
	Ne I $2s^2\ 2p^5\ 3s\ {}^3P^0_1$ (cm^{-1})	Ne I $2s^2\ 2p^5\ 3s\ {}^1P^0_1$ (cm^{-1})	Ne I $\Delta\nu({}^1P^0_1 - {}^3P^0_1)$ (cm^{-1})	Series Limit $2s^2\ 2p^6\ {}^1S_0$ (cm^{-1})
Ti	3 709 200	3 753 600	44 400	2 351 530
V	4 202 700	4 275 100	54 400	2 713 130
Cr	4 727 500	4 793 200	65 700	3 099 630
Mn	5 281 200	5 360 800	79 600	3 511 210
Fe	5 864 800	5 961 600	96 800	3 947 840
Co	6 477 900	6 592 400	114 500	4 410 480
Ni	7 128 000	7 262 000	134 000	4 897 400
Cu	7 800 000	7 962 000	162 000	5 410 000

Table 2. Newly classified lines in the Na I isoelectronic sequence $2s^2 2p^6 3s^2 S - 2s^2 2p^5 3s^2 \, ^2P^0$.

		$^2S_{1/2} - ^2P^0_{3/2}$		$^2S_{1/2} - ^2P_{1/2}$		$\Delta\upsilon(^2P^0_{1/2} - ^2P^0_{3/2})$
		λ(Å)	υ(cm^{-1})	λ(Å)	υ(cm^{-1})	(cm^{-1})
Ti	xii	27.818	3 594 700	27.489	3 637 900	43 200
V	xiii	24.517	4 078 800	24.202	4 131 900	53 100
Cr	xiv	21.770	4 593 500	21.467	4 658 300	64 800
Mn	xv	[19.450]	[5 141 400]	[19.155]	[5 220 600]	[79 200]
Fe	xvi	17.491	5 717 200	17.206	5 811 900	94 700
Co	xvii	15.828	6 317 900	15.551	6 430 500	112 600
Ni	xviii	14.37	6 959 000	14.10	7 092 000	133 000
Cu	xix	13.11	7 628 000			

Data in [ ] are from interpolation.

wavelengths. The lines must therefore belong to ions of lower degrees of ionization. It is reasonable to ascribe these lines to transitions of the type $2s^2 2p^5 3s$ (NL) - $2s^2 2p^6$ (NL), where NL represents one or more additional electrons in the $n \geq 3$ shells. A first possibility is the addition of another 3s electron, which give transitions of the type:
$2s^2 2p^5 3s^2\ {}^2P^0_{3/2\ 1/2}$ - $2s^2 2p^6 3s\ {}^2S_{1/2}$ of the Na I iso-electronic sequence. In this case we can expect two lines of energy difference close to that of the transitions $2s^2 2p^5 3s\ {}^1S_0$ - $2s^2 2p^6\ {}^3P^0_1$, ${}^1P^0_1$. Two lines fitting such a description appear on our plates for all the ions from Ti to Cu (Table II), and they have been ascribed accordingly. We call these lines Group A in Figure 1.

The rest of these additional lines are similarly interpreted. The lines which are of lower wavelengths than those in Group A, probably arise from levels with an additional electron in a shell other than the 3s. The lines which are of longer wavelength than Group A probably arise from levels with two additional electrons. We have not yet classified these lines.

Table III gives the wavelengths and energies of such lines for Ti and V. The wavelengths in Table 2 and 3 not including Ni and Cu data were measured to and accuracy of better than ± 0.005A. For Ni and Cu the wavelength accuracy is ± 0.01A. As references for wavelengths calibration we used known lines of the same element isoelectronic with Ne I [2,3,4].

Table 3. Unclassified lines ascribed to transitions of the type $2s^2\ 2p^6$ (NL) - $2s^2\ 2p^5\ 3s$ (NL) where (NL) represents one or more electrons.

Ti λ (Å)	Int	υ (cm^{-1})	V λ (Å)	Int	υ (cm^{-1})
26.86	0	3 723 000	23.678	0	4 223 300
27.20*	2	3 676 000	23.96*	2	4 173 600
27.306	2	3 662 200	24.083	2	4 152 300
27.590	2	3 624 500	24.330	3	4 110 200
			24.440	0	4 091 700
28.000	0	3 571 400	24.654	0	4 056 100
28.120	0	3 556 100	24.758	0	4 039 100

* Adifficult line to measure.

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