Energy Levels of Sodium, Na I through Na XI

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Energy level data are given for the atom and all positive ions of sodium ($Z=11$). These data have been critically compiled, mainly from published material on measurements and analyses of the optical spectra. We have derived or recalculated the levels for a number of the ions. In addition to the level value in cm^{-1} and the parity, the J value and the configuration and term assignments are listed if known. Leading percentages from the calculated eigenvectors are tabulated wherever available. Ionization energies are given for all spectra.

Key words: Atomic energy levels; atomic ions; atomic spectra; electron configurations; ionization potentials; sodium.

Contents

1. Introduction

This compilation is one of a series being published by the NBS Atomic Energy Levels Data Center. The main program of this center is the critical compilation of energy level data, with emphasis at present on the first 30 elements. The more recent publications include compilations for Mg I-XII [Martin and Zalubas, 1980], Al I-XIII [Martin and Zalubas, 1979], K I-XIX [Corliss and Sugar, 1979b], Ca I-XX [Sugar and Corliss, 1979], Sc I-XXI [Sugar and Corliss, 1980], Ti I-XXII [Corliss and Sugar, 1979a], V I-XXIII [Sugar and Corliss, 1978], Cr I-XXIV [Sugar and Corliss, 1977], Mn I-XXV [Corliss and Sugar, 1977], Fe I-XXVI [Reader and Sugar 1975], and Ni I-XXVIII [Corliss and Sugar, 1981]. Simila compilations for Si and Co are in progress.

Since the general methods used in these compilations were outlined previously [Martin and Zalubas, 1979, 1980], our explanation here is confined mainly to the tables and the material preceding them. The levels for the Na spectra have been compiled from data available to us through July, 1980.

The basic data listed after the main heading for each spectrum include the appropriate isoelectronic sequence (for ions), the configuration and term designation of the ground-state level, and the wavenumber corresponding to the principal ionization energy. The ionization energy is also given in electron-volt (eV) units, an equivalence of 1 eV to 8065.479±0.021 cm^{-1} being used for the conversion [Cohen and Taylor, 1973].

We have tried to describe our use of the data from the references for each spectrum in sufficient detail to make apparent the sources for at least all major groups of levels. More complete references, and references for several types of data not included here, are given in several bibliographic publications [Moore, 1968, Hagan and Martin, 1972, Hagan, 1977, Zalubas and Albright, 1980, Fuhr, Miller, and Martin, 1978, Miller, Fuhr, and Martin, 1980]. Our starting point in collecting the references was Moore's *Atomic Energy Levels*, Vol. I.

The symbols following the references indicate types of data or other content according to a code explained in the "Bibliography on Atomic Energy Levels and Spectra" publications [Hagan and Martin, 1972]. These symbols are especially useful for references otherwise listed without comment. We note that "EL," "CL," and "IP" refer to energy levels, classified lines, and ionization potentials, respectively, and "PT" and "AT" refer to theoretical results.

The spectroscopic notations used in energy-level compilations of the AEL Data Center are described fully in a recent publication [Martin, Zalubas, and Hagan, 1978]. This reference also describes the format of the tables in detail and includes material on coupling schemes, eigenvector percentages, allowed terms, and the Zeeman effect. In general we use the notation and conventions outlined there without comment.

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The levels are given in units of cm^{-1} with respect to the ground level at zero. Odd-parity levels are printed in italics. The assignment of a set of levels to a term is indicated by grouping the levels and by listing the configuration and term symbol for only the first (lowest) level of the group. Levels within terms are listed in order of position (*not J* value), and terms are listed in order of lowest levels, ungrouped levels being treated as terms.

The "Leading Percentages" column normally gives one or two percentages from a calculated eigenvector for the level. All percentages are rounded off to the nearest percent, and the % symbol is omitted. If the level has a name (under "Configuration" and "Term"), a first percentage not followed by a term symbol is for this name component. A first percentage followed by a term symbol normally represents the largest component in the eigenvector of a level for which no particular name is appropriate, the configuration and parentage for this component being shown under "Configuration." If two percentages are listed without comment, the second percentage is the largest of the remaining percentages from the same eigenvector as the first percentage. The configuration for the second-percentage term is omitted for a level having both percentages from the same configuration. If the levels of a term group also have second percentages from a common (second) term, this second-percentage term is usually printed only for the first level of the group.

Any variation from the above conventions for the Leading Percentages is made obvious by the notation and is mentioned in the comments.

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3. Tables of Energy Levels

Na I

$Z=11$

Ground state $1s^2 2s^2 2p^6 3s\ {}^2S_{1/2}$

Ionization energy 41 449.44±0.03 cm^{-1} (5.139117±0.000013 eV)

Experimentally Determined Levels, Series Formulae, Ionization Energy

Meissner and Luft [1937] made interferometric measurements of this spectrum from 4664 to 8195 Å in one of the earliest spectroscopic applications of an atomic beam excited by electron impact. Except for the $4s\ {}^2S$ level, all levels given here to three decimal places (without brackets) were derived from their wavelength measurements [Risberg, 1956]. The experimental uncertainty of ±0.0005 Å given by Meissner and Luft apparently does not allow for error of the Kr wavelength used as the standard, which was taken as 5570.2890 Å. Combining an accurate value of the 5570 Å line in ^{86}Kr I [Kaufman and Humphreys, 1969] with recent isotope-shift measurements for this line [Jackson, 1979], we obtain a wavelength of 5570.2894±0.0001 Å for the natural Kr mixture used by Meissner and Luft. Correction for the corresponding systematic errors would lower the $3p\ {}^2P^\circ$ and $4s\ {}^2S$ levels by 0.001 cm^{-1} and the other levels by 0.002 to 0.003 cm^{-1}. We have not applied such corrections, but give the levels directly as derived by Risberg. The combined systematic and random errors are about ±0.002 cm^{-1} for the $3p\ {}^2P^\circ$ levels and ±0.004 to ±0.006 cm^{-1} for the other levels based on Meissner and Luft's measurements. The $3d$, $4d$, $5d$, and $6d\ {}^2D$ fine-structure intervals from Meissner and Luft's measurements agree with the best current values (see below) to ±0.001 cm^{-1}.

All except two of the two-place levels not in brackets are from Risberg, who measured the spectrum from a hollow-cathode source over the range 2852–11 404 Å. Johansson's [1961] measurements of several infrared wavelengths (12 679–23 379 Å) agreed with values predicted by Risberg's levels except for the $3d\ {}^2D$—$4f\ {}^2F^\circ$ line; Johansson's redetermination of the $4f\ {}^2F^\circ$ term is used here.

The $4s\ {}^2S$ level (given to three places) and the $4p\ {}^2P^\circ$ levels as confirmed by Johansson's measurements are probably accurate to ±0.02 cm^{-1}. The other levels determined by Risberg agree with the predictions of series formulae (see below) to within ±0.02 cm^{-1}, except for the $9d$–$11d\ {}^2D$ and $9f\ {}^2F^\circ$ terms. Values of the 7d–11d ^{2}D and $4f$–$10f\ {}^2F^\circ$ terms from series formulae are given below.

The $5g\ {}^2G$ term was derived by Litzén [1970] from his measurement of the $4f$–$5g$ wavelength (40 431.88 Å) with an uncertainty of ±0.01 cm^{-1} in the experimental wavenumber. An error of the $4f\ {}^2F^\circ$ level and/or a Stark shift of the observed line would contribute to the error of the $5g\ {}^2G$ position, however. Since Litzén deduced probable Stark shifts of ~0.07 cm^{-1} for the $5g$ levels in Li I and K I under similar experimental conditions, it seems appropriate to assume an uncertainty at least that large for the Na I $5g\ {}^2G$ level. The quantum-defect formula used to calculate the higher $ng\ {}^2G$ terms given here predicts the $5g\ {}^2G$ level at 37 059.50 cm^{-1}.

Risberg derived series formulae fitting the lowest few terms of each of the series $ns\ {}^2S_{1/2}$, $np\ {}^2P^\circ_{1/2}$, $np\ {}^2P^\circ_{3/2}$, $nd\ {}^2D$, and $nf\ {}^2F^\circ$, and obtained the quoted ionization energy. The levels given here in brackets have been derived from series formulae with Risberg's value for the ionization limit. Except for the $np\ {}^2P^\circ_{3/2}$ levels, the values were calculated with formulae given by Martin [1980]; the ^{2}S, ^{2}P°, and ^{2}D formulae are equivalent to the corresponding formulae of Risberg to within <0.01 cm^{-1} in the predicted terms.

In general the uncertainty of the predicted levels with respect to the ground level is equal to the uncertainty of the limit, about ±0.03 cm^{-1}. All levels below the ionization limit can be obtained to within this approximate uncertainty from the formulae, the termination of the calculated nl levels tabulated here being arbitrary. The calculated levels are given to three decimal places because the uncertainty of any nl–$n'l'$ separation obtained from the formulae is less than 0.01 cm^{-1} for sufficiently high n and n'.

A considerable part of the more recent spectroscopy of the alkali atoms has been devoted to observations of Stark and/or hyperfine structures. Data of these types are not included here, but we note that bibliographies covering both subjects through June 1979 are available [see the introduction].

$ns\ {}^2S$ and $np\ {}^2P^\circ$ Terms: Higher Levels, $np\ {}^2P^\circ$ Fine Structure

Calculated values are listed for the $ns\ {}^2S$ and $np\ {}^2P^\circ$ levels through $n=50$. The $ns\ {}^2S$ levels for $n=13$–50 and the $np\ {}^2P^\circ_{1/2}$ levels for $n=9$–40 were calculated with the $ns\ {}^2S_{1/2}(1)$ and $np\ {}^2P^\circ_{1/2}$ quantum-defect formulae given by Martin. The $np\ {}^2P^\circ$ terms for $n=41$–50 are given at the baricenter of the $^2P^\circ_{1/2}$ and $^2P^\circ_{3/2}$ positions predicted by the respective formulae.

The $np\ {}^2P^\circ_{3/2}$ levels for $n=9$–40 were obtained by adding fine-structure intervals $\Delta E(^2P^\circ)$ to the $np\ {}^2P^\circ_{1/2}$ levels, with

$$\Delta E(^2P^\circ) = A(n^*)^{-3} - B(n^*)^{-5},$$

$$A = 179.7\pm0.4\ \mathrm{cm}^{-1}\quad (5387\pm12\ \mathrm{GHz}),$$

$$B = 73.8\pm2\ \mathrm{cm}^{-1}\quad (2212\pm60\ \mathrm{GHz}).$$

The constants A and B were derived by fitting the experimental $3p\ ^2\mathrm{P}^\circ$ interval and the $np\ ^2\mathrm{P}^\circ$ intervals as determined by microwave techniques for $n=16$–19 [Gallagher et al., 1977b] and for $n=23$–25 and 32–36 [Fabre et al., 1980]. An approximate value for the quantum defect $n - n^* = 0.855$ can be used in evaluating this $\Delta E(^2\mathrm{P}^\circ)$ expression for high values of n. In fitting the $3p\ ^2\mathrm{P}^\circ$ interval, which mainly determines the value of B, we used the n^* values of the $^2\mathrm{P}^\circ_{3/2}$ level; sufficiently accurate values of $n^*(^2\mathrm{P}^\circ_{3/2})$ [Risberg, 1956, Martin, 1980] should be used in evaluating the expression at lower values of n. The predicted $4p$ and $5p\ ^2\mathrm{P}^\circ$ intervals agree with the experimental values to within $<0.01\ \mathrm{cm}^{-1}$, and the predicted intervals for $6p$–$8p$ may well be more accurate than the experimental values. The predicted $9p$–$15p$ intervals are more accurate than the corresponding differences of levels from the Ritz formulae.

The accuracy of the above $\Delta E(^2\mathrm{P}^\circ)$ formula for high n is much greater than can be shown by the three-place intervals used for the table here, the accuracy of course deriving from the accuracy of the microwave data. For comparisons at the level of accuracy of the microwave data, it should be noted that the predicted intervals for $16p$–$19p\ ^2\mathrm{P}^\circ$ are slightly less than the experimental values, whereas most of the more accurate experimental $^2\mathrm{P}^\circ$ intervals in the $23p$–$36p$ range are slightly less than the formula values. For example, the formula gives intervals of 1067.4 MHz and 495.6 MHz for $18p$ and $23p\ ^2\mathrm{P}^\circ$, respectively, whereas the experimental values are 1068.4±1.5 MHz [Gallagher et al., 1977b] and 494.6±1.2 MHz [Fabre et al., 1980]. The internal consistency of either the $16p$–$19p$ data or the $23p$–$36p$ data would correspond to errors of the constants A and B about half those given above.

Fabre et al. [1980] observed millimeter resonances due to $ns\ ^2\mathrm{S}_{1/2}$—$n'p\ ^2\mathrm{P}^\circ_{1/2}$ and $ns\ ^2\mathrm{S}_{1/2}$—$n'p\ ^2\mathrm{P}^\circ_{3/2}$ transitions ($n' = n$ or $n' = n+1$) in the ranges $n'=23$–25 and 32–36. The frequencies of the corresponding transitions obtained from the levels here agree with the accurate microwave data to the nearest $0.001\ \mathrm{cm}^{-1}$. The levels here also give agreement with the $ns\ ^2\mathrm{S}_{1/2}$—$(n+1)s\ ^2\mathrm{S}_{1/2}$ separations obtained by Goy et al. [1980] from their observations of two-photon millimeter resonances (n ranging from 32 to 40). The microwave data are much more accurate than $\pm0.001\ \mathrm{cm}^{-1}$, and quantum-defect formulae fitting the results for these high states to within the experimental uncertainties are given by Fabre et al. [1980] and Goy et al. An earlier paper by Fabre et al. [1978] includes several experimental term separations (in the range $n=23$–41) not remeasured in the more recent work; the results have been compared with the predictions of the formulae [Martin, 1980].

Thackeray [1949] observed the $3s\ ^2\mathrm{S}_{1/2}$—$np\ ^2\mathrm{P}^\circ$ series to $n=73$, but most of his measurements deviate systematically by about $0.2\ \mathrm{cm}^{-1}$ from the wavenumbers predicted for these lines by Risberg's data [Risberg, 1956]. The $17p\ ^2\mathrm{P}^\circ$ position determined by Ducas and Zimmerman [1977], 41 028.43 $\pm0.04\ \mathrm{cm}^{-1}$, agrees with the predicted value of 41 028.44$\pm0.03\ \mathrm{cm}^{-1}$ (for the baricenter of the $17p\ ^2\mathrm{P}^\circ_{1/2}$ and $^2\mathrm{P}^\circ_{3/2}$ levels).

nd ^{2}D Terms and Fine Structure

The tabulation of these terms as obtained from the quantum-defect formula extends through $n=30$. Gallagher et al. [1976b] derived experimental quantum defects for *nd*, *nf*, and *ng* terms in the range $n=13$–17 from experimental microwave frequencies corresponding to separations of the types *nd*–*nf*, *nd*–*ng*, and *nd*–*nh*. The quantum defects predicted by the $nd\ ^2\mathrm{D}$ formula we used agree with the accurate experimental defects in this range to within equivalent term errors smaller than $0.001\ \mathrm{cm}^{-1}$ [Martin, 1980]. This agreement implies that the uncertainty of the calculated $nd\ ^2\mathrm{D}$ levels near and above $n=13$ is equal to the uncertainty of the limit, $\pm0.03\ \mathrm{cm}^{-1}$. Risberg's experimental values for the $7d$–$11d\ ^2\mathrm{D}$ levels are lower than the calculated values by 0.02 to $0.08\ \mathrm{cm}^{-1}$ [Risberg, 1956, Martin, 1980]; although Risberg was unable to explain the larger discrepancies, the predicted values for these levels are probably more accurate than the experimental values given in the main table here. We thus list the following predicted $nd\ ^2\mathrm{D}$ levels, the fine-structure intervals being taken to agree to the nearest $0.001\ \mathrm{cm}^{-1}$ with much more accurate values given in references cited below:

Term	J	Level (cm^{-1})
$7d\ ^2\mathrm{D}$	5/2	[39200.944]
	3/2	[39200.953]
$8d\ ^2\mathrm{D}$	5/2	[39728.713]
	3/2	[39728.719]
$9d\ ^2\mathrm{D}$	5/2	[40090.350]
	3/2	[40090.354]
$10d\ ^2\mathrm{D}$	5/2	[40348.908]
	3/2	[40348.911]
$11d\ ^2\mathrm{D}$	5/2	[40540.137]
	3/2	[40540.139]

Among the more recent determinations of the inverted $nd\ ^2\mathrm{D}$ fine-structure intervals are those by Salour [1976] ($n=3$, 6, 7, 8), Eckstein et al. [1978] ($n=4$), Fredriksson and Svanberg [1976] ($n=4$–9), Fabre et al. [1975] ($n=9$–16), Gallagher et al. [1976a] ($n=11$–16), Gallagher et al. [1977b] ($n=15$–17), and Leuchs and Walther [1979] ($n=21$–31). The measurements for the $4d$–$17d$ and $21d$–$31d$ terms have yielded the intervals with stated uncertainties of ±1 to ±0.1 MHz (±0.00003 to $\pm0.000003\ \mathrm{cm}^{-1}$). The data are too extensive for separate tabulation here, but we quote a two-term formula that predicts the intervals $\Delta E(^2\mathrm{D})$ for $n\geqslant4$ with good accuracy [Leuchs and Walther, 1979]:

$$\Delta E(^2\mathrm{D}) = -A(n^*)^{-3} + B(n^*)^{-5},$$

$$A = 97.8\pm1.1\ \mathrm{GHz}\quad (3.262\pm0.037\ \mathrm{cm}^{-1}),$$

$$B = 519 \pm 11\ \mathrm{GHz}\quad (17.31\pm0.37\ \mathrm{cm}^{-1}).$$

The approximation $n^* = n - 0.014$ should be used with these values of the constants, which Leuchs and Walther redetermined using the experimental $4d$ and $23d\ ^2\mathrm{D}$ intervals (-1028.4±0.4 MHz [Eckstein et al., 1978] and -8.00 ±0.10 MHz).

Theoretical calculations of the $nd\ ^2\mathrm{D}$ fine structures have been made by Luc-Koenig [1976] (n=3-16), Holmgren et al. [1976] (n=3-6), and Sternheimer et al. [1978] (n=3-6), for example.

