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THEORETICAL WAVELENGTHS AND TRANSITION PROBABILITIES FOR THE $3d^9$–$3d^8 4p$ AND $3d^8 4s$–$3d^8 4p$ TRANSITION ARRAYS IN Ni II

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A complete tabulation of theoretical electric-dipole (E1) emission lines is presented for transitions between the $3d^9$–$3d^8 4p$ and the $3d^8 4s$–$3d^8 4p$ configurations of Ni II. For these configurations with an open d shell, we applied extensive multiconfiguration Dirac–Fock wave functions to compute excitation energies, transition probabilities, and lifetimes. Our *ab initio* data will be compared with available measurements and other calculations, where the overall agreement is seen to be satisfactory. Experimental data are still very scarce for these two transition arrays. Therefore, the present data set not only supports the evaluation of the currently available data base, but may also help to identify or calibrate additional (less intense and intercombination) lines in the low-lying spectrum of Ni II.

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CONTENTS

INTRODUCTION

Nickel is known to be an essential component in the manufacturing of stainless steel and other corrosion-resistant alloys. In combination with titanium and chromium, various nickel alloys occur inside of magnetic fusion devices as a first-wall material. Therefore, knowing the spectral data of nickel at different stages of ionization is important both for plasma diagnostics and for a better understanding of the influence of impurities on the temporal behavior of fusion plasmas. Moreover, reliable data for the highly abundant iron-group elements not only are helpful in fusion research but are also needed for the interpretation of astronomical observations since the iron-group elements often dominate the photospheric spectra of many stellar objects. For a reliable spectral synthesis, for example, one not only requires information about a few individual lines but also often needs the (theoretical) knowledge of the line intensities for a whole spectral range in order to be able to substract away the dominant parts of some spectrum, thereby opening up access to much weaker lines of other, lower-abundance elements.

For the low-lying levels of Ni II, the need for accurate transition data has led to several compilations in the past which list wavelengths and transition probabilities in the optical and near-ultraviolet region [1, 2]. A critical and very useful review on the available transition data of nickel atoms and ions (at different stages of ionization) was carried out, in particular, by Wiese and Musgrove [3], who provide wavelengths and transition rates for several prominent lines as well as for some less intense ones. However, as pointed out by Wiese and Musgrove, some of the transition probabilities are (presumably) not very accurate and provide just a first approximation to these spectra. Also, the overall amount of available data remains small and much work needs to be done before these spectra are fully understood. Apart from earlier measurements on Ni II in the past, Ferrero et al. [4] recently determined branching ratios for several strong lines from which they derived absolute transition probabilities by applying semiempirical computations of lifetimes that they compared with the lifetime measurements of Lawler and Salih [5].

The rather small amout of the presently available data for Ni II is related to the lack of accurate structure calculations on spectra with open *d* shells. For a long time, such computations have not been feasible due to the complexity of these open-shell structures. To demonstrate recent progress in the field of atomic structure calculations and to facilitate the identification of further lines of the (low-lying) Ni II spectrum, we report here on an elaborate *ab initio* calculation for the $3d^9$–$3d^8 4p$ and $3d^8 4s$–$3d^8 4p$ transition arrays. Hence, the present study is being carried out not only to provide a consistent data set for all transitions among the low-lying levels of Ni II, but also to exhibit the present-day capabilities of *ab initio* studies to support the spectral analysis of open *d*-shell ions. Our compilation contains data for about 450 emission lines of Ni II which have been investigated by using large-scale wave functions. In contrast to previous measurements and evaluations which, over the years, have become more and more interdependent owing to semiempirical adjustments with regard to the generation as well as normalization of data, our *ab initio* computations have been performed independently. In our calculations, we describe the effects of relativity, correlation, and the rearrangement of the electron density within a common framework. Owing to the large number of emission lines, however, no attempt has been made to provide a completely systematic investigation. Such systematic studies must include a convergence analysis and are presently restricted to atoms and ions with much simpler shell structures [6].

To calculate the level energies and transition probabilities, we applied the multiconfiguration Dirac–Fock (MCDF) method. Since the capabilities of this method have been proven in quite a number of case studies during recent years (although mainly for simpler shell structures), we will not repeat much about either the underlying techniques or the representation of the wave functions. In the present study, moreover, we follow lines similar to two recent investigations on silicon- [7] and phosphorus-like [8] ions. To generate appropriate MCDF wave functions, we applied the relativistic structure code Grasp92 [9], which approximates an atomic state with given angular momentum and parity (J^P) by a linear combination of configuration state functions (CSF) of the same symmetry

$$|\psi_\alpha(PJM)\rangle = \sum_r^{n_c} c_r(\alpha)\,|\gamma_r PJM\rangle. \tag{1}$$

In contrast to previous investigations on ions with open s and p shells, however, d-shell configurations are indeed much more demanding regarding the size of the wave function expansions. Expansions of several ten thousand CSF in Eq. (1) are often required to describe the atomic levels of such shell structures properly. Consequently, new programs had first to be developed before transition probabilities and lifetimes could be calculated for the given spectra. In our group, these developments finally led to a revised version of the REOS program [10, 11] which now supports much larger expansions than were previously possible [12] and, thus, might help to promote better understanding of open d- and f-shell atoms in the future.

