# THE LOWEST TERMS IN THE SPARK SPECTRUM OF NICKEL AND COPPER (NI II AND CU II)

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Abstract

The lowest terms $^2D_{2,3}$ in the spark spectrum of nickel (from the state $d^9$) are found to lie 6884 and 8391 cm$^{-1}$ below $a^4F'_5$. In the spark spectrum of copper (Cu II) the lowest term is $^1S_0(d^{10})$ and lies 21925 cm$^{-1}$ below $a^3D_3$.

THE spectra of Ni II and Cu II have been very thoroughly analysed by Shenstone.[1,2] In each of these spectra the lowest term was not found, the lines resulting from combinations between known terms and these lowest terms falling in the region just beyond the absorption of the air.

The author, at the suggestion of Dr. Shenstone, has made a careful search for these lines with the vacuum spectrograph and has succeeded in locating most of them.

## Results for Ni II

It was pointed out by Shenstone[1] that the lowest term of the spectrum of Ni II, according to the Hund theory, should be $^2D(d^{10})$ and should have a value of from 5000 to 10,000 cm$^{-1}$ below $a^4F_5'$ which was the lowest term found by him and given zero value. He stated also that its combinations with $d^8p$ might be expected to be very intense.

Several sources were tried including the vacuum-spark, the spark in hydrogen and the inductive vacuum-arc. The latter was found unsatisfactory in the case of nickel. The pure metal was tried and also nickel chloride cored into the pure metal but it was found very difficult to get any radiation from an arc in the region under investigation. All the lines which were obtained appeared also in the spark in hydrogen.

In Table I a summary is given of the results of the investigation in which all the lines are listed which may be expected to appear, whether these were found or not, and the intensities of those found are given for the three types of source used. The term values calculated from the lines found are $^2D_2 = -6884$ $^2D_3 = -8391$. In column two the wave-numbers of the lines calculated from these values for $^2D$ and Shenstone's values for the terms of $d^8p$, which may combine with them, are listed and beneath each one the actual wave-number of the line measured is enclosed in brackets. In column three the relative intensity to be expected for each line is given as it was very kindly supplied by Dr. Shenstone to the author.

The intensity of the second, fourth, seventh and twelfth lines is quite anomalous but the wave numbers in all but two cases are remarkably close

[1] Shenstone, Phys. Rev. **30**, 255 (1927).
[2] Shenstone, Phys. Rev. **29**, 380 (1927).

to the calculated values and leave little doubt regarding the validity of the $^2D$ terms. The term $^2D_3$ should now be given zero value and 8391cm$^{-1}$ added to all the terms of the Ni II spectrum as given by Shenstone.

TABLE I. *Combinations with the low $^2D$ levels of Ni II. $^2D_2 = -6884$; $^2D_3 = -8391$.*

| Designation | $\nu$ | Intensity expected | λ(I. A. vac.) | vac. spark | sp. in $H_2$ | arc |
|---|---|---|---|---|---|---|
| $^2D_2-{}^2D_2'$ | 57195 (96) | strong | 1748.37 | 7 | 5 | 1 |
| $^2D_2-{}^2D_3'$ | 55910 (10) | weak | 1788.57 | 6 | 4 | 1 |
| $^2D_3-{}^2D_3'$ | 57416 (17) | strong | 1741.63 | 7 | 5 | 2 |
| $^2D_3-{}^2D_2'$ | 58702 (03) | weak | 1703.49 | 4 | 0 | |
| $^2D_2-{}^2F_3$ | 56983 (83) | strong | 1754.90 | 3 | 1 | 0? |
| $^2D_3-{}^2F_4$ | 57077 (78) | strong | 1751.99 | 5 | 5 | 1 |
| $^2D_3-{}^2F_3$ | 58490 (89) | weak | 1709.72 | 5 | 3 | 1 |
| $^2D_2-{}^4D_2'$ | 52125 | possibly strong | | | | |
| $^2D_2-{}^4D_3'$ | 51228 (23) | weak | 1952.23 | 0 | | |
| $^2D_2-{}^4D_1'$ | 52666 | weak | | | | |
| $^2D_3-{}^4D_3'$ | 52735 | possibly strong | | | | |
| $^2D_3-{}^4D_4'$ | 51555 (54) | weak | 1939.71 | 4 | | |
| $^2D_3-{}^4D_2'$ | 52632 | weak | | | | |
| $^2D_2-{}^4F_3$ | 54565 (65) | possibly strong | 1832.68 | 2 | | |
| $^2D_2-{}^4F_2$ | 54914 | weak | | | | |
| $^2D_3-{}^4F_4$ | 55415 (17) | possibly strong | 1804.50 | 5 | 1 | |
| $^2D_3-{}^4F_3$ | 56072 | weak | | | | |
| $^2D_3-{}^4F_2$ | 56421 | very weak | | | | |
| $^2D_2-{}^4G_3'$ | 53509 | possibly strong | | | | |
| $^2D_3-{}^4G_4'$ | 54260 | possibly strong | | | | |
| $^2D_3-{}^4G_3'$ | 55016 (14) | weak | 1817.71 | 1 | | |
| $^2D_3-{}^2G_4'$ | 56368 (73) | possibly strong | 1773.85 | 6 | 1 | |

## RESULTS FOR CU II

In the spectrum of Cu II the lowest term[2] should be $^1S_0(d^{10})$ and should lie about 22224 cm$^{-1}$ lower than $a^3D_3$. The expected combinations are with $d^9p$ and consist of but three lines, one with each of the known terms, $a^3P_1 = 45987.8$, $a^3D_1' = 51173.3$ and $a^1P_1 = 51667.1$. Shenstone states also that the combination with the last of these three terms should give the most intense line.

TABLE II. *Combinations with the lowest term $^1S_0$ of Cu II.*

| Designation | λ (I. A. vac.) | $\nu$ | arc |
|---|---|---|---|
| $^1S_0-a^3P_1$ | 1472.48 | 67913 | 1 |
| $^1S_0-a^3D_1'$ | 1368.00 | 73099 | 2 |
| $^1S_0-a^1P_1$ | 1358.84 | 73592 | 12 |

Three lines found in a photograph from an inductive interrupted copper arc in vacuo meet these requirements very well. The strongest of them appears rather intensely in the vacuum spark also but they were not found in the spark in hydrogen because of the absorption of the fluorite window used between the spark chamber and the spectrograph.

The value of the lowest term as calculated from these three lines is $^1S_0 = -21925$. This value should now be added to all the term values of Cu II as listed by Shenstone.

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