Cooke et al. [1977] measured the frequencies of $nd\ ^2\mathrm{D}_{3/2}$—$(n+1)p\ ^2\mathrm{P}^\circ_{1/2}$ and $nd\ ^2\mathrm{D}_{3/2}$—$(n+1)p\ ^2\mathrm{P}^\circ_{3/2}$ transitions for n=30-32. The corresponding frequencies predicted by quantum-defect formulae for the $nd\ ^2\mathrm{D}$ (baricenter) and $np\ ^2\mathrm{P}^\circ_{1/2}$ positions [Martin, 1980], together with the formulae for the $\Delta E(^2\mathrm{D})$ and $\Delta E(^2\mathrm{P}^\circ)$ intervals, agree with the observed frequencies to within the experimental errors of ±4 MHz (±0.00013 cm^{-1}). Similarly predicted frequencies for the $29d\ ^2\mathrm{D}$—$31p\ ^2\mathrm{P}^\circ$ and $28d\ ^2\mathrm{D}$—$29d\ ^2\mathrm{D}$ separations agree with the measurements of Fabre et al. [1978] to within their experimental errors.

nl (*l*⩾3) Terms and Fine Structure

The $nf\ ^2\mathrm{F}^\circ$ terms are given through n=30, the $ng\ ^2\mathrm{G}$ terms through n=20, and the $nh\ ^2\mathrm{H}^\circ$ and $ni\ ^2\mathrm{I}$ terms through n=10. The derivations of the formulae used to calculate the bracketed levels have been described elsewhere [Martin, 1980]. Accurate experimental quantum defects for the $13f$–$17f\ ^2\mathrm{F}^\circ$ terms [Gallagher et al., 1976b] were included in the evaluation of the $nf\ ^2\mathrm{F}^\circ$-formula constants. The quantum defects from the $ng\ ^2\mathrm{G}$ and $nh\ ^2\mathrm{H}^\circ$ formulae, also, agree with experimental values [Gallagher et al., 1976b] and theoretical values [Freeman and Kleppner, 1976] for $13g$–$15g\ ^2\mathrm{G}$ and $13h$–$15h\ ^2\mathrm{H}^\circ$ to within equivalent term errors that are negligible compared with the ±0.03 cm^{-1} uncertainty of the limit. For comparison with the experimental values in the main table, the predicted values of the $4f$–$10f\ ^2\mathrm{F}^\circ$ terms are:

Term	Level (cm^{-1})
$4f\ ^2\mathrm{F}^\circ$	[34586.902]
$5f\ ^2\mathrm{F}^\circ$	[37057.672]
$6f\ ^2\mathrm{F}^\circ$	[38399.792]
$7f\ ^2\mathrm{F}^\circ$	[39209.003]
$8f\ ^2\mathrm{F}^\circ$	[39734.183]
$9f\ ^2\mathrm{F}^\circ$	[40094.226]
$10f\ ^2\mathrm{F}^\circ$	[40351.751]

There is some indication that the calculated $nf\ ^2\mathrm{F}^\circ$ levels in the region of n=28 are too high with respect to the nearby calculated $nd\ ^2\mathrm{D}$ levels by ~100 MHz (0.003 to 0.004 cm^{-1}) [Martin, 1980].

Measurements of the fine-structure intervals for several $nf\ ^2\mathrm{F}^\circ$ terms have shown them to be close to hydrogenic values. Bjorkholm and Liao [1976] observed non-allowed two-photon $3s\ ^2\mathrm{S}_{1/2}$—$4f\ ^2\mathrm{F}^\circ$ transitions and determined the $4f\ ^2\mathrm{F}^\circ$ interval as 229±4 MHz; the value given by the hydrogenic formulae [Erickson, 1977] adjusted to the Na nuclear mass is 228.6 MHz (0.007626 cm^{-1}). Gallagher et al. [1977a] measured the intervals for the $11f$, $13f$, and $14f\ ^2\mathrm{F}^\circ$ terms to about 2% uncertainties and obtained values about 5% less than the hydrogenic values. Less accurate values for the $11f$–$17f\ ^2\mathrm{F}^\circ$ intervals were measured earlier by Gallagher et al. [1976a].

The results for the $nf\ ^2\mathrm{F}^\circ$ intervals lead to the expectation of near-hydrogenic fine structures for the terms of higher angular momentum (l⩾4). The $13g$–$17g\ ^2\mathrm{G}$ and $13h$–$15h\ ^2\mathrm{H}^\circ$ intervals measured by Gallagher et al. [1976b] are consistent with hydrogenic values, but the uncertainties are, respectively, comparable to and about three times larger than the hydrogenic intervals.

g_J Values

Accurate measurements of the relatively small deviations from Landé g_J values (corrected for the anomalous magnetic moment of the electron) are of interest in one-electron spectra. Beahn and Bedard [1977] determined the g_J value of the $3s\ ^2\mathrm{S}_{1/2}$ ground state of $^{23}\mathrm{Na}$ as 2.00229563 ±0.00000016 using a spin-exchange optical pumping technique and known data for $^{87}\mathrm{Rb}$ and for the electron. Hartmann [1970], by the optical double-resonance technique, obtained a value of 0.66581±0.00012 for the g_J value of the $3p\ ^2\mathrm{P}^\circ_{1/2}$ level.

Levels Above the Ionization Limit

Configurations involving excitations from the $2p$ or $2s$ shell have been identified in the interpretation of photoabsorption spectra below 410 Å. Lines observed in absorption from the ground level were assumed to arise from transitions to odd-parity levels having $J=\frac{1}{2}$ or $\frac{3}{2}$. Connerade et al. [1971] measured such features in the region 180–410 Å, their classifications including the outstanding doublet $2s^22p^63s\ ^2\mathrm{S}_{1/2}$—$2s^22p^53s^2\ ^2\mathrm{P}^\circ_{3/2,\ 1/2}$ near 400 Å. Wolff et al. [1972] also observed the ground-level absorption spectrum, including many (mostly weaker) lines not observed by Connerade et al. Most of the odd levels given here between the Na II $2s^22p^6\ ^1\mathrm{S}_0$ and $2s^22p^53s\ ^1\mathrm{P}^\circ_1$ limits are from lines measured by both of these groups, the two wavenumber determinations having been averaged. A few levels from lines measured only by Wolff et al. are included. Most of the levels are probably accurate to within ±20 cm^{-1}. These levels must belong mainly to $2s^22p^53sns$ and $2s^22p^53snd$ (n⩾3) configurations, but their detailed interpretation will in most cases probably require calculations including the significant configuration interactions [Wolff et al., 1972]. We have followed Wolff et al. in listing a number of the levels below 306 500 cm^{-1} without configuration assignments. Their suggested assignments for some of the other levels in this region are given tentatively. Connerade et al. suggested different assignments for most of these levels. The identifications of higher members of the overlapping series $2s^22p^53s(^1\mathrm{P}^\circ)nd$ ($n=6$–12) and $2s^22p^53s(^1\mathrm{P}^\circ)ns\ ^2\mathrm{P}^\circ$ ($n=7$–9) were made by Connerade et al. These series were extended by Wolff et al. to $n=20$ and to $n=12$, respectively, the $(^1\mathrm{P}^\circ)nd$ features being interpreted as arising from all three transitions (to the $J=\frac{1}{2}$, $\frac{3}{2}$, $\frac{3}{2}$ levels) allowed by the J selection rule. We have not listed these $(^1\mathrm{P}^\circ)nd$ positions above $n=12$.

The levels of the $2s^22p^53s3p$ and $2s^22p^53s4p$ even configurations are from absorption lines (356–398 Å) observed by Sugar et al. [1979] and classified as transitions from the excited $2s^22p^63p\ ^2\mathrm{P}^\circ$ lower term. We have evaluated the upper levels directly from the experimental wavelengths; since the $3p\ ^2\mathrm{P}^\circ_{3/2}$—$^2\mathrm{P}^\circ_{1/2}$ separation of 17 cm^{-1} was not resolved, the upper levels having $J=\frac{1}{2}$ or $\frac{3}{2}$ were obtained with values for the lower $3p\ ^2\mathrm{P}^\circ$ term adjusted to the theoretical (statistical) intensities of the two unresolved components of each line. The stated wavelength error of ±0.02 Å corresponds to a level error of about ±15 cm^{-1}.

Even-parity autoionizing levels of Na I have also been identified from ejected-electron spectra [see, e.g., Ross et al., 1976, and Pegg et al., 1975]. Sugar et al. reinterpreted several features in these spectra on the basis of their calculations of the above configurations (including interactions with additional configurations). The levels derived from electron data are not included here. Berry et al. [1974] suggested the classification $2s^22p^5(^2\mathrm{P}^\circ)3s3p(^3\mathrm{P}^\circ)\ ^4\mathrm{D}_{7/2}$—$2s^22p^5(^2\mathrm{P}^\circ)3s3d(^3\mathrm{D})\ ^4\mathrm{F}^\circ_{9/2}$ for a line observed at 3882.8 Å in beam-foil spectra. No other optical lines involving these levels have been classified, but the $^4\mathrm{D}_{7/2}$ level can be estimated from the calculations of Sugar et al. as near 266 500 cm^{-1}.

Connerade et al. and Wolff et al. observed features in the absorption spectrum above the Na II $2s^22p^53s\ ^1\mathrm{P}^\circ$ limit due to transitions of the type $2s^22p^63s\ ^2\mathrm{S}_{1/2}$—$2s^22p^5nln'l'$, with neither nl nor $n'l'$ (in the principal configuration of the upper odd-parity term) being a $3s$ electron. The positions and $2s^22p^53p^2$ configuration assignments of the lowest two such levels listed by Connerade et al. are tabulated here. Most of the observed features are asymmetric and very autoionization-broadened, and they include a number of window resonances. Several additional levels (up to 335 200 cm^{-1}) with assignments to $2s^22p^53pnp$ ($n=3$–7) configurations are given by Connerade et al.

The four $^2\mathrm{P}^\circ$ terms assigned to configurations with a $2s$ vacancy (535 330–586 200 cm^{-1}) are from resonances observed in absorption from the ground level by LaVilla et al. [1981]. The positions correspond to the absorption maxima to within estimated uncertainties of 200 cm^{-1} (for the lowest of these terms) to 350 cm^{-1}. The three lower-energy features were classified earlier by Wolff et al.; their values for the energies, which are above the corresponding absorption maxima by about 1800 cm^{-1}, are less accurately determined but closer to the resonance centers. The strong $2s(^2\mathrm{S})2p^63s3p(^3\mathrm{P}^\circ)\ ^2\mathrm{P}^\circ$ resonance, which was first observed by Connerade et al., has a striking Beutler-Fano profile with a width of about 2700 cm^{-1} [Codling et al., 1977]. LaVilla et al. give the energies and tentative classifications for several higher resonances (up to 636 600 cm^{-1}).

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Na I

Configuration	Term	*J*	Level (cm^{-1})
3*s*	^{2}S	1/2	0.000
3*p*	^{2}P°	1/2	*16 956.172*
		3/2	*16 973.368*
4*s*	^{2}S	1/2	25 739.991
3*d*	^{2}D	5/2	29 172.839
		3/2	29 172.889
4*p*	^{2}P°	1/2	*30 266.99*
		3/2	*30 272.58*
5*s*	^{2}S	1/2	33 200.675
4*d*	^{2}D	5/2	34 548.731
		3/2	34 548.766
4*f*	^{2}F°	5/2,7/2	*34 586.92*
5*p*	^{2}P°	1/2	*35 040.38*
		3/2	*35 042.85*
6*s*	^{2}S	1/2	36 372.620
5*d*	^{2}D	5/2	37 036.754
		3/2	37 036.774
5*f*	^{2}F°	5/2,7/2	*37 057.65*
5*g*	^{2}G	7/2,9/2	37 059.54
6*p*	^{2}P°	1/2	*37 296.32*
		3/2	*37 297.61*
7*s*	^{2}S	1/2	38 012.044
6*d*	^{2}D	5/2	38 387.257
		3/2	38 387.270
6*f*	^{2}F°	5/2,7/2	*38 399.79*
6*g*	^{2}G	7/2,9/2	[38 400.896]
6*h*	^{2}H°	9/2,11/2	[*38 401.140*]
7*p*	^{2}P°	1/2	*38 540.18*
		3/2	*38 540.93*
8*s*	^{2}S	1/2	38 968.51
7*d*	^{2}D	5/2,3/2	39 200.93
7*f*	^{2}F°	5/2,7/2	*39 208.98*
7*g*	^{2}G	7/2,9/2	[39 209.717]
7*h*	^{2}H°	9/2,11/2	[*39 209.87*
7*i*	^{2}I	11/2,13/2	[39 209.927
8*p*	^{2}P°	1/2	*39 298.35*
		3/2	*39 298.84*
9*s*	^{2}S	1/2	39 574.85
8*d*	^{2}D	5/2,3/2	39 728.70
8*f*	^{2}F°	5/2,7/2	*39 734.16*
8*g*	^{2}G	7/2,9/2	[39 734.669
8*h*	^{2}H°	9/2,11/2	[*39 734.77*
8*i*	^{2}I	11/2,13/2	[39 734.814
9*p*	^{2}P°	1/2	[*39 794.48*
		3/2	[*39 794.81*
10*s*	^{2}S	1/2	39 983.27
9*d*	^{2}D	5/2,3/2	40 090.31
9*f*	^{2}F°	5/2,7/2	*40 094.19*
9*g*	^{2}G	7/2,9/2	[40 094.571
9*h*	^{2}H°	9/2,11/2	[*40 094.64*
9*i*	^{2}I	11/2,13/2	[40 094.674
10*p*	^{2}P°	1/2	[*40 136.805*
		3/2	[*40 137.03*
11*s*	^{2}S	1/2	40 271.38
10*d*	^{2}D	5/2,3/2	40 348.83
10*f*	^{2}F°	5/2,7/2	*40 351.77*
10*g*	^{2}G	7/2,9/2	[40 352.004
10*h*	^{2}H°	9/2,11/2	[*40 352.06*
10*i*	^{2}I	11/2,13/2	[40 352.081
11*p*	^{2}P°	1/2	[*40 382.92*
		3/2	[*40 383.091*
12*s*	^{2}S	1/2	40 482.22
11*d*	^{2}D	5/2,3/2	40 540.07
11*f*	^{2}F°	5/2,7/2	[*40 542.282*

Na I—Continued

Configuration	Term	J	Level (cm^{-1})	Configuration	Term	J	Level (cm^{-1})
11*g*	^{2}G	7/2,9/2	[40 542.474]	17*p*	^{2}P°	1/2 3/2	[*41 028.410*] [*41 028.453*]
12*p*	^{2}P°	1/2 3/2	[*40 565.777*] [*40 565.906*]	18*s*	^{2}S	1/2	[41 053.690]
13*s*	^{2}S	1/2	[40 641.138]	17*d*	^{2}D	3/2,5/2	[41 069.075]
12*d*	^{2}D	3/2,5/2	[40 685.535]	17*f*	^{2}F°	5/2,7/2	[*41 069.663*]
12*f*	^{2}F°	5/2,7/2	[*40 687.193*]	17*g*	^{2}G	7/2,9/2	[41 069.716]
12*g*	^{2}G	7/2,9/2	[40 687.341]	18*p*	^{2}P°	1/2 3/2	[*41 076.096*] [*41 076.132*]
13*p*	^{2}P°	1/2 3/2	[*40 705.337*] [*40 705.437*]	19*s*	^{2}S	1/2	[41 097.261]
14*s*	^{2}S	1/2	[40 763.874]	18*d*	^{2}D	3/2,5/2	[41 110.196]
13*d*	^{2}D	3/2,5/2	[40 798.656]	18*f*	^{2}F°	5/2,7/2	[*41 110.692*]
13*f*	^{2}F°	5/2,7/2	[*40 799.964*]	18*g*	^{2}G	7/2,9/2	[41 110.737]
13*g*	^{2}G	7/2,9/2	[40 800.081]	19*p*	^{2}P°	1/2 3/2	[*41 116.116*] [*41 116.146*]
14*p*	^{2}P°	1/2 3/2	[*40 814.265*] [*40 814.344*]	20*s*	^{2}S	1/2	[41 134.012]
15*s*	^{2}S	1/2	[40 860.637]	19*d*	^{2}D	3/2,5/2	[41 144.992]
14*d*	^{2}D	3/2,5/2	[40 888.393]	19*f*	^{2}F°	5/2,7/2	[*41 145.414*]
14*f*	^{2}F°	5/2,7/2	[*40 889.442*]	19*g*	^{2}G	7/2,9/2	[41 145.452]
14*g*	^{2}G	7/2,9/2	[40 889.536]	20*p*	^{2}P°	1/2 3/2	[*41 150.030*] [*41 150.056*]
15*p*	^{2}P°	1/2 3/2	[*40 900.913*] [*40 900.976*]	21*s*	^{2}S	1/2	[41 165.298]
16*s*	^{2}S	1/2	[40 938.271]	20*d*	^{2}D	3/2,5/2	[41 174.697]
15*d*	^{2}D	3/2,5/2	[40 960.772]	20*f*	^{2}F°	5/2,7/2	[*41 175.059*]
15*f*	^{2}F°	5/2,7/2	[*40 961.626*]	20*g*	^{2}G	7/2,9/2	[41 175.092]
15*g*	^{2}G	7/2,9/2	[40 961.703]	21*p*	^{2}P°	1/2 3/2	[*41 179.020*] [*41 179.042*]
16*p*	^{2}P°	1/2 3/2	[*40 970.967*] [*40 971.019*]	22*s*	^{2}S	1/2	[41 192.149]
17*s*	^{2}S	1/2	[41 001.504]	21*d*	^{2}D	3/2,5/2	[41 200.257]
16*d*	^{2}D	3/2,5/2	[41 019.998]	21*f*	^{2}F°	5/2,7/2	[*41 200.570*]
16*f*	^{2}F°	5/2,7/2	[*41 020.703*]	22*p*	^{2}P°	1/2 3/2	[*41 203.994*] [*41 204.013*]
16*g*	^{2}G	7/2,9/2	[41 020.766]	23*s*	^{2}S	1/2	[41 215.367]