The two considered transition arrays of Ni II comprise 18 even-parity levels from the (lower) $3d^9$ and $3d^84s$ configurations and 45 odd-parity levels from the (upper) $3d^84p$ configuration. For our computations, we categorized these levels into groups of common total angular momentum and parity (J^P). The five even-parity states with $J = 5/2$, including the $3d^9\ ^2D_{5/2}$ ground state, for instance, form such a level group for each of which, in turn, a separate optimization procedure was carried out by minimizing the total energy. This partitioning of the atomic levels into different groups has been found to be a useful compromise between two basic requirements in atomic calculations [7, 8], namely, (i) to obtain sufficiently accurate wave functions for the transition probability calculations while (ii) keeping the effort feasible for the given (large) numbers of lower and upper levels. On the other hand, a separate optimization for the wave functions of each J^P level group ensures that an essential part of the rearrangement of the electron density—when the ion undergoes some transition—is taken into account. Using a MCDF approach, we also include relativistic contributions (i.e., the spin–orbit and the dominant parts of the Breit interaction) even though their effects on the level energies remain small for Ni II when compared with the uncertainties which arise from neglected correlations. Our recent experience has shown, however, that even *small* relativistic contributions (with regard to the energies) may significantly influence the transition probabilities and lifetimes of weak and medium lines [13, 14] and thus should be incorporated from the very beginning.

Systematic expansions of the atomic wave functions as used in the present study are most easily classified in terms of virtual excitations, which are included in Eq. (1). In practice, these excitations should incorporate at least all the interactions of the given set of levels with those from configurations which are nearby in energy. Concerning the required classes of excitations, our previous case studies [7, 13, 14] have led to the conclusion that, in order to obtain converged transition probabilities (at least for most strong and medium lines), typically *two additional layers of correlation orbitals* need to be taken into account beyond the spectroscopically occupied shells. In contrast, core–valance and core–core correlations seem to be of minor importance if the valance shells include four or more electrons. This is very much the case for the shell structure of Ni II, which has nine valence electrons outside of a deeply-bound core. When including virtual excitations for open d shells, on the other hand, the wave function expansions are about 5–10 times larger than for open s- or p-shell ions. In the present investigation, we include single (S), double (D), and triple (T) excitations (outside of the argon-like core) from the $3d^9$, $3d^84s$, and $3d^84p$ configurations into the $4s$, $4p$, and $4d$ subshells as well as single and double excitations from these configurations into the $4f$ and $5l$ shells. The size of the correspondingly obtained expansions for each symmetry (J^P) can be seen from Table A; this table also shows the number of levels for each symmetry as obtained from a zero-order expansion, i.e., without any *excitation* from the spectroscopically occupied shells. In the last column of Table A, we list the number of determinants, n_D, for a transformed representation of the wave functions which is applied for calculating the transition probabilities and lifetimes [11, 14]. For example, the even-parity $J = 5/2$ levels are represented by 18,542 jj-coupled CSF (to generate the

TABLE A
Number of CSF in the Wave Function Expansions of Different J^P Level Groups [Eq. (1)] for the Calculation of Level Energies and Transition Probabilities

J^P level group	$4l^a$	$5l$	n_D
1/2+	3	8135	87071
3/2+	5	14673	80523
5/2+	5	18542	68595
7/2+	3	19334	53712
9/2+	2	17594	38555
1/2−	7	13424	185042
3/2−	11	24152	171805
5/2−	11	30289	147674
7/2−	9	31366	117403
9/2−	5	28143	86037
11/2−	2	22340	57896

Note. These expansions include up to triple excitations from the $3d$ subshell into $4s$, $4p$, and $4d$ as well as single and double excitations into the $4f$ and the $5l$ shells. An equivalent, *transformed* representation of the wave functions in terms of n_D determinants (last column) has been applied for calculating the *relaxed–orbital* transition probabilities.

[a] Number of levels as obtained from a zero-order approximation without virtual excitations.

wave functions) or, equivalently, by 68,595 determinants (in their later application). Even larger expansions were needed for most of the excited levels.

Because of the rapid increase of the wave function expansions as further correlation orbitals are included in the active space, an extension beyond the $5l$ layer is presently unmanageable. While this situation hampers a detailed analysis of the convergence of our results, we have nevertheless arrived at a representation of the atomic levels which includes (at least) the dominant correlation and relativistic effects as well as the rearrangement of the electron density within the same model. Test calculations have indicated that such large expansions seem to be inevitable in order to obtain a reliable data set for the E1 emission lines among the low-lying levels of Ni II. By including relaxation effects, in addition, we obtained transition probabilities for which the different gauges agree (typically) much better than in all cases for which a single set of (one-electron) orbital functions is used to represent both the initial and final atomic levels. For details of these so-called *relaxed-orbital* transition probability calculations and the usually applied gauges for the coupling of the radiation field to the atom, one may refer to Refs. [7, 12].

