Z-DEPENDENCE OF THE LEVEL INTERVALS IN
2s^2 2p^2, 2s^2 2p^3 AND 2s^2 2p^4

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Abstract. Values of the level intervals in the ground configurations 2s^2 2p^2, 2s^2 2p^3 and 2s^2 2p^4 have been critically compiled from laboratory observations and from observations of nebular and coronal forbidden transitions. The data are represented within experimental errors by means of semi-empirical extrapolation formulae which contain from 3 to 5 adjusted parameters. The results provide means for checking laboratory and astrophysical identifications and measurements. Tables of 'best' level values are given for the configurations concerned.

1. Introduction

The level intervals in the ground configurations ns^2 np^k with k = 1–5 and n = 2 and 3 are of special astrophysical interest as being involved in the majority of the forbidden lines observed in gaseous nebulae and in the solar corona. The intervals can be obtained either from laboratory observations of the resonance lines, which for higher stages of ionization fall in the extreme ultraviolet, or directly as the wavenumbers of observed nebular or coronal lines. The latter source usually gives the most accurate values and is in many cases the only one for the singlet-triplet or the doublet-quartet intervals.

The recent development of highly ionizing light sources, such as theta-pinches and laser-produced plasmas, has made it possible to extend observations of resonance lines to quite high members of the iso-electronic sequences here concerned. The only transitions of interest in this connection are of the type ns^2 2p^k–nsnp^k+1 and 3s^2 3p^k–3s^2 3p^{k-1} 3d, where Δn = 0. Work of this kind has been reported during the past few years notably from the Culham Laboratory in England, the Lebedev Institute in Moscow, and the High Altitude Observatory in Boulder, Colorado, U.S.A. Even though the accuracy in these measurements leaves something to be desired, they are of crucial importance in the search for the asymptotic Z-dependence of the ns^2 np^k intervals. Important new data have become available also from the astrophysical side from recent ground-based observations of the solar corona and especially from the rocket observations of the region 1000–2200 Å made at the solar eclipse of March 7, 1970 (Gabriel et al., 1971). This latter extension of the known coronal spectrum gave the immediate incentive to the investigation reported below on the configurations 2s^2 2p^2, 2s^2 2p^3 and 2s^2 2p^4. Similar investigations have already been published of 2s^2 2p and 2s^2 2p^5 by the present author (1969) and of 3s^2 3p^k by Svensson (1971).

In the present work we express the intervals by functions of Z which have the general form given by theory and contain a number of parameters adjusted so that
the observations are reproduced within the experimental errors. The basic assumption underlying this procedure is, of course, that the intervals are indeed 'smooth' functions of Z. So far we have found no definite indication against this assumption. In the case of $2s^2 2p^2$ and $2s^2 2p^4$ we derive from two intervals, judiciously selected, the two parameters $F_2(2p2p)$ and $\zeta_{2p}$, which are then expressed in terms of $Z$ by formulæ containing as many adjusted constants as is necessary to achieve the desired accuracy. Two or three pairs of intervals are treated in this way to obtain the relative positions of the five levels of each configuration. Since the formulæ for deriving $F_2$ and $\zeta_{2p}$ do not include effects of either spin-spin or configuration interactions, the values of these parameters obtained from different pairs of intervals will in general be different from each other and from the values as defined by theory. This is of no consequence for the present purpose because the form chosen for their $Z$-dependence will automatically include those terms in $Z$ that arise from the neglected interactions. The adopted procedure has the advantage of giving a simple and exact transition from the level intervals to the auxiliary quantities $F_2$ and $\zeta_{2p}$, and vice versa. In the case of $2s^2 2p^3$ it is necessary to adopt a different approach as will be described in the section on that configuration.

2. The Configuration $2s^2 2p^4$

We first consider the intervals involving the levels $^1D_2$, $^3P_1$, $^3P_2$. With the abbreviations $a=(^1D_2-^3P_2)$ and $b=(^3P_1-^3P_2)$ we get from theory (see e.g. Edlén, 1964, p. 112) the relations

$$a = [(6F_2)^2 + 6F_2\zeta_{2p} + (1.5 \zeta_{2p})^2]^{1/2},$$

$$2b = a - 6F_2 + 1.5 \zeta_{2p},$$

which lead to

$$12F_2 = a - 2b + [a^2 + 2(a - b) b]^{1/2},$$

$$3\zeta_{2p} = 2b (6F_2 + b)/(4F_2 + b).$$

The values of $F_2$ (in $\text{cm}^{-1}$) obtained from the observed intervals by means of (3) are accommodated by the formula:

$$F_2 = 762.10[Z - 4.12602 - 1.9803(Z - 3.30)^{-1}].$$

The coefficient 762.10 is to be compared with the 'hydrogenic' value $F_2^{\text{H}}(2p2p)=R \times 9/1280 = 771.6 \text{ cm}^{-1}$. By inserting in (4) the results of (5) together with the observed intervals $b$ we get the values of $\zeta_{2p}$ from which the following 3-parameter formula is derived:

$$\zeta_{2p} = [y + 1.684 \times 10^{-5} (\zeta_{2p})^{3/4}]^{4},$$

$$y = 0.6979(Z - 2.53688 - 1.3751 y^{-1}).$$

The coefficient 0.6979 comes reasonably close to the hydrogenic value 0.7029 cm$^{-1}$. The second term in the first equation is included to represent higher terms in the