Na I—Continued

Configuration	Term	J	Level (cm^{-1})
22*d*	$^2\mathrm{D}$	3/2, 5/2	[41 222.410]
22*f*	$^2\mathrm{F}^\circ$	5/2, 7/2	[*41 222.682*]
23*p*	$^2\mathrm{P}^\circ$	1/2 3/2	[*41 225.662*] [*41 225.679*]
24*s*	$^2\mathrm{S}$	1/2	[41 235.578]
23*d*	$^2\mathrm{D}$	3/2, 5/2	[41 241.734]
23*f*	$^2\mathrm{F}^\circ$	5/2, 7/2	[*41 241.973*]
24*p*	$^2\mathrm{P}^\circ$	1/2 3/2	[*41 244.582*] [*41 244.596*]
25*s*	$^2\mathrm{S}$	1/2	[41 253.280]
24*d*	$^2\mathrm{D}$	3/2, 5/2	[41 258.693]
24*f*	$^2\mathrm{F}^\circ$	5/2, 7/2	[*41 258.903*]
25*p*	$^2\mathrm{P}^\circ$	1/2 3/2	[*41 261.200*] [*41 261.213*]
26*s*	$^2\mathrm{S}$	1/2	[41 268.872]
25*d*	$^2\mathrm{D}$	3/2, 5/2	[41 273.656]
25*f*	$^2\mathrm{F}^\circ$	5/2, 7/2	[*41 273.842*]
26*p*	$^2\mathrm{P}^\circ$	1/2 3/2	[*41 275.875*] [*41 275.886*]
27*s*	$^2\mathrm{S}$	1/2	[41 282.676]
26*d*	$^2\mathrm{D}$	3/2, 5/2	[41 286.925]
26*f*	$^2\mathrm{F}^\circ$	5/2, 7/2	[*41 287.090*]
27*p*	$^2\mathrm{P}^\circ$	1/2 3/2	[*41 288.899*] [*41 288.909*]
28*s*	$^2\mathrm{S}$	1/2	[41 294.955]
27*d*	$^2\mathrm{D}$	3/2, 5/2	[41 298.747]
27*f*	$^2\mathrm{F}^\circ$	5/2, 7/2	[*41 298.894*]
28*p*	$^2\mathrm{P}^\circ$	1/2 3/2	[*41 300.510*] [*41 300.519*]
29*s*	$^2\mathrm{S}$	1/2	[41 305.927]
28*d*	$^2\mathrm{D}$	3/2, 5/2	[41 309.324]
28*f*	$^2\mathrm{F}^\circ$	5/2, 7/2	[*41 309.456*]
29*p*	$^2\mathrm{P}^\circ$	1/2 3/2	[*41 310.905*] [*41 310.913*]
30*s*	$^2\mathrm{S}$	1/2	[41 315.770]
29*d*	$^2\mathrm{D}$	3/2, 5/2	[41 318.825]
29*f*	$^2\mathrm{F}^\circ$	5/2, 7/2	[*41 318.944*]
30*p*	$^2\mathrm{P}^\circ$	1/2 3/2	[*41 320.249*] [*41 320.256*]
31*s*	$^2\mathrm{S}$	1/2	[41 324.634]
30*d*	$^2\mathrm{D}$	3/2, 5/2	[41 327.392]
30*f*	$^2\mathrm{F}^\circ$	5/2, 7/2	[*41 327.499*]
31*p*	$^2\mathrm{P}^\circ$	1/2 3/2	[*41 328.678*] [*41 328.685*]
32*s*	$^2\mathrm{S}$	1/2	[41 332.644]
32*p*	$^2\mathrm{P}^\circ$	1/2 3/2	[*41 336.309*] [*41 336.315*]
33*s*	$^2\mathrm{S}$	1/2	[41 339.908]
33*p*	$^2\mathrm{P}^\circ$	1/2 3/2	[*41 343.238*] [*41 343.243*]
34*s*	$^2\mathrm{S}$	1/2	[41 346.514]
34*p*	$^2\mathrm{P}^\circ$	1/2 3/2	[*41 349.550*] [*41 349.555*]
35*s*	$^2\mathrm{S}$	1/2	[41 352.540]
35*p*	$^2\mathrm{P}^\circ$	1/2 3/2	[*41 355.315*] [*41 355.320*]
36*s*	$^2\mathrm{S}$	1/2	[41 358.052]
36*p*	$^2\mathrm{P}^\circ$	1/2 3/2	[*41 360.596*] [*41 360.600*]
37*s*	$^2\mathrm{S}$	1/2	[41 363.107]
37*p*	$^2\mathrm{P}^\circ$	1/2 3/2	[*41 365.444*] [*41 365.448*]
38*s*	$^2\mathrm{S}$	1/2	[41 367.754]
38*p*	$^2\mathrm{P}^\circ$	1/2 3/2	[*41 369.906*] [*41 369.909*]

Na I—Continued

Configuration	Term	J	Level (cm^{-1})
$39s$	^2S	1/2	[41 372.035]
$39p$	$^2P^\circ$	1/2 3/2	[*41 374.021*] [*41 374.024*]
$40s$	^2S	1/2	[41 375.989]
$40p$	$^2P^\circ$	1/2 3/2	[*41 377.825*] [*41 377.828*]
$41s$	^2S	1/2	[41 379.647]
$41p$	$^2P^\circ$	1/2,3/2	[*41 381.351*]
$42s$	^2S	1/2	[41 383.038]
$42p$	$^2P^\circ$	1/2,3/2	[*41 384.620*]
$43s$	^2S	1/2	[41 386.188]
$43p$	$^2P^\circ$	1/2,3/2	[*41 387.660*]
$44s$	^2S	1/2	[41 389.119]
$44p$	$^2P^\circ$	1/2,3/2	[*41 390.490*]
$45s$	^2S	1/2	[41 391.852]
$45p$	$^2P^\circ$	1/2,3/2	[*41 393.131*]
$46s$	^2S	1/2	[41 394.402]
$46p$	$^2P^\circ$	1/2,3/2	[*41 395.598*]
$47s$	^2S	1/2	[41 396.787]
$47p$	$^2P^\circ$	1/2,3/2	[*41 397.906*]
$48s$	^2S	1/2	[41 399.020]
$48p$	$^2P^\circ$	1/2,3/2	[*41 400.069*]
$49s$	^2S	1/2	[41 401.114]
$49p$	$^2P^\circ$	1/2,3/2	[*41 402.099*]
$50s$	^2S	1/2	[41 403.080]
$50p$	$^2P^\circ$	1/2,3/2	[*41 404.006*]
Na II $2s^22p^6(^1S_0)$	***Limit***		**41 449.44**
$2s^2 2p^5 3s^2$	$^2P^\circ$	3/2 1/2	*248 159* *249 503*
$2s^2 2p^5(^2P^\circ)3s3p(^3P^\circ)$	^4P	5/2 3/2 1/2	268 533 268 933
$2s^2 2p^5(^2P^\circ)3s3p(^3P^\circ)$	^2D	3/2 5/2	269 727 270 196
$2s^2 2p^5(^2P^\circ)3s3p(^3P^\circ)$	^2P	1/2 3/2	270 582 270 881
$2s^2 2p^5(^2P^\circ)3s3p(^3P^\circ)$	^2S	1/2	273 240
$2s^2 2p^5(^2P^\circ)3s3p(^1P^\circ)$	^2D	5/2 3/2	280 596 282 063
$2s^2 2p^5(^2P^\circ)3s3p(^1P^\circ)$	^2S	1/2	280 785
$2s^2 2p^5(^2P^\circ)3s3p(^1P^\circ)$	^2P	3/2 1/2	281 032 282 334
$2s^2 2p^5 3s(^3P^\circ)4s$	$^2P^\circ$?	3/2 1/2	*288 470* *288 666*
$2s^2 2p^5 3s(^3P^\circ)3d$?		1/2,3/2	*290 232*
$2s^2 2p^5 3s(^3P^\circ)3d$?		1/2,3/2	*290 488*
$2s^2 2p^5 3s(^3P^\circ)3d$?		1/2,3/2	*290 806*
$2s^2 2p^5 3s(^3P^\circ)3d$?		1/2,3/2	*291 404*
		1/2,3/2	*292 103*
$2s^2 2p^5 3s(^3P^\circ)4p$	^2D	5/2 3/2	 295 054
		1/2,3/2	*295 317*
$2s^2 2p^5 3s(^1P^\circ)4p$	^2D	5/2 3/2	296 576 297 048
$2s^2 2p^5 3s(^1P^\circ)4p$	^2S	1/2	296 618
$2s^2 2p^5 3s(^1P^\circ)4p$	^2P	3/2 1/2	296 808 297 121
$2s^2 2p^5 3s(^3P^\circ)4d$?		1/2,3/2	*297 660*
$2s^2 2p^5 3s(^3P^\circ)4d$?		1/2,3/2	*297 856*
$2s^2 2p^5 3s(^3P^\circ)4d$?		1/2,3/2	*298 989*
$2s^2 2p^5 3s(^3P^\circ)5d$?		1/2,3/2	*300 614*
$2s^2 2p^5 3s(^3P^\circ)5d$?		1/2,3/2	*300 786*

Na I—Continued

Configuration	Term	J	Level (cm^{-1})
$2s^2 2p^5 3s(^3\mathrm{P}^\circ)5d$?		$1/2, 3/2$	*301 974*
		$1/2, 3/2$	*302 430*
		$1/2, 3/2$	*304 056*
		$1/2, 3/2$	*304 528*
		$1/2, 3/2$	*304 894*
		$1/2, 3/2$	*305 192*
		$1/2, 3/2$	*305 671*
Na II $2s^2 2p^5 3s(^3\mathrm{P}^\circ_2)$	*Limit*		*306 374*
		$1/2, 3/2$	*306 438*
$2s^2 2p^5 3s(^1\mathrm{P}^\circ)6d$		$1/2, 3/2$	*306 890*
Na II $2s^2 2p^5 3s(^3\mathrm{P}^\circ_1)$	*Limit*		*307 139*
$2s^2 2p^5 3s(^1\mathrm{P}^\circ)8s$	$^2\mathrm{P}^\circ$	$1/2, 3/2$	*307 502*
Na II $2s^2 2p^5 3s(^3\mathrm{P}^\circ_0)$	*Limit*		*307 731*
$2s^2 2p^5 3s(^1\mathrm{P}^\circ)7d$		$1/2, 3/2$	*307 786*
$2s^2 2p^5 3s(^1\mathrm{P}^\circ)9s$	$^2\mathrm{P}^\circ$	$1/2, 3/2$	*308 146*
$2s^2 2p^5 3s(^1\mathrm{P}^\circ)8d$		$1/2, 3/2$	*308 368*
$2s^2 2p^5 3s(^1\mathrm{P}^\circ)10s$	$^2\mathrm{P}^\circ$	$3/2$ $1/2$	*308 566* *308 623*
$2s^2 2p^5 3s(^1\mathrm{P}^\circ)9d$		$1/2, 3/2$	*308 745*
$2s^2 2p^5 3s(^1\mathrm{P}^\circ)11s$	$^2\mathrm{P}^\circ$	$3/2$ $1/2$	*308 890* *308 938*
$2s^2 2p^5 3s(^1\mathrm{P}^\circ)10d$		$1/2, 3/2$	*309 029*
$2s^2 2p^5 3s(^1\mathrm{P}^\circ)12s$	$^2\mathrm{P}^\circ$	$1/2, 3/2$	*309 157*
$2s^2 2p^5 3s(^1\mathrm{P}^\circ)11d$		$1/2, 3/2$	*309 219*
$2s^2 2p^5 3s(^1\mathrm{P}^\circ)12d$		$1/2, 3/2$	*309 369*
Na II $2s^2 2p^5 3s(^1\mathrm{P}^\circ_1)$	*Limit*		*310 212*
$2s^2 2p^5 3p^2$		$1/2, 3/2$	*310 977*
$2s^2 2p^5 3p^2$		$1/2, 3/2$	*312 188*
……	……	……	……
$2s(^2\mathrm{S})2p^6 3s3p(^3\mathrm{P}^\circ)$	$^2\mathrm{P}^\circ$	$1/2, 3/2$	*535 330*
$2s(^2\mathrm{S})2p^6 3s3p(^1\mathrm{P}^\circ)$	$^2\mathrm{P}^\circ$	$1/2, 3/2$	*546 600*
$2s2p^6 3s(^3\mathrm{S})4p$	$^2\mathrm{P}^\circ$	$1/2, 3/2$	*559 600*
Na II $2s2p^6 3s(^3\mathrm{S}_1)$	*Limit*		573 300
Na II $2s2p^6 3s(^1\mathrm{S}_0)$	*Limit*		577 300
$2s2p^6 3p(^3\mathrm{P}^\circ)4s$	$^2\mathrm{P}^\circ$	$1/2, 3/2$	*586 200*

Na II

$Z=11$

Ne I isoelectronic sequence

Ground state $1s^22s^22p^6\ ^1\mathrm{S}_0$

Ionization energy 381 390.2±2 cm^{-1} (47.2867±0.0003 eV)

Wu [1971] reobserved this spectrum and extended the analysis to include the classification of more than 500 lines from 270 to 6566 Å. His line list has not been published, but the wavelengths and classifications listed by Kelly and Palumbo [1973] for the region below 2000 Å are from his results. The tables of Bowen [1928] and Frisch [1931] give most of the lines classified in the earlier analyses, the original *LS* term designations for the $2p^53d$ and $4s$ levels being due to Söderqvist [1934]. Tsui et al. [1965] list 18 lines due to $3d$–$4f$ transitions (4293–4533 Å).

Most of the levels below the ionization limit are from Wu's thesis. All the excited levels have a standard-deviation error of 2 cm^{-1} with respect to the $2p^6\ ^1\mathrm{S}_0$ ground level. The standard-deviation error of differences between the excited levels varies from perhaps 0.5 cm^{-1} or less for levels given to one decimal place to less than 0.1 cm^{-1} for most of the two-place levels.

The levels are arranged into terms of the most appropriate coupling scheme, *LS* or $J_1\,l$, for each configuration. The leading percentages are from Hansen's calculations [1980]. The first percentages listed for the $2p^53s$ and $2p^53p$ levels apply to the *LS*-coupling designations, the leading percentages in $J_1\,l$ coupling being given after the word "or". The first percentages for the $2p^53d$, $2p^54s$, and $2p^54p$ levels are for the $J_1\,l$-coupling designations, with the leading *LS* percentages following. Hansen's calculation of the $2p^53p$ levels included a ^{3}S correction discussed in his 1973 paper. The calculation for $2p^53d$ and $2p^54s$ included the interaction between these configurations; the largest configuration mixing occurs between the $2p^5(^2\mathrm{P}^\circ_{3/2})3d\ ^2[^3/_2]^\circ$ and $2p^5(^2\mathrm{P}^\circ_{3/2})4s\ ^2[^3/_2]^\circ$ pairs. the eigenvectors for each of these terms including a large (21–31%) component from the other term.

Several of Wu's $2p^54p$ levels have unexpectedly large deviations from the relative positions predicted by Hansen's calculations. Pending further results on the analysis, we have omitted four of these levels and tentatively changed one *J* value. The reality of Wu's $2p^5(^2\mathrm{P}^\circ_{1/2})4p\ ^2[\frac{1}{2}]_0$ level has been previously questioned [Artru and Kaufman, 1975, A. M. Crooker, private communication, 1975]. We have replaced his $(^2\mathrm{P}^\circ_{3/2})4p\ ^2[^5/_2]_3$ level with a new value based on two previously unclassified lines. One of the $2p^54d$ levels is shown as tentative, and one $2p^55f$ level was omitted. Two $2p^56f$ levels are listed as questionable, and we have also made minor revisions in the values of a few higher $2p^5nf$ and ng levels.

Wu determined the energy of the Na III $2p^5\ ^2\mathrm{P}^\circ$ term baricenter with respect to the Na II ground level by fitting a core-polarization formula to the Na II $2p^54f$, $5f$, and $6f$ configurations. Since the resulting values of the Na III $2p^5\ ^2\mathrm{P}^\circ$ levels are probably accurate to within a few tenths of one cm^{-1} with respect to the excited Na II levels, these $^2\mathrm{P}^\circ$ limits should have about the same accuracy as the excited levels with respect to the Na II ground level (±2 cm^{-1}). The baricenter of any Na II $2p^5nl$ ($l\geqslant3$) configuration can be predicted from the Na III $2p^5\ ^2\mathrm{P}^\circ$ baricenter and the polarization parameters; Wu gives predicted values for the $2p^5nf$, ng, and nh configurations through $n=10$.

The three lowest terms above the Na III $2s^22p^5\ ^2\mathrm{P}^\circ$ limits, i.e., the $2s2p^63s\ ^3\mathrm{S}$ and $^1\mathrm{S}$ and $2s2p^63p\ ^3\mathrm{P}^\circ$ terms, are from measurements of ejected-electron spectra by Breuckmann et al. [1977]. The autoionization width of each of the $2s2p^63s$ levels (~2100 cm^{-1}) is about half their separation and is larger than the separation of the Na III $2s^22p^5\ ^2\mathrm{P}^\circ_{3/2}$ and $^2\mathrm{P}^\circ_{1/2}$ final states. We have taken the $2s2p^63s\ ^3\mathrm{S}_1$ level as 18.65 eV above the Na III $^2\mathrm{P}^\circ_{3/2}$ limit [Fig. 7 of Breuckmann et al.], and used the $2s2p^63s\ ^1\mathrm{S}_0$—$^3\mathrm{S}_1$ separation of 0.50 eV derived by Breuckmann et al. from their analysis of the overlapping resonances. The $2s2p^63s$ levels are probably accurate to within ±350 cm^{-1} and the $2s2p^63p\ ^3\mathrm{P}^\circ$ term to within ±250 cm^{-1}. Other Na II terms above the principal ionization energy have been determined from such spectra by Breuckmann et al. and by Ross et al. [1976], for example. Eissner et al. [1980] have calculated positions and autoionization widths for a number of the $2s2p^6ns$ and $2s2p^6np$ terms.

Lucatorto and McIlrath [1976] observed the $2s^22p^6\ ^1\mathrm{S}_0$—$2s2p^6np\ ^1\mathrm{P}^\circ_1$ series ($n=3$–8) in absorption in the 157–177 Å region. The autoionizing $2s2p^6np\ ^1\mathrm{P}^\circ$ levels obtained from their measurements are probably accurate to ±200 cm^{-1}. Lucatorto and McIlrath also extended observations of the $2s^22p^6$—$2s^22p^5ns$ and nd ($J=1$) series to higher members than are tabulated here (to $n=13$ or 14), the lines being classified as blends of transitions to $2p^5nd$ and $(n+1)s$ levels.