Our *ab initio* results are displayed and compared with available evaluated data in four tabulations. Table I lists the excitation energies of the 18 even-parity levels from the $3d^9$ and $3d^8 4s$ configurations relative to the $3d^9\ ^2D_{5/2}$ ground state. For each level, we display the level number and its designation (as taken from the NIST Spectroscopic Database [15]). To facilitate the usage of Tables III and IV, we also include some redundant information like the even-parity superscript (^{e}) or an additional column for the total angular momenta and parities. This is done because in Tables III and IV we omit the full designation of the (lower and upper) levels and, instead, specify the transition just by the corresponding level numbers and parities. Note that, in *ab initio* calculations, a unique identification of the levels is always possible owing to their overall symmetry J^P and the sequence of their total energies. Rather satisfying agreement of our *ab initio* energies with experimental data is found if the two $^2D_{5/2,3/2}$ ground-state levels are recalculated separately. An independent optimization for this doublet results in a downward shift of about 4000 cm^{-1}; this shift has been incorporated in the excitation energies of Tables I and II but has not been applied to the mixing coefficients for these two levels (in order to keep them orthogonal with respect to other levels of the same total symmetry). The "experimental" level energies in the last column of Table I are also taken from the NIST database [15], which, for Ni II, is built upon an earlier analysis of Shenstone [16, 17]. (Note that throughout this paper, we use "experimental" to mean the experimental or critically evaluated data given in the NIST database.)

Excitation energies and lifetimes for the 45 odd-parity levels of the (upper) $3d^8 4p$ configuration are shown in Table II. All energies are given with respect to the $^2D_{5/2}$ ground state. Even though differences of up to 2000 cm^{-1} occur for a few of the higher levels, the level ordering is well reproduced with only a very few "crossings" for levels with different symmetries. Somewhat larger deviations arise for the two highest levels (44^o and 45^o), which, in fact, belong to the $3d^7 4s4p$ configuration. These two levels are described only very approximately in the present computation due to the incorporation of virtual excitations in expansion (1) and have been added to these tabulations just for the sake of completeness.

In Table II, the lifetimes are derived from the transition probabilities in Table III by applying "experimental/evaluated" transition energies (see below). We display the lifetimes in two gauges, i.e., in length and velocity gauge (or Babushkin and Coulomb gauge, respectively, within a relativistic notation) in order to indicate the level of agreement found in the present computations since accidental agreement also occurs. In fact, the (presently not always satisfying) agreement of the different gauges is often interpreted as an indication of the quality of the data even though it cannot prove the correctness of any individual result. For a large number of transitions, however, the overall conformance of results from different gauges for the coupling of the radiation field can well be taken as a measure to estimate the accuracy in cases where a full convergence analysis of the data by a systematically enlarged wave function space cannot be demonstrated explicitly. Although length gauge results for E1 transitions are often accepted to be more reliable, we display the transition probabilities in Tables III and IV also in the velocity gauge to facilitate the evaluation of our theoretical data in the future.

For the odd-parity levels, our lifetimes provide upper limits in the sense that we do not include the decay rates into the lower-lying levels of the $3d^7 4s^2$ configuration. Test calculations show, however, that owing to the small transition energies and the *effective two-electron character* of these transitions, i.e., $3d^8 4p \rightarrow 3d^7 4s^2$, these rates should not yield any significant contribution. Since, in addition, the two odd-parity levels 44^o and 45^o effectively belong to the $3d^7 4s 4p$ configuration, we do not give lifetimes for these levels.

In Table III, we display the transition probabilities for all allowed electric-dipole (E1) transitions for the $3d^9$–$3d^8 4p$ and $3d^8 4s$–$3d^8 4p$ transition arrays. Reference to the full designation of the lower and upper levels is made via the level numbers as displayed in Tables I and II. All transitions are shown in standard spectroscopic notation with the lower (even-parity) level given first and are tabulated in descending order of the transition wavelength. Our theoretical wavelength data are again compared with "experimental" ones from the NIST database. For all transitions for which measured (or evaluated) probabilities are available, we display the experimental wavelength data (superscripted ^{a}) from the corresponding tabulation of transition probabilities. Note that these transition wavelengths are not fully consistent with those obtained from the level energies of the NIST database; deviations of up to about 1 Å have been found which, however, do not influence the accuracy of the present study. To assess the uncertainty of our theoretical transition probabilities, owing to the deviations of the computed transition wavelengths from experiment, two different computational models have been applied in Table III. Our best *ab initio* values were obtained with theoretical (T) transition energies. Overall, the theoretical and "experimental" transition wavelengths agree well in the range between 1900 and 2600 Å. Somewhat bigger deviations arise for smaller and larger wavelengths, however, due to shifts of our *ab initio* values for the excitation energies of these levels. Thus, in order to provide an *experimentally adapted* set of transition probabilities for the $3d^9$–$3d^8 4p$ and $3d^8 4s$–$3d^8 4p$ arrays which takes into account the correct energy dependence of the rates, we recalculated all rates using "experimental" (E) wavelengths. This experimentally adapted set of transition probabilities, in particular, may be taken as a consistent basis for future evaluations.