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Na II

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$2p^6$	^1S	0	0.0				
$2p^5 3s$	$^3P^\circ$	2	*264 924.32*	100	or	100	$(^2P^\circ_{3/2})\ ^2[3/2]^\circ$
		1	*265 689.62*	96	or	55	$(^2P^\circ_{3/2})\ ^2[3/2]^\circ$
		0	*266 281.62*	100	or	100	$(^2P^\circ_{1/2})\ ^2[1/2]^\circ$
$2p^5 3s$	$^1P^\circ$	1	*268 762.96*	96	or	55	$(^2P^\circ_{1/2})\ ^2[1/2]^\circ$
$2p^5 3p$	^3S	1	293 220.33	99	or	75	$(^2P^\circ_{3/2})\ ^2[1/2]$
$2p^5 3p$	^3D	3	297 248.82	100	or	100	$(^2P^\circ_{3/2})\ ^2[5/2]$
		2	297 635.61	88	or	70	$(^2P^\circ_{3/2})\ ^2[5/2]$
		1	298 165.44	91	or	56	$(^2P^\circ_{1/2})\ ^2[3/2]$
$2p^5 3p$	^1D	2	299 189.96	65	or	61	$(^2P^\circ_{3/2})\ ^2[3/2]$
$2p^5 3p$	^1P	1	299 885.37	60	or	56	$(^2P^\circ_{3/2})\ ^2[3/2]$
$2p^5 3p$	^3P	2	300 103.92	67	or	68	$(^2P^\circ_{1/2})\ ^2[3/2]$
		0	300 387.82	100	or	60	$(^2P^\circ_{1/2})\ ^2[1/2]$
		1	300 507.11	66	or	75	$(^2P^\circ_{1/2})\ ^2[1/2]$
$2p^5 3p$	^1S	0	308 860.80	100	or	60	$(^2P^\circ_{3/2})\ ^2[1/2]$
$2p^5(^2P^\circ_{3/2})3d$	$^2[1/2]^\circ$	0	*330 549.35*	97	or	97	$^3P^\circ$
		1	*330 636.75*	74	or	89	
$2p^5(^2P^\circ_{3/2})3d$	$^2[3/2]^\circ$	2	*330 789.05*	56	or	61	$^3P^\circ$
		1	*331 745.06*	52	or	59	$^1P^\circ$
$2p^5(^2P^\circ_{3/2})3d$	$^2[7/2]^\circ$	4	*331 123.04*	100	or	100	$^3F^\circ$
		3	*331 186.70*	99	or	53	
$2p^5(^2P^\circ_{3/2})4s$	$^2[3/2]^\circ$	2	*331 496.51*	68	or	68	$^3P^\circ$
		1	*331 873.93*	63	or	48	
$2p^5(^2P^\circ_{3/2})3d$	$^2[5/2]^\circ$	2	*331 665.59*	88	or	57	$^3F^\circ$
		3	*331 707.90*	89	or	46	$^3D^\circ$
$2p^5(^2P^\circ_{1/2})4s$	$^2[1/2]^\circ$	0	*332 710.11*	97	or	97	$^3P^\circ$
		1	*333 162.94*	79	or	58	$^1P^\circ$
$2p^5(^2P^\circ_{1/2})3d$	$^2[5/2]^\circ$	2	*332 802.21*	88	or	43	$^3F^\circ$
		3	*332 841.93*	89	or	54	$^3D^\circ$
$2p^6(^2P^\circ_{1/2})3d$	$^2[3/2]^\circ$	2	*332 962.57*	85	or	51	$^3D^\circ$
		1	*333 107.74*	83	or	61	
$2p^5(^2P^\circ_{3/2})4p$	$^2[1/2]$	1	340 239.8	87	or	94	^3S
		0		96	or	53	^3P

Na II—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$2p^5(^2P^\circ_{3/2})4p$	$^2[5/2]$	3	341 255.6	100	or	100	^3D
		2	341 457.7	81	or	70	
$2p^5(^2P^\circ_{3/2})4p$	$^2[3/2]$	1		94	or	41	^1P
		2?	341 907.0	83	or	67	^3P
$2p^5(^2P^\circ_{1/2})4p$	$^2[3/2]$	1	342 738.6	94	or	62	^3D
		2		96	or	44	^1D
$2p^5(^2P^\circ_{1/2})4p$	$^2[1/2]$	1	342 971.0	87	or	64	^3P
		0		96	or	53	^1S
$2p^5(^2P^\circ_{3/2})4d$	$^2[1/2]^\circ$	0	*352 969.8*				
		1	*353 032.9*				
$2p^5(^2P^\circ_{3/2})4d$	$^2[3/2]^\circ$	2	*353 151.8*				
		1	*353 600.6*				
$2p^5(^2P^\circ_{3/2})4d$	$^2[7/2]^\circ$	4	*353 202.6*				
		3	*353 240.4*				
$2p^5(^2P^\circ_{3/2})4d$	$^2[5/2]^\circ$	2	*353 463.2*				
		3	*353 483.8*				
$2p^5(^2P^\circ_{3/2})5s$	$^2[3/2]^\circ$	2	*353 536.7*				
		1	*353 719.3*				
$2p^5(^2P^\circ_{3/2})4f$	$^2[3/2]$	1	353 837.23				
		2	353 838.44				
$2p^5(^2P^\circ_{3/2})4f$	$^2[9/2]$	5	353 881.13				
		4	353 881.16				
$2p^5(^2P^\circ_{3/2})4f$	$^2[5/2]$	3	353 925.81				
		2	353 926.69				
$2p^5(^2P^\circ_{3/2})4f$	$^2[7/2]$	3	353 972.42				
		4	353 972.63				
$2p^5(^2P^\circ_{1/2})4d$	$^2[5/2]^\circ$	2	*354 526.3*				
		3	*354 559.2?*				
$2p^5(^2P^\circ_{1/2})4d$	$^2[3/2]^\circ$	2	*354 707.0*				
		1	*354 876.5*				
$2p^5(^2P^\circ_{1/2})5s$	$^2[1/2]^\circ$	0	*354 859.8*				
		1	*354 997.8*				
$2p^5(^2P^\circ_{1/2})4f$	$^2[7/2]$	3	355 280.89				
		4	355 281.16				
$2p^5(^2P^\circ_{1/2})4f$	$^2[5/2]$	3	355 283.70				
		2	355 284.53				
$2p^5(^2P^\circ_{3/2})5d$	$^2[1/2]^\circ$	0	*363 332.2*				
		1	*363 347.4*				

Na II—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$2p^5(^2P^\circ_{3/2})5d$	$^2[3/2]^\circ$	2	*363 441.7*	
		1	*363 631.9*	
$2p^5(^2P^\circ_{3/2})6s$	$^2[3/2]^\circ$	2	*363 610.2*	
		1	*363 725.8*	
$2p^5(^2P^\circ_{3/2})5f$	$^2[3/2]$	1	363 767.98	
		2	363 769.03	
$2p^5(^2P^\circ_{3/2})5f$	$^2[9/2]$	5	363 790.60	
		4	363 790.64	
$2p^5(^2P^\circ_{3/2})5f$	$^2[5/2]$	3	363 814.78	
		2	363 815.38	
$2p^5(^2P^\circ_{3/2})5f$	$^2[7/2]$	3	363 837.82	
		4	363 837.94	
$2p^5(^2P^\circ_{1/2})5d$	$^2[3/2]^\circ$	2	*364 744.1*	
		1	*364 931.1*	
$2p^5(^2P^\circ_{1/2})6s$	$^2[1/2]^\circ$	0	*365 009.9*	
		1	*365 043.5*	
$2p^5(^2P^\circ_{1/2})5f$	$^2[7/2]$	3	365 173.42	
		4	365 173.7	
$2p^5(^2P^\circ_{1/2})5f$	$^2[5/2]$	3	365 174.10	
		2		
$2p^5(^2P^\circ_{3/2})6d$	$^2[1/2]^\circ$	0		
		1	*368 494.1*	
$2p^5(^2P^\circ_{3/2})7s$	$^2[3/2]^\circ$	2		
		1	*369 070.5*	
$2p^5(^2P^\circ_{3/2})6f$	$^2[3/2]$	1	369 158.71	
		2	369 159.46	
$2p^5(^2P^\circ_{3/2})6f$	$^2[9/2]$	5	369 171.93	
		4	369 172.01	
$2p^5(^2P^\circ_{3/2})6g$	$^2[5/2]^\circ$	3,2	*369 184.02*	
$2p^5(^2P^\circ_{3/2})6f$	$^2[5/2]$	3	369 186.50	
		2	369 186.73	
$2p^5(^2P^\circ_{3/2})6g$	$^2[11/2]^\circ$	6,5	*369 189.22*	
$2p^5(^2P^\circ_{3/2})6g$	$^2[7/2]^\circ$	4,3	*369 198.7*	
$2p^5(^2P^\circ_{3/2})6f$	$^2[7/2]$	3,4	*369 199.6*	
$2p^5(^2P^\circ_{3/2})6g$	$^2[9/2]^\circ$	5,4	*369 203.4*	
$2p^5(^2P^\circ_{1/2})6d$	$^2[3/2]^\circ$	2		
		1	*370 035.6*	

Na II—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$2p^5(^2P^\circ_{1/2})7s$	$^2[1/2]^\circ$	0		
		1	*370 378.6*	
$2p^5(^2P^\circ_{1/2})6f$	$^2[7/2]$	3,4	370 547.8	
$2p^5(^2P^\circ_{1/2})6f$	$^2[5/2]$	3	370 548.06?	
		2	370 548.50?	
$2p^5(^2P^\circ_{1/2})6g$	$^2[9/2]^\circ$	5,4	*370 560.6*	
	$^2[7/2]^\circ$	4,3		
$2p^5(^2P^\circ_{3/2})7f$	$^2[3/2]$	1	372 407.6	
		2	372 407.9	
$2p^5(^2P^\circ_{3/2})7f$	$^2[9/2]$	5,4	372 415.9	
$2p^5(^2P^\circ_{3/2})7g$	$^2[5/2]^\circ$	3,2	*372 423.4*	
$2p^5(^2P^\circ_{3/2})7f$	$^2[5/2]$	3,2	372 425.4	
$2p^5(^2P^\circ_{3/2})7g$	$^2[11/2]^\circ$	6,5	*372 426.7*	
$2p^5(^2P^\circ_{3/2})7g$	$^2[7/2]^\circ$	4,3	*372 432.3*	
$2p^5(^2P^\circ_{3/2})7f$	$^2[7/2]$	4,3	372 433.3	
$2p^5(^2P^\circ_{3/2})7g$	$^2[9/2]^\circ$	5,4	*372 436.2*	
$2p^5(^2P^\circ_{1/2})7f$	$^2[7/2]$	4,3	373 787.8	
$2p^5(^2P^\circ_{1/2})7f$	$^2[5/2]$	3,2	373 788.1	
$2p^5(^2P^\circ_{1/2})7g$	$^2[9/2]^\circ$	5,4	*373 796.4*	
	$^2[7/2]^\circ$	4,3		
$2p^5(^2P^\circ_{3/2})8f$	$^2[3/2]$	2,1	374 514.9	
$2p^5(^2P^\circ_{3/2})8f$	$^2[9/2]$	5,4	374 520.3	
$2p^5(^2P^\circ_{3/2})8f$	$^2[7/2]$	4,3	374 532.1	
$2p^5(^2P^\circ_{1/2})8f$	$^2[7/2]$	4,3	375 890.0	
	$^2[5/2]$	3,2		
Na III ($^2P^\circ_{3/2}$)	***Limit***		***381 390.2***	
Na III ($^2P^\circ_{1/2}$)	*Limit*		*382 756.5*	
$2s2p^6 3s$	^3S	1	531 810	
$2s2p^6 3s$	^1S	0	535 840	
$2s2p^6 3p$	$^3P^\circ$	0–2	*562 780*	

Na II—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$2s2p^6 3p$	$^1\mathrm{P}^\circ$	1	*564 210*	
$2s2p^6 4p$	$^1\mathrm{P}^\circ$	1	*606 350*	
$2s2p^6 5p$	$^1\mathrm{P}^\circ$	1	*622 430*	
$2s2p^6 6p$	$^1\mathrm{P}^\circ$	1	*630 240*	
$2s2p^6 7p$	$^1\mathrm{P}^\circ$	1	*634 720*	
$2s2p^6 8p$	$^1\mathrm{P}^\circ$	1	*637 430*	
Na III $2s2p^6(^2\mathrm{S}_{1/2})$	*Limit*		645 845	

Na III

$Z = 11$

F I isoelectronic sequence

Ground state $1s^22s^22p^5\ ^2P^\circ_{3/2}$

Ionization energy 577 654 cm^{-1} (71.6205 eV)

The levels are from new observations and analysis of the spectrum by Lundström and Minnhagen [1972], Minnhagen and Nietsche [1972], and Minnhagen [1975]. Lundström and Minnhagen give wavelengths for 90 Na III lines in the 181–380 Å range and for the $2s2p^6\ ^2S_{1/2}$—$2s^22p^4(^3P)3p\ ^2P^\circ_{3/2}$ line at 649.5 Å. Their measurements allowed determination of the $2s^22p^5\ ^2P^\circ$ interval to better than ±1 cm^{-1}, the $2s2p^6\ ^2S_{1/2}$ level and the $2s^22p^4(^3P)3s$, $3p$, $3d$, and $4s$ levels being determined to about ±1.5 to ±2.5 cm^{-1} with respect to the ground level. The $2s^22p^4(^1D)3s$, $3p$, $3d$, and $4s$ levels should be accurate to about ±3 cm^{-1} relative to the ground level, the $(^1S)3s$, $3p$, $3d$, and $4s$ levels to about ±4 cm^{-1}, and the $2s^22p^44d$ and $5s$ levels to about ±6 cm^{-1}. Most of the levels are from Minnhagen and Nietsche, who also list the wavelengths and classifications of 177 lines in the 1325–2638 Å region. They established the relative positions of the $(^3P)3s$, $3p$, $3d$, and $4s$ levels to ±0.1 to ±0.2 cm^{-1}, and the relative positions within the $(^1D)3s$, $3p$, $3d$, $4s$ group to about the same uncertainties; the uncertainties of differences between these two groups are about ±0.5 cm^{-1}. The $(^1S)3s$, $3p$, and $3d$ levels are internally consistent to about 0.15 cm^{-1}, and the $(^1S)4s\ ^2S$ level should be accurate to about ±0.5 cm^{-1} with respect to this group. These levels having ^1S parentage are connected to the groups based on ^3P and ^1D only through ground-term combinations.

Minnhagen classified about 80 lines (1755–2010 Å) as $2p^43d$–$4f$ transitions. Most of the $2p^44f$ levels are accurate to about ±0.1 to ±0.3 cm^{-1} with respect to the $2p^43d$ levels, which means an uncertainty of about ±3 cm^{-1} relative to the ground level.

A significant feature of the level determinations by Minnhagen and Nietsche is that the quartet-doublet level differences, within and between the different configuration groups as discussed above, have the same accuracies as corresponding differences within the multiplicity systems. Minnhagen and Nietsche give details of their extension and revision of the term system. Most of the previously known levels retained by them were first located by Söderqvist [1934], whose monograph includes references to earlier work on Na III.

The leading percentages for the $2p^43p$ and $2p^43d$ levels are from Minnhagen and Nietsche, who list all percentages ⩾3%. The *LS*-coupling purities of the $2p^43p$ levels are mostly high, but two of the $2p^43d$ levels ($J=5/2$) have the same $2p^4(^3P)3d\ ^2D$ leading component. The designations here are those of Minnhagen and Nietsche, except that we omit any name for one of these levels, 465 398 cm^{-1}. Minnhagen and Nietsche also calculated the $2p^43s$ and $2p^44s$ levels. The *LS* purities are high, the largest mixing being between $2p^4(^3P)4s\ ^4P_{3/2}$ and $^2P_{3/2}$ (a 6% mixture in each of the two eigenvectors).

Minnhagen notes that the $2p^44f$ levels fall into five groups, according to the $2p^4$ parent levels, and are further grouped into close pairs. The leading percentages in the J_1l coupling scheme, from Minnhagen's paper, verify the high purity of these levels in this scheme. The missing $2p^4(^1S_0)4f\ ^2[3]^\circ$ level pair is calculated to lie near 582 270 cm^{-1}, i.e., above the Na IV $2p^4\ ^3P$ limits, and Minnhagen notes matrix elements allowing autoionization from these levels.

Johannesson and Lundström derived the ionization energy by careful isoelectronic interpolation. No estimate of the error was given, but it may be comparable to the error of ±10 cm^{-1} estimated for their Mg IV limit determination.

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Na III

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$2s^2 2p^5$	$^2P^\circ$	$3/2$	*0.0*			
		$1/2$	*1 366.3*			
$2s2p^6$	^2S	$1/2$	264 455.0			
$2s^2 2p^4(^3P)3s$	^4P	$5/2$	366 154.41			
		$3/2$	367 040.66			
		$1/2$	367 550.17			
$2s^2 2p^4(^3P)3s$	^2P	$3/2$	373 632.32			
		$1/2$	374 679.91			
$2s^2 2p^4(^1D)3s$	^2D	$5/2$	399 174.71			
		$3/2$	399 182.31			
$2s^2 2p^4(^3P)3p$	$^4P^\circ$	$5/2$	*406 190.15*	99		
		$3/2$	*406 550.63*	99		
		$1/2$	*406 865.11*	100		
$2s^2 2p^4(^3P)3p$	$^4D^\circ$	$7/2$	*410 976.94*	100		
		$5/2$	*411 536.38*	97		
		$3/2$	*411 951.78*	98		
		$1/2$	*412 189.46*	100		
$2s^2 2p^4(^3P)3p$	$^2D^\circ$	$5/2$	*414 281.85*	98		
		$3/2$	*415 172.28*	98		
$2s^2 2p^4(^3P)3p$	$^2S^\circ$	$1/2$	*416 909.31*	80	16	$^2P^\circ$
$2s^2 2p^4(^3P)3p$	$^4S^\circ$	$3/2$	*417 403.98*	99		
$2s^2 2p^4(^3P)3p$	$^2P^\circ$	$3/2$	*418 417.50*	85	13	$(^1D)\ ^2P^\circ$
		$1/2$	*418 556.54*	69	20	$^2S^\circ$
$2s^2 2p^4(^1S)3s$	^2S	$1/2$	435 028.00			
$2s^2 2p^4(^1D)3p$	$^2F^\circ$	$5/2$	*440 940.20*	100		
		$7/2$	*441 055.67*	100		
$2s^2 2p^4(^1D)3p$	$^2D^\circ$	$3/2$	*445 797.52*	99		
		$5/2$	*445 873.20*	100		
$2s^2 2p^4(^1D)3p$	$^2P^\circ$	$3/2$	*447 547.96*	86	[illegible]	[illegible]
		$1/2$	*448 107.31*	86	[illegible]	
$2s^2 2p^4(^3P)3d$	^4D	$7/2$	460 257.21	98		
		$5/2$	460 409.70	[illegible]		
		$3/2$	460 593.62	[illegible]		
		$1/2$	460 746.98	[illegible]		
$2s^2 2p^4(^3P)3d$	^4F	$9/2$	462 891.04			
		$7/2$	463 245.76			
		$5/2$	463 691.90			
		$3/2$	464 077.16			
$2s^2 2p^4(^3P)3d$	^2F	$7/2$	463 970.9[illegible]			

Na III—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages			
$2s^2 2p^4(^3P)3d$	^2D	$5/2$	464 390.17	44		32	^2F
		$3/2$	465 017.83	76		14	^4P
$2s^2 2p^4(^3P)3d$	^4P	$1/2$	464 411.94	99			
		$3/2$	464 631.29	82		10	^2D
		$5/2$	464 945.37	56		37	^2F
$2s^2 2p^4(^3P)3d$		$5/2$	465 398.59	42	^2D	35	^4P
$2s^2 2p^4(^3P)3d$	^2P	$1/2$	466 011.91	98			
		$3/2$	466 788.03	93		6	^2D
$2s^2 2p^4(^1S)3p$	$^2P^\circ$	$1/2$	*478 842.99*	99			
		$3/2$	*478 884.07*	99			
$2s^2 2p^4(^3P)4s$	^4P	$5/2$	479 975.34				
		$3/2$	480 779.21				
		$1/2$	481 358.65				
$2s^2 2p^4(^3P)4s$	^2P	$3/2$	482 402.20				
		$1/2$	483 388.55				
$2s^2 2p^4(^1D)3d$	^2G	$9/2$	492 313.91	100			
		$7/2$	492 316.41	100			
$2s^2 2p^4(^1D)3d$	^2P	$3/2$	493 192.06	99			
		$1/2$	493 293.98	99			
$2s^2 2p^4(^1D)3d$	^2S	$1/2$	493 849.24	100			
$2s^2 2p^4(^1D)3d$	^2D	$5/2$	494 602.73	99			
		$3/2$	494 685.86	99			
$2s^2 2p^4(^1D)3d$	^2F	$5/2$	495 429.75	100			
		$7/2$	495 435.20	100			
$2s^2 2p^4(^1D)4s$	^2D	$3/2$	511 433.8				
		$5/2$	511 434.3				
$2s^2 2p^4(^3P)4d$	^4F	$5/2$	514 007				
		$3/2$	514 241				
$2s^2 2p^4(^3P)4d$	^4P	$3/2$	514 069				
		$5/2$	514 608?				
$2s^2 2p^4(^3P)4d$	^2F	$5/2$	514 688				
$2s^2 2p^4(^3P)4d$	^2D	$3/2$	515 017				
		$5/2$	515 365				
$2s^2 2p^4(^3P)4d$	^2P	$1/2$	515 140				
		$3/2$	515 984				
$2s^2 2p^4(^3P_2)4f$	$^2[4]^\circ$	$9/2$	*515 595.6*	98			
		$7/2$	*515 607.27*	93		5	$^2[3]^\circ$
$2s^2 2p^4(^3P_2)4f$	$^2[3]^\circ$	$5/2$	*515 635.09*	98			
		$7/2$	*515 635.4*	93		5	$^2[4]^\circ$

Na III—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$2s^2 2p^4(^3P_2)4f$	$^2[2]^\circ$	$3/2$	*515 764.23*	94	6	$(^3P_1)\ ^2[2]^\circ$
		$5/2$	*515 773.67*	94	5	
$2s^2 2p^4(^3P_2)4f$	$^2[5]^\circ$	$11/2$	*515 871.96*	100		
		$9/2$	*515 872.81*	100		
$2s^2 2p^4(^3P_2)4f$	$^2[1]^\circ$	$1/2$	*515 994.5*	100		
		$3/2$	*516 000.6*	100		
$2s^2 2p^4(^3P_1)4f$	$^2[2]^\circ$	$3/2$	*516 817.76*	94	6	$(^3P_2)\ ^2[2]^\circ$
		$5/2$	*516 823.62*	95	5	
$2s^2 2p^4(^3P_1)4f$	$^2[4]^\circ$	$9/2$	*516 859.91*	98		
		$7/2$	*516 864.62*	98		
$2s^2 2p^4(^3P_1)4f$	$^2[3]^\circ$	$7/2$	*517 029.6*	99		
		$5/2$	*517 033.0*	99		
$2s^2 2p^4(^3P_0)4f$	$^2[3]^\circ$	$7/2$	*517 374.54*	98		
		$5/2$	*517 377.58*	98		
$2s^2 2p^4(^3P)5s$	^2P	$3/2$	522 720			
		$1/2$	523 527			
$2s^2 2p^4(^1S)3d$	^2D	$5/2$	529 461.64	100		
		$3/2$	529 497.70	99		
$2s^2 2p^4(^1D)4d$	^2S	$1/2$	543 640			
$2s^2 2p^4(^1D)4d$	^2P	$3/2$	544 226			
		$1/2$	544 278			
$2s^2 2p^4(^1D)4d$	^2D	$5/2$	544 749			
		$3/2$	544 788			
$2s^2 2p^4(^1D)4d$	^2F	$5/2$	544 915			
$2s^2 2p^4(^1D_2)4f$	$^2[1]^\circ$	$3/2$	*546 187.1?*	100		
		$1/2$		100		
$2s^2 2p^4(^1D_2)4f$	$^2[5]^\circ$	$11/2$	*546 440.3*	100		
		$9/2$	*546 441.0*	100		
$2s^2 2p^4(^1D_2)4f$	$^2[2]^\circ$	$3/2$	*546 509.3*	100		
		$5/2$	*546 510.55?*	100		
$2s^2 2p^4(^1D_2)4f$	$^2[3]^\circ$	$7/2$	*546 810.1*	100		
		$5/2$	*546 811*	100		
$2s^2 2p^4(^1D_2)4f$	$^2[4]^\circ$	$7/2$	*546 887.36*	100		
		$9/2$	*546 888.34*	100		
$2s^2 2p^4(^1S)4s$	^2S	$1/2$	547 910.7			

Na III—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages
$2s^2 2p^4(^1D)5s$	^2D	$^3/_2$	552 404	
		$^5/_2$	552 416?	
…………	…………	…………	…………	
Na IV ($^3P_2$)	***Limit***		**577 654**	
Na IV ($^3P_1$)	*Limit*		578 760	
Na IV ($^3P_0$)	*Limit*		579 230	
Na IV ($^1D_2$)	*Limit*		608 494	
Na IV ($^1S_0$)	*Limit*		644 150	

Na IV

$Z=11$

O I isoelectronic sequence

Ground state $1s^22s^22p^4\ ^3P_2$

Ionization energy 797 800 cm^{-1} (98.92 eV)

Söderqvist's analysis of this spectrum included classification of 73 lines in the 129–412 Å region as transitions to the $2s^22p^4$ ground-configuration levels from upper $2s2p^5$ and $2s^22p^3ns$, nd singlet and triplet levels [Söderqvist, 1934]. A few $2s^22p^33s$–$3p$ and $3p$–$3d$ transitions as observed in beam-foil spectra were classified by Gaillard et al. and by Dufay et al. Minnhagen [1976] has used new observations of the 136–412 Å and 1456–2156 Å regions to make a major extension of the analysis and to improve the values of most of the previously known levels. A total of about 150 lines are classified.

The triplet and singlet terms are from Minnhagen's paper, except for the $2p^6\ ^1S$ level, which is from Edlén [1980]. Minnhagen determined the $2s^22p^4\ ^3P$ and $2s2p^5\ ^3P°$ levels to about ±1 cm^{-1}. We list the $2s^22p^4\ ^1D_2$ level to the nearest 0.1 cm^{-1}, since its determination from the $2s^22p^4\ ^3P$–^1D nebular lines [Bowen, 1960] should be accurate to about ±1 cm^{-1}. The $2s^22p^4\ ^1S$, $2s2p^5\ ^1P°$, and $2p^6\ ^1S$ levels are probably accurate to about ±2 cm^{-1}. The uncertainties of the higher triplet and singlet levels with respect to the ground term are generally larger, increasing to about ±10 cm^{-1} for some of the highest levels. The *relative* positions of those higher levels given to the nearest 0.1 cm^{-1}, however, should be accurate to about ±0.2 to ±0.4 cm^{-1}.

Minnhagen also established the levels of the three quintet terms with good relative accuracy, but no lines connecting them with the triplet and singlet systems have been classified. An unknown common correction "x" is thus added to each quintet level. The position of the quintet system for $x=0$ is a prediction based on the values of the $2s^22p^3(^4S°)3s\ ^5S°$ and $(^4S°)3d\ ^5D°$ terms calculated by Kaufman and Wyart [1980] and the experimental separation of these two terms. This prediction differs by only 80 cm^{-1} from the connection predicted by Minnhagen, and the standard error is about 300 cm^{-1}.

Söderqvist [1946] and Minnhagen have located one term belonging to a configuration of the type $2s2p^4nl$ ($n \geqslant 3$), the $2s2p^4(^4P)3d\ ^3D$ term lying above the ionization limit. Buchet and Buchet-Poulizac classified a line at 220 Å as the unresolved Na IV multiplet $2s2p^5\ ^3P°$—$2s2p^4(^4P)3s\ ^3P$. The resulting $2s2p^4(^4P)3s\ ^3P$ position near 699 000 cm^{-1} appears consistent with the data for Mg V and Al VI, but we have not included the term here pending more accurate wavelength measurements and resolution of the fine structure.

Minnhagen's paper includes the results of theoretical calculations of the $2s^22p^33s$, $3p$ and $3d$ configurations. The leading eigenvector percentages given here for the $2s^22p^33p$ levels are from these calculations, some of the percentages close to 100% and some smaller second percentages being from a private communication [Minnhagen, 1980]. Minnhagen [1976] notes a few doubtful points in the analysis and includes comparisons of several configurations along the isoelectronic sequence.

The leading percentages for the $2s2p^5$, $2s^22p^33s$, and $2s^22p^33d$ levels are from a recent calculation that included the interactions of these three odd-parity configurations [Kaufman and Wyart, 1980; see Artru and Kaufman, 1980]. Although the configuration mixing in the eigenvectors is at most a few percent, Artru and Kaufman found inclusion of the configuration interactions important to account for rather large displacements of several terms from their predicted single-configuration positions.

The ground-configuration $2s^22p^4$ levels are very pure in *LS* coupling, but the small mixing of the two $J=2$ states and of the two $J=0$ states is important for calculation of forbidden-line transition probabilities. Garstang gives expansion formulae for the mixing coefficients for the p^2 and p^4 configurations. These formulae and his values for the spin interaction parameters give 0.057% mixing of the Na IV $2s^22p^4\ ^3P_2$ and $^1D_2$ states and 0.18% mixing of the $^3P_0$ and $^1S_0$ states (these being the squares of Garstang's coefficients b and d, respectively, expressed as percentages).

The ionization energy was derived by Edlén [1964] from formulae adjusted to give a best fit for the isoelectronic data. His value agrees well with the value given by Söderqvist, 797 741 cm^{-1}. No uncertainty was stated, but an error greater than a few hundred cm^{-1} is unlikely.

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Na IV

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$2s^2 2p^4$	^{3}P	2	0.0			
		1	1 106.3			
		0	1 576.0			
$2s^2 2p^4$	^{1}D	2	30 839.8			
$2s^2 2p^4$	^{1}S	0	66 496			
$2s2p^5$	^{3}P°	2	*243 681.9*	99		
		1	*244 687.6*	99		
		0	*245 238.8*	99		
$2s2p^5$	^{1}P°	1	*343 688*	99	1	$2p^3(^2\mathrm{D}^\circ)3d\ ^1\mathrm{P}^\circ$
$2s^2 2p^3(^4\mathrm{S}^\circ)3s$	^{5}S°	2	*473 950.0+x*	100		
$2s^2 2p^3(^4\mathrm{S}^\circ)3s$	^{3}S°	1	*486 650.2*	100		
$2s^2 2p^3(^4\mathrm{S}^\circ)3p$	^{5}P	1	524 773.3+x	100		
		2	524 838.6+x	100		
		3	524 950.6+x	100		
$2s^2 2p^3(^2\mathrm{D}^\circ)3s$	^{3}D°	3	*525 085*	100		
		2	*525 117*	100		
		1	*525 139*	100		
$2s^2 2p^3(^2\mathrm{D}^\circ)3s$	^{1}D°	2	*531 410*	99		
$2s^2 2p^3(^4\mathrm{S}^\circ)3p$	^{3}P	1	536 159.1	94	5	$(^2\mathrm{D}^\circ)\ ^3\mathrm{P}$
		2	536 178.8	94	5	
		0	536 184.9	94	5	
$2s^2 2p^3(^2\mathrm{P}^\circ)3s$	^{3}P°	1	*550 157*	99	1	$2p^3(^2\mathrm{D}^\circ)3d\ ^3\mathrm{P}^\circ$
		0	*550 158?*	99	1	
		2	*550 186*	99	1	
$2s^2 2p^3(^2\mathrm{P}^\circ)3s$	^{1}P°	1	*556 796*	99	1	$2p^3(^2\mathrm{D}^\circ)3d\ ^1\mathrm{P}^\circ$
$2p^6$	^{1}S	0	570 823			
$2s^2 2p^3(^2\mathrm{D}^\circ)3p$	^{3}D	1	572 379.5	92	6	$(^2\mathrm{P}^\circ)\ ^3\mathrm{D}$
		2	572 393.8	94	5	
		3	572 546.0	95	5	
$2s^2 2p^3(^2\mathrm{D}^\circ)3p$	^{3}F	2	575 768.1	99	1	$(^2\mathrm{D}^\circ)\ ^3\mathrm{D}$
		3	575 821.0	99	1	
		4	575 886.6	100		
$2s^2 2p^3(^2\mathrm{D}^\circ)3p$	^{1}F	3	577 782.7	100		

Na IV—*Continued*

Configuration	Term	J	Level (cm⁻¹)	Leading percentages		
$2s^2 2p^3(^4S^\circ)3d$	$^5D^\circ$	4	*587 960.7+x*	100		
		3	*587 964.3+x*	100		
		2	*587 971.2+x*	100		
		1	*587 977.2+x*	100		
		0	*587 979.6+x*	100		
$2s^2 2p^3(^4S^\circ)3d$	$^3D^\circ$	1	*594 888.1*	99	1	$(^2D^\circ)\ ^3D^\circ$
		2	*594 899.2*	99	1	
		3	*594 934*	99	1	
$2s^2 2p^3(^2D^\circ)3p$	^1D	2	596 578.9	96	2	$(^2P^\circ)\ ^1D$
$2s^2 2p^3(^2P^\circ)3p$	^3D	3	600 509.6	95	4	$(^2D^\circ)\ ^3D$
		2	600 534.1	94	5	
		1	600 567.7	94	6	
$2s^2 2p^3(^2P^\circ)3p$	^1P	1	606 831?	75	14	$(^2D^\circ)\ ^1P$
$2s^2 2p^3(^2P^\circ)3p$	^1D	2	612 611?	98	2	$(^2D^\circ)\ ^1D$
$2s^2 2p^3(^2D^\circ)3d$	$^3F^\circ$	2	*635 566.0*	97	2	$(^2P^\circ)\ ^3F^\circ$
		3	*635 675.6*	97	2	
		4	*635 817.2*	98	1	
$2s^2 2p^3(^2D^\circ)3d$	$^3G^\circ$	5	*637 669.6*	100		
		4	*637 705.1*	99	1	$(^2D^\circ)\ ^3F^\circ$
		3	*637 728.0*	99	1	
$2s^2 2p^3(^2D^\circ)3d$	$^1G^\circ$	4	*638 188.6*	99		
$2s^2 2p^3(^2D^\circ)3d$	$^3D^\circ$	3	*638 825*	98	1	$(^4S^\circ)\ ^3D^\circ$
		2	*638 943*	99	1	
		1	*639 007*	99	1	
$2s^2 2p^3(^2D^\circ)3d$	$^1P^\circ$	1	*641 193*	95	2	$(^2P^\circ)\ ^1P^\circ$
$2s^2 2p^3(^2D^\circ)3d$	$^3P^\circ$	2	*643 052*	97	2	$(^2P^\circ)\ ^3P^\circ$
		1	*643 311*	95	2	$(^2D^\circ)\ ^3S^\circ$
		0	*643 420?*	98	1	$2p^3(^2P^\circ)3s\ ^3P^\circ$
$2s^2 2p^3(^2D^\circ)3d$	$^1D^\circ$	2	*643 625.6*	94	6	$(^2P^\circ)\ ^1D^\circ$
$2s^2 2p^3(^2D^\circ)3d$	$^3S^\circ$	1	*644 166*	97	2	$(^2D^\circ)\ ^3P^\circ$
$2s^2 2p^3(^4S^\circ)4s$	$^3S^\circ$	1	*644 819*			
$2s^2 2p^3(^2D^\circ)3d$	$^1F^\circ$	3	*646 419.6*	100		
$2s^2 2p^3(^2P^\circ)3d$	$^3P^\circ$	0	*663 137?*	99		
		1	*663 509*	99	1	$(^2D^\circ)\ ^3P^\circ$
		2	*663 623*	98	2	
$2s^2 2p^3(^2P^\circ)3d$	$^3F^\circ$	4	*663 150.5*	98	1	$(^2D^\circ)\ ^3F^\circ$
		3	*663 176.3*	98		
		2	*663 212.4*	96		
$2s^2 2p^3(^2P^\circ)3d$	$^1D^\circ$	2	*664 637*	86	8	[illegible]

Na iv—Continued

Configuration	Term	J	Level (cm^{-1})	Leading percentages		
$2s^2 2p^3(^2P^\circ)3d$	$^3D^\circ$	3	*665 344*	98	1	$(^2D^\circ)\ ^3D^\circ$
		2	*665 370*	91	6	$(^2P^\circ)\ ^1D^\circ$
		1	*665 400*	99		
$2s^2 2p^3(^2P^\circ)3d$	$^1F^\circ$	3	*667 442*	100		
$2s^2 2p^3(^2P^\circ)3d$	$^1P^\circ$	1	*673 140*	98	2	$(^2D^\circ)\ ^1P^\circ$
$2s^2 2p^3(^4S^\circ)4d$	$^3D^\circ$	2	*684 626*			
		3	*684 630*			
		1	*684 640*			
$2s^2 2p^3(^2D^\circ)4s$	$^3D^\circ$	3	*689 753*			
		2	*689 789*			
		1	*689 808*			
$2s^2 2p^3(^2D^\circ)4s$	$^1D^\circ$	2	*691 781*			
$2s^2 2p^3(^2P^\circ)4s$	$^3P^\circ$	0	*714 468?*			
		1	*714 468*			
		2	*714 483*			
$2s^2 2p^3(^2P^\circ)4s$	$^1P^\circ$	1	*716 509*			
$2s^2 2p^3(^2D^\circ)4d$	$^3D^\circ$	3	*730 702*			
		2	*730 728*			
		1	*730 742*			
$2s^2 2p^3(^2D^\circ)4d$	$^1P^\circ$	1	*731 684*			
$2s^2 2p^3(^2D^\circ)4d$	$^3P^\circ$	2	*732 325*			
		1	*732 346*			
		0				
$2s^2 2p^3(^2D^\circ)4d$	$^3S^\circ$	1	*732 979*			
$2s^2 2p^3(^2D^\circ)4d$	$^1D^\circ$	2	*733 288*			
$2s^2 2p^3(^2D^\circ)4d$	$^1F^\circ$	3	*733 919*			
$2s^2 2p^3(^2P^\circ)4d$	$^1D^\circ$	2	*755 785*			
$2s^2 2p^3(^2P^\circ)4d$	$^1F^\circ$	3	*756 995*			
Na v ($^4S^\circ_{3/2}$)	***Limit***		***797 800***			
$2s2p^4(^4P)3d$	^3D	3	813 494			
		2	813 527			
		1	813 648?			

Na V

$Z=11$

N I isoelectronic sequence

Ground state $1s^22s^22p^3\ {}^4S^\circ_{3/2}$

Ionization energy 1 116 300 cm^{-1} (138.40 eV)

Söderqvist observed and analyzed this spectrum, his 1946 paper giving 103 lines classified as Na V transitions in the region 100–515 Å. The line list of Goto, Gautam, and Joshi includes a few additional lines classified as transitions between Na V levels from Söderqvist's analysis (163–1806 Å).

We have reevaluated the doublet levels, based on the quartet-doublet intersystem connection discovered by Edlén [1964] and consideration of the entire combination array. A value of –36 cm^{-1} is adopted for both intervals $2s^22p^3\ {}^2D^\circ_{5/2}$–${}^2D^\circ_{3/2}$ and $2s2p^4\ {}^2D_{5/2}$ – ${}^2D_{3/2}$, this value for the former interval agreeing somewhat better with the observations and with Edlén's [1972] predicted value of –46 cm^{-1} than does Söderqvist's value of –25 cm^{-1}. The $2s2p^4\ {}^4P$ levels are probably accurate to within ±10 to ±15 cm^{-1}, and the doublet levels up to the $2p^5\ {}^2P^\circ$ term should have about this accuracy within the doublet system; the errors of intersystem differences may be several times larger, but the experimental system connection differs from Edlén's [1972] predicted value by only 23 cm^{-1}. Beginning a little below 900 000 cm^{-1} we have rounded most of the levels to the nearest 10 cm^{-1}, since some of the levels in this region may have errors up to ±100 cm^{-1} or more.

A number of the upper levels appear questionable in that they are derived from single weak lines or lines also assigned to other ionization stages. Most such levels are assigned to $2s^22p^24s$, $4d$, or $5d$ terms. We have specifically indicated some of the more questionable doublet levels as tentative. Söderqvist's $2s^22p^2(^3P)4d\ {}^2F_{5/2}$ and $2s^22p^2(^3P)4s\ {}^4P_{3/2}$ levels are omitted, the former having two inconsistent combinations and the latter no combinations in the line list.

Söderqvist's [1946] value for the ionization energy as derived from series data is quoted above, to the nearest 100 cm^{-1}. Edlén's [1964] fit of semiempirical formulae to the isoelectronic sequence yielded a value 100 cm^{-1} lower. No estimate of the uncertainty was given.