For most transitions with a decay rate of more than, say, 10^7 s^{-1}, we find good agreement between the two gauge forms ($\leq$20%). For these lines, the theoretical and experimental uncertainties in the transition probabilities now become comparable with each other. Somewhat bigger uncertainties are typically associated with medium-intense and weak lines. Up to the present, however, most of these lines have neither been measured nor calculated. Nevertheless, they often exhibit a line strength which could be resolved in near-optical ultraviolet spectra if sufficient theoretical assist is available. Our present tabulation aims to provide this required support.

To provide assessment of the *quality* of the present results, Table IV compares our (*ab initio*) calculations with critically evaluated data [1, 3] as well as with the measurements and semiempirical computations by Ferrara et al. [4]. In this Table, "experimental" energies are applied to calculate the transition probabilities; the corresponding *ab initio* results for these lines can be found in Table III. As seen here, good agreement is obtained for most strong lines both between the two gauge forms and in comparisons with previous compilations. An analysis of the different evaluations of data in columns 5–8 of Table IV clearly reveals the difficulty but also the necessity of reducing the errors of measured branching ratios to a minimum because of their effect on the determination of transition probabilities from lifetime measurements. In the past, different (critical) evaluations yielded rates which sometimes differ by a factor two and more, mainly due to different normalizations. While an earlier compilation from Fuhr et al. [1] was based on oscillator strengths according to Bell et al. [18], these data were later renormalized by Wiese and Musgrove [3] on the basis of new lifetime measurements by Lawler and Salih [5], who applied laser-induced fluorescence techniques. In the compilation by Wiese and Musgrove [3], the accuracy of the known transition probabilities for Ni II is estimated to about 10–25% for most of the lines in Table IV.

Many transitions from the $3d^8 4s$–$3d^8 4p$ configurations are in the vacuum UV region. For this spectral region, much attention to the availability of reliable data was prompted by the need to support the interpretation of astronomical observations from the Hubble Space Telescope [19]. Today, similar spectra can also be resolved using time-resolved, laser-induced fluorescence spectroscopy since powerful enough lasers in this short wavelength domain have become now available. For example, Raman-shifted dye laser systems may provide complete VUV coverage, down to wavelengths of about 1380 Å [20]. To enable further line identifications, also in the VUV region, we have attached importance to the calculation of the entire spectrum among the low-lying levels of Ni II.

In summary, we have provided a tabulation of all allowed E1 transitions from the $3d^9$–$3d^8 4p$ and $3d^8 4s$–$3d^8 4p$ transition arrays. Comparing our transition probabilities in different gauges with previously evaluated data, we estimate an accuracy of better than 25% for most strong lines and somewhat larger uncertainties for weak and medium-intense transitions. From a theoretical viewpoint, our investigations certainly verge on what is presently feasible. The present work has enhanced, however, our confidence that we will be able to provide useful *ab initio* data for spectra with similar or even more complex shell structures in the future. Furthermore, to improve the capabilities of these extensive case studies, we have recently started new program developments including the implementation of a new technique for the decomposition of the many-electron Hamiltonian matrix [21]. But meanwhile, with the present type of investigation, we can offer experimentalists the means to carry out such case studies for similar spectra.

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EXPLANATION OF TABLES

TABLE I. Excitation Energies of Even-Parity Levels in Ni II

TABLE II. Excitation Energies and Lifetimes of Odd-Parity Levels in Ni II

Excitation energies of the $3d^9$ and $3d^8 4s$ even-parity levels (Table I) and $3d^8 4p$ odd-parity levels relative to the $3d^9\ ^2D_{5/2}$ ground state (Table II) are given as wave numbers (cm^{-1}) in ascending order, and are compared with the data from the NIST Spectroscopic Database [15]. Numbers in brackets denote powers of ten.

No.	Level number of the even-parity (^{e}) or odd-parity (^{o}) levels (1^e = ground state).
Designation	Configuration and term of the state in LS coupling.
J^P	Total angular momentum and parity.
Energy	Level energy (in cm^{-1}) relative to the ground state.
Calc.	Present work.
Exp.	Level energies as taken from the NIST Spectroscopic Database [15].
Lifetime	Theoretical lifetimes (in ns) as derived from the transition probabilities in Table III obtained with “experimental” transition energies, given for length and velocity gauge.

TABLE III. Wavelengths and E1 Transition Probabilities for the $3d^9$–$3d^8 4p$ and $3d^8 4s$–$3d^8 4p$ Transition Arrays in Ni II

Electric-dipole (E1) allowed transitions from the $3d^8 4p$ excited levels to the lower-lying even-parity levels of the $3d^9$ and $3d^8 4s$ configurations are listed in descending order of the “experimental” transition wavelengths. Apart from pure *ab initio* results, wavelengths and transition probabilities as derived from “experimental” transition energies are also displayed. All final levels are of even parity and all initial levels are of odd parity with level numbers which refer to Tables I and II.

Trans.	Level numbers of the even- and odd-parity levels from Tables I and II.
J_F	Total angular momentum of the lower $3d^9\ J_F$ or $3d^8 4s\ J_F$ even-parity level.
J_I	Total angular momentum of the upper $3d^8 4p\ J_I$ excited odd-parity level.
Type	Multipolarity of the transition (all E1).
Wavelength	Wavelength of the transition (in Å); here we also display “experimental” wavelengths as derived from the level energies of the NIST Spectroscopic Database [15]. Experimental wavelengths with a superscript ^{a} refer to measurements and are taken from the NIST Database of Transition Wavelengths and Probabilities.
A (1/s)	Transition probability (in s^{-1}). Values are given for both length and velocity gauge by using our theoretical (T) *ab initio* and the “experimental” (E) wavelengths, respectively. Numbers in brackets denote powers of ten.

TABLE IV. Comparison of Our *Ab initio* Results with Those of Previous Works

Comparison of the $3d^9$–$3d^8 4p$ and $3d^8 4s$–$3d^8 4p$ transition probabilities with previous measurements and compilation is given as far as data are available. Transition probabilities as obtained using “experimental” transition energies are listed in both length and velocity gauge. Numbers in brackets denote powers of ten.

Transition	Level numbers of the even- and odd-parity levels from Tables I and II.
Wavelength	“Experimental” wavelength of the transition (in Å) as derived from the level energies of the NIST Spectroscopic Database.
A (1/s) Present	Transition probability (in s^{-1}) using “experimental” (E) wavelengths, given for length and velocity gauge.
A (1/s) Previous Works	Transition probability (in s^{-1}) from previous critical evaluations and experiments as well as from a semiempirical computation (last column).

TABLE I. Excitation Energies of Even-Parity Levels in Ni II

See page 161 for Explanation of Tables

Ni II Levels				Energy (cm^{-1})	
No.	Designation		J^P	Calc.	Exp. [15]
1^e	$3d^9$	$^2D_{5/2}$	$5/2+$	0.00	0.00
2^e	$3d^9$	$^2D_{3/2}$	$3/2+$	1503.40	1506.94
3^e	$3d^84s$	$^4F_{9/2}$	$9/2+$	6607.36	8393.90
4^e	$3d^84s$	$^4F_{7/2}$	$7/2+$	7922.01	9330.04
5^e	$3d^84s$	$^4F_{5/2}$	$5/2+$	8878.02	10115.66
6^e	$3d^84s$	$^4F_{3/2}$	$3/2+$	9295.52	10663.89
7^e	$3d^84s$	$^2F_{7/2}$	$7/2+$	12140.31	13550.39
8^e	$3d^84s$	$^2F_{5/2}$	$5/2+$	13890.34	14995.57
9^e	$3d^84s$	$^4P_{5/2}$	$5/2+$	23581.05	23108.28
10^e	$3d^84s$	$^2D_{3/2}$	$3/2+$	24345.30	23796.18
11^e	$3d^84s$	$^4P_{3/2}$	$3/2+$	25738.96	24788.20
12^e	$3d^84s$	$^4P_{1/2}$	$1/2+$	25662.15	24835.93
13^e	$3d^84s$	$^2D_{5/2}$	$5/2+$	25904.63	25036.38
14^e	$3d^84s$	$^2P_{3/2}$	$3/2+$	30053.83	29070.93
15^e	$3d^84s$	$^2P_{1/2}$	$1/2+$	30681.53	29593.46
16^e	$3d^84s$	$^2G_{9/2}$	$9/2+$	33760.76	32499.53
17^e	$3d^84s$	$^2G_{7/2}$	$7/2+$	33841.97	32523.54
18^e	$3d^84s$	$^1S_{1/2}$	$1/2+$	64649.62	68709.76