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Na V

Configuration	Term	J	Level (cm^{-1})	Configuration	Term	J	Level (cm^{-1})
$2s^22p^3$	${}^4S^\circ$	3/2	*0*	$2p^5$	${}^2P^\circ$	3/2	*568 348*
						1/2	*569 977*
$2s^22p^3$	${}^2D^\circ$	5/2	*48 330*				
		3/2	*48 366*	$2s^22p^2(^3P)3s$	${}^4P$	1/2	671 136
$2s^22p^3$	${}^2P^\circ$	1/2	*73 218*			3/2	671 790
		3/2	*73 255*			5/2	672 757
$2s2p^4$	${}^4P$	5/2	215 860	$2s^22p^2(^3P)3s$	${}^2P$	1/2	683 238
		3/2	216 896			3/2	684 434
		1/2	217 440				
				$2s^22p^2(^1D)3s$	${}^2D$	5/2,3/2	710 089
$2s2p^4$	${}^2D$	5/2	297 880				
		3/2	297 916	$2s^22p^2(^1S)3s$	${}^2S$	1/2	749 402
$2s2p^4$	${}^2S$	1/2	350 747	$2s^22p^2(^3P)3d$	${}^2P$	3/2	793 104
						1/2	793 617
$2s2p^4$	${}^2P$	3/2	372 731				
		1/2	373 932	$2s^22p^2(^3P)3d$	${}^4D$	7/2	
						5/2,3/2	797 060
						1/2	797 270

Na v—Continued

Configuration	Term	J	Level (cm^{-1})
$2s^2 2p^2(^3P)3d$	^2F	$5/2$	798 059
		$7/2$	799 295
$2s^2 2p^2(^3P)3d$	^4P	$5/2$	798 174
		$3/2$	798 620
		$1/2$	798 862
$2s2p^3(^5S^\circ)3s$	$^4S^\circ$	$3/2$	*801 950*
$2s^2 2p^2(^3P)3d$	^2D	$3/2$	809 314
		$5/2$	809 682
$2s^2 2p^2(^1D)3d$	^2F	$7/2$	829 269
		$5/2$	829 463
$2s^2 2p^2(^1D)3d$	^2D	$3/2$	832 846
		$5/2$	832 988
$2s^2 2p^2(^1D)3d$	^2P	$1/2$	838 200
		$3/2$	838 485
$2s^2 2p^2(^1D)3d$	^2S	$1/2$	842 829
$2s2p^3(^5S^\circ)3p$	^4P	$1/2$–$5/2$	847 539
$2s^2 2p^2(^1S)3d$	^2D	$3/2, 5/2$	867 530?
$2s2p^3(^3D^\circ)3s$	$^4D^\circ$	$1/2$–$7/2$	*878 320*
$2s^2 2p^2(^3P)4s$	^4P	$1/2$	892 240
		$3/2$	
		$5/2$	893 820
$2s2p^3(^3D^\circ)3s$	$^2D^\circ$	$3/2, 5/2$	*894 860*
$2s^2 2p^2(^3P)4s$	^2P	$1/2$	896 715?
		$3/2$	897 910?
$2s2p^3(^5S^\circ)3d$	$^4D^\circ$	$1/2$–$7/2$	*908 710*
$2s2p^3(^3P^\circ)3s$	$^4P^\circ$	$1/2$–$5/2$	*919 070*
$2s^2 2p^2(^1D)4s$	^2D	$5/2, 3/2$	928 830?
$2s^2 2p^2(^3P)4d$	^2P	$3/2$	938 430?
$2s^2 2p^2(^3P)4d$	^4D	$7/2$	
		$5/2, 3/2$	939 060
		$1/2$	939 860
$2s^2 2p^2(^3P)4d$	^4P	$5/2$	940 720
		$3/2$	940 930
		$1/2$	
$2s^2 2p^2(^3P)4d$	^2F	$7/2$	942 150?
$2s^2 2p^2(^3P)4d$	^2D	$3/2$	944 790
		$5/2$	945 100
$2s2p^3(^3D^\circ)3p$	^2F	$7/2$	950 220
		$5/2$	950 760?
$2s^2 2p^2(^1D)4d$	^2F	$7/2, 5/2$	974 110?
$2s^2 2p^2(^1D)4d$?	^2D?	$3/2, 5/2$	974 800
$2s2p^3(^3D^\circ)3d$	$^4P^\circ$	$5/2$	*1 004 400*
		$3/2$	*1 004 620*
		$1/2$	*1 004 790*
$2s2p^3(^3D^\circ)3d$	$^4D^\circ$	$1/2$–$7/2$	*1 008 210*
$2s2p^3(^3D^\circ)3d$	$^4S^\circ$	$3/2$	*1 008 940*
$2s2p^3(^3D^\circ)3d$	$^2F^\circ$	$7/2$	*1 010 850*
		$5/2$	*1 011 330*
$2s^2 2p^2(^1D)5d$	^2F	$7/2, 5/2$	1 038 970?
$2s^2 2p^2(^1D)5d$	^2D	$3/2, 5/2$	1 039 610?
Na VI ($^3P_0$)	***Limit***		**1 116 300**

Na VI

$Z=11$

C I isoelectronic sequence

Ground state $1s^2 2s^2 2p^2\ ^3P_0$

Ionization energy 1 388 750±400 cm^{-1} (172.18±0.05 eV)

The levels are based mainly on the observations and analysis by Söderqvist, whose 1946 paper gives 134 lines assigned to Na VI in the range 80–638 Å. Fawcett measured and classified the three $2s2p^3$—$2p^4$ lines arising from the $2p^4\ ^1D_2$ and $^1S_0$ levels; the isoelectronic data showed that Söderqvist's value for the former level was incorrect [Fawcett, 1971, Anno and Teruya, 1971]. Goto, Gautam, and Joshi gave a number of new lines in the 119–2205 Å range as belonging to this spectrum.

We have redetermined or confirmed the level values. Most of the $2s^2 2p^2$, $2s2p^3$, and $2p^4$ triplet levels are probably accurate to about ±15 cm^{-1}. The singlet-triplet intercombinations classified by Söderqvist occur at shorter wavelengths, and the lowest singlet levels may thus have an additional systematic error with respect to the ground and other low triplet levels; the $2s^2 2p^2\ ^1D_2$—$^3P_2$ separation adopted here, however, is only 12 cm^{-1} less than that given by Edlén's semi-empirical formulae. Beginning with the $2s^2 2p3s$ configuration we have rounded off the higher levels to the nearest 10 cm^{-1}, since the uncertainty increases and may be ±100 cm^{-1} or larger for the highest levels.

The quintet system of levels was established by Söderqvist, but he found no intercombination lines connecting this system with the triplets. Goto et al. classified two lines as transitions from the $2s2p^3\ ^5S^\circ_2$ level to the $2s^2 2p^2\ ^3P_1$ and $^3P_2$ levels (974 and 985 Å, relative intensities 10 and 5, respectively). These classifications may be questioned, however, since the transition to the $^3P_2$ level is calculated to be the stronger of the two lines in the isoelectronic sequence up to about Cr XIX [Kastner et al., 1977], and this expectation has been confirmed by observations through Ne V. We have thus taken the Na VI triplet-quintet connection given by the above classifications as tentative and listed the quintet levels with "$+x$" to indicate a possible systematic correction. The most probable value of x estimated solely from isoelectronic extrapolation procedures [Edlén et al., 1969] would appear to be about −200 to −400 cm^{-1}.

Several levels based on single weak (usually doubly classified) lines are given here as tentative and three of the more doubtful high levels were omitted; these are Söderqvist's $2s^2 2p5d\ ^3P^\circ_2$, $2s2p^2(^2D)4d\ ^3D$, and $2s2p^2(^2D)5d\ ^3F$ levels.

The $2s^2 2pnd\ ^1F^\circ_3$ levels ($n=3$ through 6) appear to constitute the best series for determination of the ionization energy. We have redetermined the limit of this series, which is the Na VII $2s^2 2p\ ^2P^\circ_{3/2}$ level, using the $2pnd\ ^1F^\circ_3$ positions given here. The resulting value for the Na VII $2s^2 2p\ ^2P^\circ_{1/2}$ principal limit is given above.

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Na VI

Configuration	Term	J	Level (cm^{-1})
$2s^2 2p^2$	^3P	0	0
		1	698
		2	1 859
$2s^2 2p^2$	^1D	2	35 498
$2s^2 2p^2$	^1S	0	74 414
$2s2p^3$	$^5S^\circ$	2	*103 362+x*
$2s2p^3$	$^3D^\circ$	3	*204 132*
		2	*204 223*
		1	*204 261*
$2s2p^3$	$^3P^\circ$	2,1,0	*241 341*
$2s2p^3$	$^1D^\circ$	2	*312 315*
$2s2p^3$	$^3S^\circ$	1	*320 589*
$2s2p^3$	$^1P^\circ$	1	*350 319*

Na vi—Continued

Configuration	Term	J	Level (cm^{-1})
$2p^4$	^{3}P	2	477 277
		1	478 597
		0	479 157
$2p^4$	^{1}D	2	506 114
$2p^4$	^{1}S	0	579 173
$2s^2 2p3s$	^{3}P°	0	
		1	*807 320*
		2	*808 800*
$2s^2 2p3s$	^{1}P°	1	*817 740*
$2s^2 2p3p$	^{3}P	0	
		1	872 580
		2	873 290
$2s^2 2p3d$	^{3}F°	2	*919 480*
$2s^2 2p3d$	^{1}D°	2	*920 850*
$2s2p^2(^4\mathrm{P})3s$	^{5}P	1	922 910+x
		2	923 620+x
		3	924 560+x
$2s^2 2p3d$	^{3}D°	1	*929 774*
		2	*930 000*
		3	*930 510*
$2s^2 2p3d$	^{3}P°	2	*933 920*
		1	*934 460*
		0	*934 740?*
$2s^2 2p3d$	^{1}F°	3	*945 450*
$2s^2 2p3d$	^{1}P°	1	*946 530*
$2s2p^2(^4\mathrm{P})3s$	^{3}P	0	949 780
		1	950 370
		2	951 390
$2s2p^2(^4\mathrm{P})3p$	^{3}S°	1	*970 840*
$2s2p^2(^4\mathrm{P})3p$	^{3}D°	1	
		2	*996 010*
		3	*996 740*
$2s2p^2(^4\mathrm{P})3p$	^{3}P°	0	
		1	*1 005 070?*
		2	*1 005 710*
$2s2p^2(^2\mathrm{D})3s$	^{3}D	1,2,3	1 016 270
$2s2p^2(^2\mathrm{D})3s$	^{1}D	2	1 033 360
$2s2p^2(^2\mathrm{D})3p$	^{3}D°	1,2,3	*1 040 220*
$2s2p^2(^4\mathrm{P})3d$	^{5}D	2,3	1 041 630+x?
$2s2p^2(^4\mathrm{P})3d$	^{5}P	3	1 045 650+x
		2	1 046 070+x
		1	1 046 400+x
$2s2p^2(^4\mathrm{P})3d$	^{3}P	2	1 047 410
		1	1 048 100
		0	
$2s2p^2(^4\mathrm{P})3d$	^{3}F	2	1 053 880
		3	1 054 500
		4	1 055 260
$2s2p^2(^4\mathrm{P})3d$	^{3}D	1	1 067 760
		2	1 067 970
		3	1 068 260
$2s2p^2(^2\mathrm{D})3p$	^{1}F°	3	*1 072 040*
$2s2p^2(^2\mathrm{D})3p$	^{1}D°	2	*1 077 890*
$2s^2 2p4s$	^{3}P°	2	*1 090 760*
$2s2p^2(^2\mathrm{D})3d$	^{3}F	2,3,4	1 125 320
$2s^2 2p4d$	^{3}F°	2	*1 128 690*
$2s2p^2(^2\mathrm{D})3d$	^{3}P	0,1,2	1 130 630
$2s^2 2p4d$	^{1}D°	2	*1 131 170*
$2s^2 2p4d$	^{3}D°	1	*1 133 490*
		2	*1 133 870*
		3	*1 134 750*
$2s2p^2(^2\mathrm{D})3d$	^{3}D	1,2,3	1 134 090
$2s^2 2p4d$	^{3}P°	2	*1 136 380*
$2s^2 2p4d$	^{1}F°	3	*1 140 860*
$2s2p^2(^2\mathrm{D})3d$	^{3}S	1	1 144 280
$2s2p^2(^2\mathrm{D})3d$	^{1}D	2	1 147 860
$2s2p^2(^2\mathrm{D})3d$	^{1}P	1	1 151 280
$2s2p^2(^4\mathrm{P})4s$	^{5}P	3	1 205 340+x
$2s2p^2(^4\mathrm{P})4s$	^{3}P	2	1 214 190?
$2s^2 2p5d$	^{3}D°	3	*1 228 210?*
$2s^2 2p5d$	^{1}F°	3	*1 231 110*

Na VI—Continued

Configuration	Term	*J*	Level (cm^{-1})	Configuration	Term	*J*	Level (cm^{-1})
$2s2p^2(^4P)4d$	^{5}P	3	1 250 010+*x*?	$2s^2 2p6d$	^{1}F°	3	*1 280 130*
		2	1 250 930+*x*?				
		1		$2s2p^2(^2D)4d$	^{3}F	2,3,4	1 334 585
$2s2p^2(^4P)4d$	^{3}F	2	1 253 370	$2s2p^2(^2D)4d$	^{3}P	0,1,2	1 335 520
		3	1 253 950				
		4	1 254 750	$2s2p^2(^4P)5d$	^{5}P	3	1 343 360+*x*?
$2s2p^2(^4P)4d$	^{3}D	1,2,3	1 258 610	……………	……………	……………	……………
$2p^3(^4S°)3p$	^{3}P	0,1,2	1 265 580	Na VII ($^2P^\circ_{1/2}$)	***Limit***		***1 388 750***

Na VII

Z = 11

B I isoelectronic sequence

Ground state $1s^2 2s^2 2p\ ^2P^\circ_{1/2}$

Ionization energy $1\ 681\ 700 \pm 250$ cm^{-1} (208.51 ± 0.03 eV)

The levels are based on the observations and analysis by Söderqvist, whose 1944 paper gives 158 lines classified as Na VII transitions in the range 62–492 Å. The positions of the $2s^2 4d\ ^2D_{5/2}$ and $2p^2(^1D)3p\ ^2D^\circ$ levels have been changed to agree better with the experimental wavenumbers of their transitions. The values of most of the other doublet levels are as given by Söderqvist, adjusted to a value of zero for the ground level, except that beginning with the $2s^2 3s\ ^2S_{1/2}$ level at 951 350 cm^{-1} all levels are rounded to the nearest 10 cm^{-1}. The errors of some of the higher levels may be ± 100 cm^{-1} or more, whereas the probable errors of most of the lower doublets (given to the nearest cm^{-1}) should be of the order of ± 10 cm^{-1}. Fawcett's observations of this spectrum included the $2s2p^2\ ^2P—2p^3\ ^2D^\circ$ doublet near 780 Å, but the measured wavelengths of the two (diagonal) lines were less accurate than predictions from Söderqvist's levels.

The quartet system of levels is listed with an unknown added quantity "x" because no quartet-doublet transitions have been definitely identified. The position of the quartets relative to the doublets is from Edlén's estimate of the $2s2p^2\ ^4P$ position (by graphic methods applied to the isoelectronic sequence). The uncertainty of this connection should be much smaller than the 209 cm^{-1} by which it differs from the previous estimate by Söderqvist. The differences between Söderqvist's values for the $2s2p^2\ ^4P$ and $2p^3\ ^4S^\circ_{3/2}$ levels are 18 cm^{-1} less than his experimental wavenumbers for the corresponding three lines connecting these terms. We have thus raised the $2p^3\ ^4S^\circ$ level, and consequently the higher even-parity quartet levels, by this amount relative to the $2s2p^2\ ^4P$ levels. Three other quartet levels have been changed by varying amounts, again to give better agreement with experimental wavenumbers.

Söderqvist gave the $2p^2(^3P)3d\ ^2F$, ^2D, and $2s2p(^1P^\circ)4d\ ^2F^\circ$ levels as tentative. We list as questionable several additional levels based entirely on lines classified as belonging partly to other Na spectra or on single weak lines. Interactions of the configurations based on the different cores ($2s^2$, $2s2p$, $2p^2$) can be expected, and the interpretation of some of the higher levels should probably be regarded as tentative.

The limit given above is the value given by Söderqvist (1 681 679 cm^{-1}) rounded to the nearest 100 cm^{-1}. We obtained a limit of 1 681 750 cm^{-1} by optimizing a quantum-defect plot of the longest series, $3s^2 nd\ ^2D_{5/2}$ ($n = 3$–8). Our estimate of the probable error is based on this series.