TABLE II. Excitation Energies and Lifetimes of Odd-Parity Levels in Ni II

See page 161 for Explanation of Tables

Ni II Levels				Energy (cm^{-1})		Lifetime (ns)	
No.	Designation		J^P	Calc.	Exp. [15]	Length	Velocity
1^o	$3d^84p$	$^4D_{7/2}$	7/2 −	49367.60	51557.85	2.62	2.37
2^o	$3d^84p$	$^4D_{5/2}$	5/2 −	50833.69	52738.45	2.58	2.36
3^o	$3d^84p$	$^4G_{9/2}$	9/2 −	51046.58	53365.17	2.54	3.18
4^o	$3d^84p$	$^4G_{11/2}$	11/2 −	50914.90	53496.49	2.30	2.96
5^o	$3d^84p$	$^4D_{3/2}$	3/2 −	50876.20	53634.62	2.63	2.39
6^o	$3d^84p$	$^4D_{1/2}$	1/2 −	52326.12	54176.26	2.63	2.41
7^o	$3d^84p$	$^4G_{7/2}$	7/2 −	52262.47	54262.63	2.41	2.97
8^o	$3d^84p$	$^4F_{9/2}$	9/2 −	52308.56	54557.05	2.35	2.61
9^o	$3d^84p$	$^4G_{5/2}$	5/2 −	52929.67	55018.71	2.39	3.04
10^o	$3d^84p$	$^2G_{9/2}$	9/2 −	53438.86	55299.65	2.52	4.01
11^o	$3d^84p$	$^4F_{7/2}$	7/2 −	53441.05	55417.84	2.28	2.52
12^o	$3d^84p$	$^4F_{5/2}$	5/2 −	54196.04	56075.26	2.29	2.46
13^o	$3d^84p$	$^2G_{7/2}$	7/2 −	54384.79	56371.41	2.84	3.28
14^o	$3d^84p$	$^4F_{3/2}$	3/2 −	54523.06	56424.49	2.32	2.52
15^o	$3d^84p$	$^2F_{7/2}$	7/2 −	55166.12	57080.55	1.12	1.20
16^o	$3d^84p$	$^2D_{5/2}$	5/2 −	55440.46	57420.16	1.83	1.57
17^o	$3d^84p$	$^2F_{5/2}$	5/2 −	56610.26	58493.21	2.10	1.93
18^o	$3d^84p$	$^2D_{3/2}$	3/2 −	56970.20	58705.95	1.80	1.25
19^o	$3d^84p$	$^4P_{5/2}$	5/2 −	66418.58	66571.34	2.40	2.40
20^o	$3d^84p$	$^4P_{3/2}$	3/2 −	66512.96	66579.71	2.54	2.51
21^o	$3d^84p$	$^4P_{1/2}$	1/2 −	67092.37	67031.02	2.68	2.73
22^o	$3d^84p$	$^2F_{5/2}$	5/2 −	67480.84	67694.64	2.38	2.69
23^o	$3d^84p$	$^2F_{7/2}$	7/2 −	67853.95	68131.21	2.26	2.63
24^o	$3d^84p$	$^2D_{3/2}$	3/2 −	68163.41	68154.31	2.12	2.05
25^o	$3d^84p$	$^2P_{1/2}$	1/2 −	68382.88	68281.62	2.69	2.64
26^o	$3d^84p$	$^2D_{5/2}$	5/2 −	68848.17	68735.98	2.08	2.03
27^o	$3d^84p$	$^2P_{3/2}$	3/2 −	69034.72	68965.65	2.50	2.46
28^o	$3d^84p$	$^4D_{5/2}$	5/2 −	70992.44	70635.46	2.23	2.56
29^o	$3d^84p$	$^4D_{3/2}$	3/2 −	71075.84	70706.77	2.26	2.67
30^o	$3d^84p$	$^4D_{1/2}$	1/2 −	70891.95	70748.70	2.27	2.67
31^o	$3d^84p$	$^4D_{7/2}$	7/2 −	71067.06	70778.12	2.18	2.55
32^o	$3d^84p$	$^2D_{5/2}$	5/2 −	72085.42	71770.83	2.41	2.59
33^o	$3d^84p$	$^2D_{3/2}$	3/2 −	72577.04	72375.42	2.06	2.12
34^o	$3d^84p$	$^2P_{3/2}$	3/2 −	73015.99	72985.65	1.26	1.25
35^o	$3d^84p$	$^2P_{1/2}$	1/2 −	74181.40	73903.25	1.27	1.25
36^o	$3d^84p$	$^2S_{1/2}$	1/2 −	74820.07	74283.33	2.09	2.14
37^o	$3d^84p$	$^4S_{3/2}$	3/2 −	74921.03	74300.93	1.91	2.12
38^o	$3d^84p$	$^2H_{9/2}$	9/2 −	75783.57	75149.48	2.66	3.59
39^o	$3d^84p$	$^2H_{11/2}$	11/2 −	76172.04	75721.68	2.60	3.40
40^o	$3d^84p$	$^2F_{7/2}$	7/2 −	76648.30	75917.63	1.69	1.48
41^o	$3d^84p$	$^2F_{5/2}$	5/2 −	77104.81	76402.03	1.63	1.45
42^o	$3d^84p$	$^2G_{7/2}$	7/2 −	80796.37	79823.03	0.64	0.51
43^o	$3d^84p$	$^2G_{9/2}$	9/2 −	80901.72	79923.88	2.12	2.36
44^o	$3d^74s4p$	$^6F_{3/2}$	3/2 −	109084.45	88582.01		
45^o	$3d^74s4p$	$^6F_{1/2}$	1/2 −	108456.76	88881.59		

TABLE III. Wavelengths and E1 Transition Probabilities for the $3d^9$–$3d^84p$ and $3d^84s$–$3d^84p$ Transition Arrays in Ni II
See page 161 for Explanation of Tables

Ni II Emission Lines				Wavelength (Å)		A (1/s)			
Trans.	J_F	J_I	Type	Calc.	Exp.	Length(T)	Velocity(T)	Length(E)	Velocity(E)
$18^e - 27^o$	1/2	3/2	E1	22793.1	390792.	3.01(+3)	8.85(+4)	5.97(−1)	5.16(+3)
$18^e - 25^o$	1/2	1/2	E1	26786.2	233645.	1.51(+3)	5.53(+4)	2.27(+3)	6.34(+3)
$18^e - 24^o$	1/2	3/2	E1	28441.5	180180.	2.35(+1)	1.47(+3)	2.26(−1)	2.32(+2)
$18^e - 21^o$	1/2	1/2	E1	40937.4	59568.5	1.81(+2)	1.38(+4)	5.87(+1)	9.51(+3)
$18^e - 29^o$	1/2	3/2	E1	15556.0	50075.3	2.82(+1)	4.59(+2)	8.45(−1)	1.43(+3)
$18^e - 30^o$	1/2	1/2	E1	16015.2	49045.1	4.76	9.53(+1)	1.66(−1)	3.11
$18^e - 20^o$	1/2	3/2	E1	53603.9	46947.2	4.99(+1)	7.01(+3)	1.43(+2)	7.46(+3)
$18^e - 33^o$	1/2	3/2	E1	12611.0	27280.2	6.00(−1)	3.05	5.93(−2)	1.41
$18^e - 34^o$	1/2	3/2	E1	11949.5	23386.9	4.16(+2)	2.79(+3)	5.55(+1)	1.43(+3)
$18^e - 35^o$	1/2	1/2	E1	10491.2	19254.9	1.90(+3)	1.34(+4)	3.07(+2)	7.29(+3)
$18^e - 36^o$	1/2	1/2	E1	9832.40	17941.8	2.77(+3)	1.56(+4)	4.56(+2)	8.55(+3)
$18^e - 37^o$	1/2	3/2	E1	9735.76	17885.3	1.53(+3)	8.08(+3)	2.47(+2)	4.40(+3)
$17^e - 1^o$	7/2	7/2	E1	6440.65	5253.67	4.47(+1)	2.07(+2)	8.23(+1)	2.53(+2)
$16^e - 1^o$	9/2	7/2	E1	6407.44	5247.05	4.80(+2)	3.68(+3)	8.75(+2)	4.49(+3)
$18^e - 44^o$	1/2	3/2	E1	2250.37	5032.14	3.98(+8)	3.78(+8)	3.56(+7)	1.69(+8)
$18^e - 45^o$	1/2	1/2	E1	2282.61	4957.41	3.79(+8)	3.57(+8)	3.70(+8)	1.64(+8)
$17^e - 2^o$	7/2	5/2	E1	5885.22	4946.84	1.00(+3)	5.06(+3)	1.69(+3)	6.03(+3)
$17^e - 3^o$	7/2	9/2	E1	5813.14	4798.09	4.45(+1)	5.29(+1)	7.91(+1)	6.41(+1)
$16^e - 3^o$	9/2	9/2	E1	5785.09	4792.57	3.28(+3)	5.62(+3)	5.77(+3)	6.79(+3)
$16^e - 4^o$	9/2	11/2	E1	5829.07	4762.59	1.78(+2)	5.95(+1)	3.26(+2)	6.90(+1)
$17^e - 7^o$	7/2	7/2	E1	5428.85	4600.01	3.33(+3)	6.60(+3)	5.47(+3)	7.78(+3)
$16^e - 7^o$	9/2	7/2	E1	5404.73	4594.93	6.97(+3)	2.65(+4)	1.13(+4)	3.12(+4)
$17^e - 8^o$	7/2	9/2	E1	5416.18	4538.54	1.89(−1)	1.15(+2)	3.21(−1)	1.38(+2)
$16^e - 8^o$	9/2	9/2	E1	5391.47	4533.60	1.52(+3)	2.58(+3)	2.55(+3)	2.71(+3)
$17^e - 9^o$	7/2	5/2	E1	5238.37	4445.40	1.74(+3)	4.75(+3)	2.85(+3)	5.60(+3)
$17^e - 10^o$	7/2	9/2	E1	5102.85	4390.56	3.12(+1)	2.86(+2)	4.90(+1)	3.32(+2)
$16^e - 10^o$	9/2	9/2	E1	5081.23	4385.94	5.70(+3)	9.33(+3)	8.86(+3)	1.07(+3)
$17^e - 11^o$	7/2	7/2	E1	5100.61	4367.90	2.30(+3)	8.17(+3)	3.66(+3)	9.54(+3)
$16^e - 11^o$	9/2	7/2	E1	5079.31	4363.33	8.01(+4)	2.57(+5)	1.26(+5)	2.99(+5)
$17^e - 12^o$	7/2	5/2	E1	4913.02	4245.97	2.17(+4)	6.60(+4)	3.37(+4)	7.63(+4)
$14^e - 2^o$	3/2	5/2	E1	4812.35	4225.20	3.16(+2)	1.29(+3)	4.68(+2)	1.47(+3)
$17^e - 13^o$	7/2	7/2	E1	4867.89	4193.25	2.57(+4)	4.40(+4)	4.03(+4)	5.11(+4)
$16^e - 13^o$	9/2	7/2	E1	4848.30	4189.03	2.32(+4)	7.47(+4)	3.60(+4)	8.65(+4)
$15^e - 5^o$	1/2	3/2	E1	4718.17	4159.53	4.47(+3)	6.31(+3)	6.52(+3)	7.15(+3)
$17^e - 15^o$	7/2	7/2	E1	4689.73	4072.16	8.96(+3)	2.92(+4)	1.37(+4)	3.36(+4)
$14^e - 5^o$	3/2	3/2	E1	4581.99	4071.05	5.67(+3)	9.40(+3)	8.09(+3)	1.06(+4)
$16^e - 15^o$	9/2	7/2	E1	4671.72	4068.18	4.06(+5)	1.13(+6)	6.15(+5)	1.29(+6)
$15^e - 6^o$	1/2	1/2	E1	4620.09	4067.83	9.58(+2)	1.36(+3)	1.40(+3)	1.54(+3)
$17^e - 16^o$	7/2	5/2	E1	4629.95	4016.61	1.27(+5)	3.67(+5)	1.95(+5)	4.23(+5)
$14^e - 6^o$	3/2	1/2	E1	4489.88	3983.22	5.98(+3)	1.02(+4)	8.56(+3)	1.15(+4)
$14^e - 9^o$	3/2	5/2	E1	4371.42	3853.89	1.35(+2)	4.09(+2)	1.97(+2)	4.64(+2)
$17^e - 17^o$	7/2	5/2	E1	4392.07	3850.65	6.07(+5)	1.54(+6)	9.01(+5)	1.75(+6)
$13^e - 1^o$	5/2	7/2	E1	4262.24	3770.53	8.03(+5)	1.27(+6)	1.16(+6)	1.44(+6)
$15^e - 14^o$	1/2	3/2	E1	4194.36	3727.03	5.88(+3)	1.15(+4)	8.39(+3)	1.29(+4)
$14^e - 12^o$	3/2	5/2	E1	4142.12	3703.11	3.32(+2)	7.23(+2)	4.65(+2)	8.09(+2)
$14^e - 14^o$	3/2	3/2	E1	4086.40	3655.83	1.00(+2)	6.50(+2)	1.40(+2)	7.27(+2)
$13^e - 2^o$	5/2	5/2	E1	4011.56	3609.84	2.64(+5)	4.14(+5)	3.62(+5)	4.60(+5)
$11^e - 2^o$	3/2	5/2	E1	3984.90	3577.79	1.40(+6)	2.08(+6)	1.93(+6)	2.31(+6)
$14^e - 16^o$	3/2	5/2	E1	3939.08	3527.43	2.85(+5)	5.33(+5)	3.97(+5)	5.95(+5)