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Na VII

Configuration	Term	J	Level (cm^{-1})	Configuration	Term	J	Level (cm^{-1})
$2s^2 2p$	$^2P^\circ$	1/2	*0*	$2p^3$	$^2D^\circ$	5/2	*412 311*
		3/2	*2 139*			3/2	*412 395*
$2s2p^2$	^4P	1/2	114 978+x	$2p^3$	$^2P^\circ$	1/2	*465 017*
		3/2	115 711+x			3/2	*465 111*
		5/2	116 778+x	$2s^2 3s$	^2S	1/2	951 350
$2s2p^2$	^2D	5/2	205 412	$2s^2 3p$	$^2P^\circ$	1/2	
		3/2	205 448			3/2	*1 008 420*
$2s2p^2$	^2S	1/2	264 400	$2s^2 3d$	^2D	3/2	1 060 580
$2s2p^2$	^2P	1/2	283 869			5/2	1 060 700
		3/2	285 189				
$2p^3$	$^4S^\circ$	3/2	*367 290*+x				

Na VII—Continued

Configuration	Term	J	Level (cm^{-1})
$2s2p(^3P^\circ)3s$	$^4P^\circ$	1/2	*1 077 250+x*
		3/2	*1 077 980+x*
		5/2	*1 079 310+x*
$2s2p(^3P^\circ)3s$	$^2P^\circ$	1/2	*1 103 220*
		3/2	*1 104 620*
$2s2p(^3P^\circ)3p$	^2P	1/2	1 126 810
		3/2	1 127 430
$2s2p(^3P^\circ)3p$	^2D	3/2	1 154 780
		5/2	1 156 180
$2s2p(^3P^\circ)3p$	^2S	1/2	1 172 340
$2s2p(^3P^\circ)3d$	$^4D^\circ$	1/2	
		3/2	*1 185 720+x*
		5/2	*1 185 980+x*
		7/2	*1 186 460+x*
$2s2p(^3P^\circ)3d$	$^2D^\circ$	3/2	*1 186 630*
		5/2	*1 187 890*
$2s2p(^3P^\circ)3d$	$^4P^\circ$	5/2	*1 192 330+x*
		3/2	*1 192 850+x*
		1/2	*1 193 190+x*
$2s2p(^1P^\circ)3s$	$^2P^\circ$	1/2,3/2	*1 198 290*
$2s2p(^3P^\circ)3d$	$^2F^\circ$	5/2	*1 209 910*
		7/2	*1 211 240*
$2s2p(^3P^\circ)3d$	$^2P^\circ$	3/2	*1 217 190*
		1/2	*1 217 950*
$2s2p(^1P^\circ)3p$	^2D	3/2	1 251 670
		5/2	1 252 010
$2s2p(^1P^\circ)3p$	^2P	1/2	1 253 350
		3/2	1 253 780
$2s2p(^1P^\circ)3p$	^2S	1/2	1 258 880
$2p^2(^3P)3s$	^4P	1/2	
		3/2	1 290 030+x
		5/2	1 291 560+x
$2s2p(^1P^\circ)3d$	$^2F^\circ$	5/2,7/2	*1 292 330*
$2s^2 4s$	^2S	1/2	1 294 910
$2s2p(^1P^\circ)3d$	$^2D^\circ$	3/2	*1 303 450?*
		5/2	*1 303 610*
$2s2p(^1P^\circ)3d$	$^2P^\circ$	1/2,3/2	*1 306 470*
$2p^2(^1D)3s$	^2D	3/2	1 331 140
		5/2	1 331 970
$2s^2 4d$	^2D	3/2	1 335 810
		5/2	1 335 830
$2p^2(^3P)3p$	$^4D^\circ$	7/2	*1 338 450+x*
$2p^2(^3P)3p$	$^4P^\circ$	5/2	*1 344 830+x*
$2p^2(^3P)3p$	$^2D^\circ$	3/2,5/2	*1 348 720*
$2p^2(^3P)3p$	$^4S^\circ$	3/2	*1 362 950+x*
$2p^2(^1D)3p$	$^2F^\circ$	5/2	*1 377 820*
		7/2	*1 378 300*
$2p^2(^3P)3d$	^2F	5/2	1 388 500?
		7/2	1 388 970?
$2p^2(^3P)3d$	^2D	3/2,5/2	1 390 450?
$2p^2(^1D)3p$	$^2D^\circ$	3/2,5/2	*1 392 800*
$2p^2(^3P)3d$	^4P	5/2	1 399 050+x
		3/2	1 399 580+x
		1/2	1 399 870+x
$2p^2(^1D)3d$	^2D	3/2,5/2	1 415 630
$2s2p(^3P^\circ)4s$	$^4P^\circ$	5/2	*1 422 870+x*
$2p^2(^1D)3d$	^2F	5/2	1 428 720
		7/2	1 428 800
$2p^2(^1D)3d$	^2P	1/2	1 432 140
		3/2	1 432 610
$2s2p(^3P^\circ)4s$	$^2P^\circ$	1/2	
		3/2	*1 432 600?*
$2s2p(^3P^\circ)4p$	^2P	1/2	1 442 710
		3/2	1 443 170
$2s2p(^3P^\circ)4p$	^2D	3/2	1 452 100
		5/2	1 453 350
$2s^2 5d$	^2D	3/2	1 461 520
		5/2	1 461 590
$2s2p(^3P^\circ)4d$	$^4D^\circ$	1/2	
		3/2	*1 462 380+x*
		5/2	*1 462 420+x*
		7/2	*1 463 250+x*
$2s2p(^3P^\circ)4d$	$^2D^\circ$	3/2	
		5/2	*1 464 050*

Na VII—Continued

Configuration	Term	J	Level (cm^{-1})	Configuration	Term	J	Level (cm^{-1})
$2s2p(^3P^\circ)4d$	$^4P^\circ$	$5/2$	*1 464 850+x*	$2s2p(^3P^\circ)5d$	$^4D^\circ$	$1/2$–$7/2$	*1 589 270+x*
$2s2p(^3P^\circ)4d$	$^2F^\circ$	$5/2$ $7/2$	*1 471 560* *1 472 730*	$2s2p(^3P^\circ)5d$	$^4P^\circ$	$1/2$–$5/2$	*1 590 050+x*
$2s2p(^3P^\circ)4d$	$^2P^\circ$	$3/2$ $1/2$	*1 473 810?* *1 474 530?*	$2s2p(^3P^\circ)5d$	$^2F^\circ$	$5/2$ $7/2$	*1 592 820* *1 593 920*
$2s^2 6d$	^2D	$3/2,5/2$	1 529 460	$2s^2 8d$	^2D	$3/2,5/2$	1 596 400
$2s2p(^1P^\circ)4s$	$^2P^\circ$	$1/2,3/2$	*1 538 950?*	$2p^2(^3P)4p$	$^4D^\circ$	$3/2$–$7/2$	*1 646 110+x*
$2s2p(^1P^\circ)4p$	^2D	$3/2,5/2$	1 561 890?	$2s2p(^3P^\circ)6d$	$^4D^\circ$	$1/2$–$7/2$	*1 657 520+x*
$2s^2 7d$	^2D	$3/2,5/2$	1 570 080	$2p^2(^3P)4d$	^4P	$5/2$ $3/2$ $1/2$	1 668 320+x? 1 668 920+x?
$2s2p(^1P^\circ)4d$	$^2F^\circ$	$5/2,7/2$	*1 577 810?*				
$2s2p(^3P^\circ)5p$	^2P	$1/2,3/2$	1 578 350	…………	…………	…………	…………
$2s2p(^3P^\circ)5p$	^2D	$3/2,5/2$	1 583 740	Na VIII ($^1S_0$)	***Limit***		**1 681 700**

Na VIII

$Z=11$

Be I isoelectronic sequence

Ground state $1s^22s^2\ ^1S_0$

Ionization energy 2 131 300±250 cm^{-1} (264.25±0.03 eV)

Levels Below the Principal Ionization Limit

Söderqvist analyzed this spectrum as obtained with a vacuum-spark source. The classified lines occurred in two regions, with three longer-wavelength transitions comprising the $2s^2\ ^1S_0$—$2s2p\ ^1P_1^\circ$ resonance line (411 Å) and two $2s2p\ ^3P^\circ$—$2p^2\ ^3P$ lines. Fawcett's measurements of the $2s2p$—$2p^2$ lines (492–500 Å) include the complete $^3P^\circ$–^3P multiplet and the $^1P_1^\circ$–$^1S_0$ line. The $2s2p$ and $2p^2$ levels given here are from Edlén, who has evaluated the levels of these configurations for Be I-like spectra by combining the experimental data with requirements of isoelectronic regularity. It appears that the probable errors for these Na VIII levels are not greater than a few cm^{-1}. The values of the $2s2p\ ^3P^\circ$ and $2p^2\ ^3P$ levels with respect to the $2s^2\ ^1S_0$ ground level as determined by Edlén may be as accurate as the intrasystem separations (singlet-singlet or triplet-triplet); we have, however, listed the triplet levels with a quantity "$+x$" to indicate the lack of an experimental determination of the intersystem connection for Na VIII.

Söderqvist's 1944 paper has 83 lines in the range 51–118 Å classified as transitions from $2snl$ and $2pnl$ ($n \geqslant 3$) levels of Na VIII. We have redetermined these higher levels by combining Söderqvist's wavenumbers with the low levels from Edlén. Most of the higher levels are rounded to the nearest 10 cm^{-1}, the probable errors varying from perhaps 20 or 30 cm^{-1} to more than 100 cm^{-1}. (The quantity "x" is probably negligible compared to the experimental uncertainties of these levels.)

A number of the higher levels are given here as tentative, each being derived from a single line not normally expected to be the strongest combination or otherwise questionably classified. The classification of the weaker lines is complicated by interactions between the two series types ($2snl$ and $2pnl'$) known to occur in this isoelectronic sequence. The lowest missing term, $2s3p\ ^3P^\circ$, is predicted to lie about 3000 cm^{-1} *above* the $2s3p\ ^1P^\circ$ term [Odabasi, 1969]. Odabasi's configuration-interaction eigenvectors for the $2s3p$ terms in this sequence indicate that depression of the $2s3p\ ^1P^\circ$ term by interaction with $2p3s\ ^1P^\circ$ is mainly responsible for this anomaly; in Na VIII the percentage composition of the $2s3p\ ^1P^\circ$ term includes 9.6% $2p3s\ ^1P^\circ$, whereas the mixing of the $^3P^\circ$ terms from these two configurations is only 0.7%. Odabasi's eigenvectors include contributions from nine configurations.

We derived the quoted ionization limit by minimizing irregularities in a quantum-defect plot for the $2snd\ ^1D_2$ series, which appears to be the least perturbed of the four-member series. This value for the limit agrees with the value given by Söderqvist (2 131 140 cm^{-1}) to within our estimate of the probable error. The designations of several levels assigned to other series are given as questionable because of intensity and quantum-defect irregularities.

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Na VIII

Configuration	Term	J	Level (cm^{-1})	Configuration	Term	J	Level (cm^{-1})
$2s^2$	^1S	0	0	$2p^2$	^1D	2	361 145
$2s2p$	$^3P^\circ$	0	*125 880*+x	$2p^2$	^1S	0	446 136
		1	*126 612*+x				
		2	*128 218*+x	$2s3s$	^3S	1	1 239 974+x
$2s2p$	$^1P^\circ$	1	*243 208*	$2s3s$	^1S	0	1 262 780
$2p^2$	^3P	0	327 476+x	$2s3p$	$^1P^\circ$	1	*1 294 230*
		1	328 310+x				
		2	329 729+x				

Na VIII—Continued

Configuration	Term	J	Level (cm^{-1})
$2s3d$	$^{3}\mathrm{D}$	1 2 3	1 327 226+x 1 327 265+x 1 327 388+x
$2s3d$	$^{1}\mathrm{D}$	2	1 347 740
$2p3s$	$^{3}\mathrm{P}^{\circ}$	0 1 2	*1 399 670*+x *1 400 470*+x *1 402 200*+x
$2p3s$	$^{1}\mathrm{P}^{\circ}$	1	*1 426 125*
$2p3p$	$^{1}\mathrm{P}$	1	1 432 980
$2p3p$	$^{3}\mathrm{D}$	1 2 3	1 439 410+x? 1 440 260+x? 1 441 880+x
$2p3p$	$^{3}\mathrm{S}$	1	1 452 400+x
$2p3p$	$^{3}\mathrm{P}$	0 1 2	 1 459 850+x 1 460 770+x
$2p3d$	$^{1}\mathrm{D}^{\circ}$	2	*1 469 150*
$2p3p$	$^{1}\mathrm{D}$	2	1 474 580
$2p3p$	$^{1}\mathrm{S}$	0	1 481 510
$2p3d$	$^{3}\mathrm{D}^{\circ}$	1 2 3	*1 485 140*+x *1 485 340*+x *1 486 080*+x
$2p3d$	$^{3}\mathrm{P}^{\circ}$	2 1 0	*1 491 980*+x *1 492 630*+x *1 492 980*+x
$2p3d$	$^{1}\mathrm{F}^{\circ}$	3	*1 507 790*
$2p3d$	$^{1}\mathrm{P}^{\circ}$	1	*1 513 730*
$2s4s$	$^{3}\mathrm{S}$	1	1 649 480+x
$2s4s$	$^{1}\mathrm{S}$	0	1 656 820
$2s4p$	$^{1}\mathrm{P}^{\circ}$	1	*1 673 390*
$2s4d$	$^{3}\mathrm{D}$	1,2,3	1 683 370+x
$2s4d$	$^{1}\mathrm{D}$	2	1 689 970
$2p4p$	$^{1}\mathrm{P}$	1	1 813 190
$2p4p$	$^{3}\mathrm{D}$	1 2 3	 1 816 010+x? 1 817 290+x
$2p4p$	$^{3}\mathrm{P}$	2	1 822 880+x
$2p4d$	$^{1}\mathrm{D}^{\circ}$	2	*1 827 570*
$2p4p$	$^{1}\mathrm{D}$	2	1 827 640
$2p4d$	$^{3}\mathrm{D}^{\circ}$	3	*1 833 530*+x
$2p4d$	$^{3}\mathrm{P}^{\circ}$	2 1 0	*1 835 010*+x *1 835 290*+x?
$2p4d$	$^{1}\mathrm{F}^{\circ}$	3	*1 838 860*
$2s5p$	$^{1}\mathrm{P}^{\circ}$	1	*1 838 910*
$2p4d$	$^{1}\mathrm{P}^{\circ}$	1	*1 843 110*
$2s5d$?	$^{3}\mathrm{D}$?	1,2,3	1 848 670+x?
$2s5d$	$^{1}\mathrm{D}$	2	1 848 960
$2s6p$	$^{1}\mathrm{P}^{\circ}$	1	*1 930 910*
$2s6d$?	$^{3}\mathrm{D}$?	1,2,3	1 933 430+x
$2s6d$	$^{1}\mathrm{D}$	2	1 935 230
$2p5p$	$^{3}\mathrm{P}$	2	1 988 680+x
$2p5p$	$^{1}\mathrm{D}$	2	1 990 540
$2p5d$	$^{1}\mathrm{D}^{\circ}$	2	*1 991 220*
$2p5d$	$^{3}\mathrm{D}^{\circ}$	3	*1 994 370*+x
$2p5d$	$^{3}\mathrm{P}^{\circ}$	2 1 0	*1 994 930*+x *1 995 200*+x?
$2p5d$	$^{1}\mathrm{F}^{\circ}$	3	*1 998 130*
$2p6p$?	$^{3}\mathrm{D}$?	1,2,3	2 076 930+x?
$2p6d$	$^{3}\mathrm{D}^{\circ}$	1,2,3	*2 080 460*+x
$2p6d$	$^{3}\mathrm{P}^{\circ}$	2,1,0	*2 081 170*+x
$2p6d$	$^{1}\mathrm{F}^{\circ}$	3	*2 083 210*
Na IX ($^{2}\mathrm{S}_{1/2}$)	***Limit***		**2 131 300**

Na IX

$Z=11$

Li I isoelectronic sequence

Ground state $1s^22s\ ^2S_{1/2}$

Ionization energy 2 418 570 cm^{-1} (299.867 eV)

Söderqvist observed the $1s^22s$—$1s^2np$ and $1s^22p$—$1s^2ns$, nd ($n\geqslant3$) series in the 44–81 Å region. Most of the $1s^2nl$ levels are from these measurements, and the $2p\ ^2P^\circ_{3/2}$ level is from his measurement of the $2s\ ^2S_{1/2}$—$2p\ ^2P^\circ_{3/2}$ line at 681.72 Å. The $2p\ ^2P^\circ_{3/2}$—$^2P^\circ_{1/2}$ interval is from one of several semi-empirical formulae for energies in this isoelectronic sequence derived by Edlén. The resulting value of the $2p\ ^2P^\circ_{1/2}$ level agrees with Fawcett's [1970] measurement of the $2s\ ^2S_{1/2}$—$2p\ ^2P^\circ_{1/2}$ wavelength (694.17 ± 0.04 Å) to within the experimental uncertainty. The agreement of Edlén's values with experimental values along the sequence makes an error greater than ~5 cm^{-1} for the Na IX $2p\ ^2P^\circ$ levels appear unlikely. We have reevaluated Sóderqvist's ns ($n\geqslant3$) and nd levels based wholly or in part on combinations with the $2p\ ^2P^\circ_{1/2}$ level, since the new value of this level is 24 cm^{-1} above his determination. The values of all the $1s^2nl$ ($n\geqslant3$) levels are rounded to the nearest 10 cm^{-1}, the estimated errors varying from perhaps ±50 cm^{-1} to about ±200 cm^{-1}.

The Ritz formulae for $1s^2ns$ and $1s^2np$ and the polarization formula for $1s^2nl$ ($l\geqslant2$) given by Edlén predict the entire spectrum for levels below the $1s^2\ ^1S_0$ limit. Levels calculated from the formulae are of course free of series irregularities arising from experimental error, and the absolute accuracy of the formulae appears to be at least comparable to the experimental accuracy. Kastner gives predicted intervals for the $np\ ^2P^\circ$, $nd\ ^2D$, and $nf\ ^2F^\circ$ terms through $n=10$ and notes the relatively large irregularities of the experimental Na IX $nd\ ^2D$ splittings for $n=4$ and 6 (almost certainly due to experimental errors).

In addition to the $2p\ ^2P^\circ$ interval, we have used Edlén's results for the ionization energy, the $4f\ ^2F^\circ$ and $5s\ ^2S$ terms, and the $4p\ ^2P^\circ$ interval (not resolved by Söderqvist). Edlén's isoelectronic-formula value for the ionization energy, which is given here rounded to the nearest 10 cm^{-1}, is 50 cm^{-1} above Söderqvist's value and 25 cm^{-1} below the (average) value obtained by Edlén using another method. The $4f\ ^2F^\circ$ and $5s\ ^2S$ levels are taken at Edlén's values with respect to the limit (not with respect to lower levels, for which the values given here differ somewhat from those used by Edlén). The quantum defect of Söderqvist' $5s\ ^2S_{1/2}$ level is very irregular in the $ns\ ^2S_{1/2}$ series, the indicated error of his measurement of the weak $2p\ ^2P^\circ_{3/2}$—$5s\ ^2S_{1/2}$ line being about 400 cm^{-1}. Edlén rejected an experimental identification of the $3d\ ^2D$—$4f\ ^2F^\circ$ line [Fawcett, 1971] as being too far from the predicted wavelength.

The wavenumber given by Söderqvist for the $2s\ ^2S_{1/2}$—$7p\ ^2P^\circ$ line gives a more regular behavior of the $np\ ^2P^\circ$ series than would the value 2 235 986 cm^{-1} corresponding to the tabulated wavelength (44.723 Å); the latter is thus assumed to be a misprint for 44.725 Å.

The terms of the $1s2s^2$, $1s2s2p$, and $1s2p^2$ configurations are included in the table. Spectral features due to such K-shell excitations, which of course lie far above the $1s^2\ ^1S_0$ ionization limit, have been observed near or blended with the Na X $1s^2\ ^1S_0$—$1snp\ ^1P^\circ$, $^3P^\circ$ resonance lines in the 11 Å region. Transitions from the $1s2s2p$ and $1s2p^2$ doublet terms are among the strongest contributors to such features in the spectra of laser-produced plasmas [see, e.g., Aglitskii et al.]. Since the available wavelength measurements for these lines in Na refer to unresolved blends, we have given the levels as obtained from energy separations calculated by Vainshtein and Safronova [1975; see also their 1978 publication]. The $1s2s^2$ and $1s2p^2$ levels were derived by combining Vainshtein and Safronova's results with the $1s^22p\ ^2P^\circ$ levels given here, and all the K-excitation levels were rounded to the nearest 100 cm^{-1}. Comparisons of theoretical and experimental values of such terms in higher spectra of this isoelectronic sequence suggest that errors greater than about ±2000 cm^{-1} are unlikely for the Na IX calculated levels. (The errors of the calculated fine-structure splittings should be much smaller.) The paper of Boiko et al. and references cited therein give wavelengths for transitions from $1s2l2l'$ terms and also $1s2l3l'$ terms. Feldman et al., for example, have assigned a feature observed by them at 11.029 Å (near the Na X $1s^2\ ^1S_0$—$1s2p\ ^1P^\circ_1$ resonance line) as arising from a blend of transitions of the type $1s^23l'$—$1s2p3l'$.

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Na IX

Configuration	Term	*J*	Level (cm^{-1})
$1s^2(^1S)2s$	^2S	1/2	0
$1s^2(^1S)2p$	$^2P^\circ$	1/2 3/2	*144 062* *146 688*
$1s^2(^1S)3s$	^2S	1/2	1 375 950
$1s^2(^1S)3p$	$^2P^\circ$	1/2 3/2	*1 415 370* *1 416 130*
$1s^2(^1S)3d$	^2D	3/2 5/2	1 430 000 1 430 200
$1s^2(^1S)4s$	^2S	1/2	1 840 350
$1s^2(^1S)4p$	$^2P^\circ$	1/2 3/2	[*1 856 440*] [*1 856 770*]
$1s^2(^1S)4d$	^2D	3/2 5/2	1 862 250 1 862 570
$1s^2(^1S)4f$	$^2F^\circ$	5/2 7/2	[*1 862 930*] [*1 862 980*]
$1s^2(^1S)5s$	^2S	1/2	[2 051 520]
$1s^2(^1S)5p$	$^2P^\circ$	1/2,3/2	*2 059 600*
$1s^2(^1S)5d$	^2D	3/2 5/2	2 062 860 2 062 910
$1s^2(^1S)6p$	$^2P^\circ$	1/2,3/2	*2 169 670*
$1s^2(^1S)6d$	^2D	3/2 5/2	2 171 390 2 171 550
$1s^2(^1S)7p$	$^2P^\circ$	1/2,3/2	*2 235 890*
$1s^2(^1S)7d$	^2D	3/2 5/2	2 237 160 2 237 170
....	....	....	....
Na X ($^1S_0$)	***Limit***		**2 418 570**
$1s2s^2$	^2S	1/2	[8 815 600]
$1s(^2S)2s2p(^3P^\circ)$	$^4P^\circ$	1/2 3/2 5/2	[*8 854 500*] [*8 855 100*] [*8 857 000*]
$1s(^2S)2s2p(^3P^\circ)$	$^2P^\circ$	1/2 3/2	[*8 963 700*] [*8 965 200*]
$1s2p^2$	^4P	1/2 3/2 5/2	[9 008 000] [9 009 200] [9 010 500]
$1s(^2S)2s2p(^1P^\circ)$	$^2P^\circ$	1/2 3/2	[*9 016 900*] [*9 017 500*]
$1s2p^2$	^2D	5/2 3/2	[9 075 600] [9 076 400]
$1s2p^2$	^2P	1/2 3/2	[9 095 100] [9 097 700]
$1s2p^2$	^2S	1/2	[9 178 900]
Na X $1s2s(^3S_1)$	*Limit*		[11 353 910]

Na X

$Z=11$

He I isoelectronic sequence

Ground state $1s^2\ ^1S_0$

Ionization energy 11 816 996 ±100 cm^{-1} (1465.133±0.012 eV)

1*sns* and 1*snp* Terms, Ionization Energy

Aglitskii et al. have observed the first two members of the $1s^2\ ^1S_0$—$1snp\ ^1P_1^\circ$ resonance series beginning near 11 Å ($n=2$). Their wavelength measurements agree with theoretical calculations, but the experimental uncertainty corresponds to ±2500 cm^{-1} in the $1s2p\ ^1P_1^\circ$ position. The calculated values for the $1snl$ levels given here should be much more accurate. The $1sns$ and $1snp$ levels for $n=2$–5, as well as the ionization energy, are from calculations by Ermolaev and Jones [unpublished supplement to their paper]. Most of the uncertainty in the ionization energy is due to the Lamb-shift contribution, the ±100 cm^{-1} given with the value above being only an order-of-magnitude estimate of the probable error based on Ermolaev and Jones' discussion. Approximately the same error would apply to all the $1sns$ and $1snp$ excited levels with respect to the ground level. The errors of the excited levels with respect to the limit are expected to be smaller, decreasing with n from perhaps about 20 cm^{-1} for $n=2$. There is at present some uncertainty about the accuracies of various theoretical energy calculations for higher ions in the He I sequence; accurate wavelength measurements for a number of transitions along the sequence will be useful in this regard (see, for example, the comparisons by Berry et al. of theoretical $1s2s\ ^3S$—$1s2p\ ^3P^\circ$ separations with available experimental values for the sequence). We give Ermolaev and Jones' values and the other $1snl$ levels to the nearest cm^{-1} for convenience in comparing with other calculations or future experimental results.[1]

The mixtures of the $1snp\ ^3P_1^\circ$ and $^1P_1^\circ$ states obtained from Ermolaev and Jones' supplementary table are not given as leading percentages below, since the eigenvector purities are >99%; their tabulated coefficients give singlet-triplet percentage mixtures of 0.10% for $1s2p$ to 0.14% for $1s5p$.

The theoretical values for the lower levels of the series can be extended to obtain values for arbitrarily high members. The $1sns$ and $1snp$ levels given for $n=6$–10 were obtained from Ritz formulae with constants derived by fitting Ermolaev and Jones' lower terms ($n=2$–5) to within maximum deviations of 1 to 3 cm^{-1}:

$$\text{Level/cm}^{-1} = 11\,816\,995.5 - 10\,973\,469(n^*)^{-2}$$

$$n - n^* = a + bn^{-2} + cn^{-4}$$

	a	b	c
$^3S_1$	0.0456129	0.0064034	0.021862
$^1S_0$	0.0184800	−0.0105071	0.009298
$^3P^\circ$	0.0175534	−0.0007314	0.006847
$^1P_1^\circ$	−0.0029084	−0.0116177	0.004739

The $^3P^\circ$ values are for the term baricenters.

1*snd* and 1*snf* Terms

Theoretical values are also given for the $1snd$ and $1snf$ terms through $n=6$. The values are based on variational calculations for $1s3d$ [Brown, 1968] and higher $1snd$ terms [Brown and Cortez, 1971] and for the $1snf$ terms [Brown, 1969]. These calculations did not include relativistic and radiative corrections, but combination of the $1snl$ term values (obtained from the total energies) with the $1s\ ^2S_{1/2}$ ionization limit of Ermolaev and Jones yields $1snl$ levels effectively including these corrections for the $1s$ electron. The error in Ermolaev and Jones' value for the ionization energy obviously must be included in the errors of the resulting $1snl$ positions with respect to the ground level. As an approximation for the largest of the remaining corrections, the relativistic shift associated with the nl electron, we assumed the Sommerfeld-Dirac correction for the baricenter of the hydrogenic nl term for core charge $Z_c=10$ [Edlén, 1964]. This smaller relativistic lowering of the levels varies from 325 cm^{-1} for the $1s3d$ terms to 43 cm^{-1} for the $1s6f$ terms.

The fine-structure separations of the $1s3d\ ^3D$ levels are from Vainshtein and Safronova's calculations [1976]. Their values for the $1s3l$ levels, which include relativistic and radiative contributions, give the $1s3d\ ^3D$ and ^1D terms lower by 83 and 153 cm^{-1}, respectively, relative to the $1s3s$ singlet-triplet mean position than is obtained with the levels given here. The $1s3l$ positions with respect to the $1s^2\ ^1S_0$ ground level as calculated by Vainshtein and Safronova, however, are higher than the values here by 453 cm^{-1} ($1s3d\ ^1D_2$) to 680 cm^{-1} (the $1s3p\ ^3P^\circ$ levels).

It is of interest to compare the $1snd$ and $1snf$ energies with predictions of the core-polarization theory of term

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[1] The estimated errors for the ionization energies and the $1sns$ and $1snp$ levels given in our compilations for Mg XI and Al XII [see references in the Introduction] were based on the accuracies of the ionization energies stated by Ermolaev and Jones in their summary Table 1. A closer reading of Sec. 3 of their paper indicates that the estimated errors of the ionization energies given in the above compilations should be increased by about an order of magnitude; these increased errors apply to all the excited levels with respect to the ground states.

defects in two-electron ions. For this purpose the energies are taken with respect to the $1s\ ^2S_{1/2}$ limit, and the appropriate quantities from Brown, or Brown and Cortez, are the differences between the calculated (non-relativistic) $1snl$ singlet-triplet mean energies and the corresponding Bohr hydrogenic energies ($100R_{Na}/n^2$). These differences, which are the calculated non-relativistic term defects, range from 268 cm^{-1} for $1s3d$ to 2 cm^{-1} for $1s6f$. They are smaller than the core-polarization defects predicted in the dipole plus quadrupole-polarizability approximation [Martin, 1970, and references therein] by 19 to 31 cm^{-1} for the $1snd$ terms and by 2 to 3 cm^{-1} for the $1snf$ terms. These results and similar comparisons for other two-electron ions indicate that, in this region of the isoelectronic sequence, the polarization formulae yield relatively accurate values for all the $1snl$ ($l \geqslant 2$) non-relativistic singlet-triplet mean energies. Levels of the higher $1snd$ and $1snf$ configurations in Na X can be derived from Ritz formulae fitted to the lower members of these series as given here.

Hyperfine Structure

The magnetic moment of the Na^{23} nucleus ($2.218u_N$, spin $^3/_2$) gives a hyperfine-structure factor $a_s = 16.7$ cm^{-1} for the Na XI $1s$ electron [Kastner, 1972]. We call attention to the resulting hyperfine structures of the Na X $1snl$ triplet levels [Kopfermann, 1958], which are thus comparable to or larger than some of the calculated fine-structure and term separations given here. It will be necessary to take the hyperfine splittings into account if sufficiently accurate observations are made.

Doubly Excited Configurations

Transitions of the type $1snl$—$2l'nl''$ ($n \geqslant 2$) from doubly excited upper configurations in Na X can give rise to "satellite" features near the Na XI $1s\ ^2S$—$2p\ ^2P^\circ$ resonance doublet at 10.02 Å. Feldman et al., for example, have observed such Na X features in the spectra of laser-produced plasmas. The main transitions involved were identified by Feldman et al., but most such features may be unresolved blends [see, for example, the more recent interpretation of the analogous Mg XI features in Table 6 of Boiko et al.]. Several of the stronger features are from $2s2p$ and $2p^2$ upper terms [Feldman et al.]. The $2s^2\ ^1S$ level, the $2s2p\ ^3P^\circ$ and $^1P^\circ$ levels, and the $2p^2\ ^1D$ and ^1S levels are given here as calculated relative to the ground level by Vainshtein and Safronova [1976]; the $2p^2\ ^3P$ levels from this reference were lowered by 400 cm^{-1} for inclusion here, to improve the overall agreement with values from the calculated $1s2p\ ^3P^\circ$—$2p^2\ ^3P$ wavelengths [Vainshtein and Safronova, 1978] combined with the $1s2p\ ^3P^\circ$ levels given here. All the doubly excited levels are rounded to the nearest 100 cm^{-1}. Such theoretical values have proved accurate to within the experimental errors of the available measurements in this region of the isoelectronic sequence [Boiko et al.], which would correspond to about ±2000 cm^{-1} for Na X.

Transitions from upper terms belonging to configurations of the type $2l'3l''$ have also been identified as contributing to satellite features of the hydrogenic-ion $1s\ ^2S$—$2p\ ^2P^\circ$ resonance doublet in the spectra of nearby elements. We have not included such terms here, but theoretical values are given by Vainshtein and Safronova [1976], for example.

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Na X

Configuration	Term	J	Level (cm^{-1})	Configuration	Term	J	Level (cm^{-1})
$1s^2$	^1S	0	0	$1s2p$	$^1P^\circ$	1	*[9 088 700]*
$1s2s$	^3S	1	[8 935 337]	$1s3s$	^3S	1	[10 558 946]
$1s2p$	$^3P^\circ$	0	*[9 022 345]*	$1s3p$	$^3P^\circ$	0	*[10 582 781]*
		1	*[9 022 867]*			1	*[10 582 947]*
		2	*[9 025 264]*			2	*[10 583 658]*
$1s2s$	^1S	0	[9 027 981]	$1s3s$	^1S	0	[10 583 431]

Na x—Continued

Configuration	Term	J	Level (cm^{-1})
$1s3d$	$^3\mathrm{D}$	1	[10 596 647]
		2	[10 596 667]
		3	[10 596 925]
$1s3d$	$^1\mathrm{D}$	2	[10 597 475]
$1s3p$	$^1\mathrm{P}^\circ$	1	[*10 601 080*]
$1s4s$	$^3\mathrm{S}$	1	[11 115 065]
$1s4p$	$^3\mathrm{P}^\circ$	0	[*11 124 873*]
		1	[*11 124 944*]
		2	[*11 125 244*]
$1s4s$	$^1\mathrm{S}$	0	[11 124 986]
$1s4d$	$^3\mathrm{D}$	1,2,3	[11 130 639]
$1s4d$	$^1\mathrm{D}$	2	[11 131 017]
$1s4f$	$^3\mathrm{F}^\circ$	2,3,4	[*11 131 051*]
$1s4f$	$^1\mathrm{F}^\circ$	3	[*11 131 056*]
$1s4p$	$^1\mathrm{P}^\circ$	1	[*11 132 393*]
$1s5s$	$^3\mathrm{S}$	1	[11 369 887]
$1s5p$	$^3\mathrm{P}^\circ$	0	[*11 374 842*]
		1	[*11 374 879*]
		2	[*11 375 032*]
$1s5s$	$^1\mathrm{S}$	0	[11 374 868]
$1s5d$	$^3\mathrm{D}$	1,2,3	[11 377 767]
$1s5d$	$^1\mathrm{D}$	2	[11 377 984]
$1s5f$	$^3\mathrm{F}^\circ$	2,3,4	[*11 377 987*]
$1s5f$	$^1\mathrm{F}^\circ$	3	[*11 377 991*]
$1s5p$	$^1\mathrm{P}^\circ$	1	[*11 378 646*]
$1s6s$	$^3\mathrm{S}$	1	[11 507 469]
$1s6s$	$^1\mathrm{S}$	0	[11 510 320]
$1s6p$	$^3\mathrm{P}^\circ$	0,1,2	[*11 510 387*]
$1s6d$	$^3\mathrm{D}$	1,2,3	[11 512 003]
$1s6f$	$^3\mathrm{F}^\circ$	2,3,4	[*11 512 130*]
$1s6f$	$^1\mathrm{F}^\circ$	3	[*11 512 133*]
$1s6d$	$^1\mathrm{D}$	2	[11 512 137]
$1s6p$	$^1\mathrm{P}^\circ$	1	[*11 512 505*]
$1s7s$	$^3\mathrm{S}$	1	[11 590 091]
$1s7s$	$^1\mathrm{S}$	0	[11 591 874]
$1s7p$	$^3\mathrm{P}^\circ$	0,1,2	[*11 591 920*]
$1s7p$	$^1\mathrm{P}^\circ$	1	[*11 593 248*]
$1s8s$	$^3\mathrm{S}$	1	[11 643 558]
$1s8s$	$^1\mathrm{S}$	0	[11 644 747]
$1s8p$	$^3\mathrm{P}^\circ$	0,1,2	[*11 644 781*]
$1s8p$	$^1\mathrm{P}^\circ$	1	[*11 645 667*]
$1s9s$	$^3\mathrm{S}$	1	[11 680 134]
$1s9s$	$^1\mathrm{S}$	0	[11 680 966]
$1s9p$	$^3\mathrm{P}^\circ$	0,1,2	[*11 680 991*]
$1s9p$	$^1\mathrm{P}^\circ$	1	[*11 681 612*]
$1s10s$	$^3\mathrm{S}$	1	[11 706 251]
$1s10s$	$^1\mathrm{S}$	0	[11 706 856]
$1s10p$	$^3\mathrm{P}^\circ$	0,1,2	[*11 706 875*]
$1s10p$	$^1\mathrm{P}^\circ$	1	[*11 707 327*]
....	....	....	....
Na XI ($^2\mathrm{S}_{1/2}$)	***Limit***		**[11 816 996]**
$2s^2$	$^1\mathrm{S}$	0	[18 757 400]
$2s2p$	$^3\mathrm{P}^\circ$	0	[*18 780 000*]
		1	[*18 781 500*]
		2	[*18 784 900*]
$2p^2$	$^3\mathrm{P}$	0	[18 856 100]
		1	[18 857 800]
		2	[18 860 700]
$2p^2$	$^1\mathrm{D}$	2	[18 900 900]
$2s2p$	$^1\mathrm{P}^\circ$	1	[*18 909 900*]
$2p^2$	$^1\mathrm{S}$	0	[19 034 800]
Na XI $2p$($^2\mathrm{P}^\circ_{1/2}$)	*Limit*		[*21 788 480*]

Na XI

$Z=11$

H I isoelectronic sequence

Ground state 1s $^2S_{1/2}$

Ionization energy 13 297 672±2 cm^{-1} (1648.714±0.004 eV)

The levels and ionization energy are based on theoretical values calculated by Erickson using the nuclear mass for the naturally occurring Na^{23} isotope. The values here are adjusted to the Rydberg constant determined by Goldsmith, Weber, and Hänsch ($R_\infty=109\ 737.31476\pm0.00032$ cm^{-1}). The standard-deviation error of ±2 cm^{-1} in the ionization energy also applies to all the excited levels with respect to the ground level. The errors for the separations of excited levels are smaller; Erickson gives each level to the number of decimal places appropriate for a stated quantum-electrodynamics error. His table is complete through $n=11$ and has the ns, np, and nl ($l=n-1$) levels through $n=20$. We give all levels through $n=5$ and list the ns and np levels through $n=10$.

The uncertainty of the ionization energy in eV units arises from the conversion factor (see the introduction).

The experimental uncertainties of wavelength measurements in the region of the Na XI 1s–np resonance series are very large in comparison with any expected errors in the corresponding theoretical wavelengths. Aglitskii et al., for example, have measured the wavelengths of the 1s ^{2}S—2p ^{2}P° and 1s ^{2}S—3p ^{2}P° unresolved doublet lines from laser-produced plasmas as 10.026±0.003 Å and 8.461 ±0.004 Å.

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Na XI

Configuration	Term	J	Level (cm^{-1})
1s	^{2}S	½	0
2p	^{2}P°	½	*[9 971 484.8]*
		3/2	*[9 976 865.6]*
2s	^{2}S	½	[9 971 713.7]
3p	^{2}P°	½	*[11 819 964.3]*
		3/2	*[11 821 558.8]*
3s	^{2}S	½	[11 820 032.8]
3d	^{2}D	3/2	[11 821 556.1]
		5/2	[11 822 086.1]
4p	^{2}P°	½	*[12 466 713.2]*
		3/2	*[12 467 385.8]*
4s	^{2}S	½	[12 466 742.2]
4d	^{2}D	3/2	[12 467 384.7]
		5/2	[12 467 608.2]
4f	^{2}F°	5/2	*[12 467 607.8]*
		7/2	*[12 467 719.6]*
5p	^{2}P°	½	*[12 765 972.1]*
		3/2	*[12 766 316.4]*
5s	^{2}S	½	[12 765 987.0]
5d	^{2}D	3/2	[12 766 315.8]
		5/2	[12 766 430.3]
5f	^{2}F°	5/2	*[12 766 430.1]*
		7/2	*[12 766 487.3]*
5g	^{2}G	7/2	[12 766 487.2]
		9/2	[12 766 521.5]
6p	^{2}P°	½	*[12 928 493.5]*
		3/2	*[12 928 692.8]*
6s	^{2}S	½	[12 928 502.2]

Na XI—Continued

Configuration	Term	J	Level (cm^{-1})
7p	^{2}P°	1/2	[*13 026 470.8*]
		3/2	[*13 026 596.2*]
7s	^{2}S	1/2	[13 026 476.2]
8p	^{2}P°	1/2	[*13 090 052.6*]
		3/2	[*13 090 136.7*]
8s	^{2}S	1/2	[13 090 056.3]
9p	^{2}P°	1/2	[*13 133 639.1*]
		3/2	[*13 133 698.1*]
9s	^{2}S	1/2	[13 133 641.7]
10p	^{2}P°	1/2	[*13 164 813.3*]
		3/2	[*13 164 856.3*]
10s	^{2}S	1/2	[13 164 815.2]
	Limit		**[13 297 671.6]**