TABLE III. Wavelengths and E1 Transition Probabilities for the $3d^9$–$3d^8 4p$ and $3d^8 4s$–$3d^8 4p$ Transition Arrays in Ni II
See page 161 for Explanation of Tables

Ni II Emission Lines				Wavelength (Å)		A (1/s)			
Trans.	J_F	J_I	Type	Calc.	Exp.	Length(T)	Velocity(T)	Length(E)	Velocity(E)
9^e – 1^o	5/2	7/2	E1	3878.06	3514.99	1.66(+6)	2.40(+6)	2.23(+6)	2.64(+6)
13^e – 5^o	5/2	3/2	E1	3850.53	3496.72	6.16(+4)	8.56(+4)	8.21(+4)	9.42(+4)
12^e – 5^o	1/2	3/2	E1	3814.75	3472.38	1.38(+6)	1.99(+6)	1.83(+6)	2.19(+6)
11^e – 5^o	3/2	3/2	E1	3825.96	3466.64	1.39(+6)	2.02(+6)	1.87(+6)	2.23(+6)
10^e – 2^o	3/2	5/2	E1	3775.24	3455.15	4.76(+5)	6.88(+5)	6.21(+5)	7.52(+5)
15^e – 18^o	1/2	3/2	E1	3803.92	3434.95	2.89(+5)	5.41(+5)	3.92(+5)	5.99(+5)
13^e – 7^o	5/2	7/2	E1	3794.10	3421.58	1.38(+4)	2.27(+4)	1.88(+4)	2.52(+4)
12^e – 6^o	1/2	1/2	E1	3750.37	3408.28	3.21(+6)	4.55(+6)	4.28(+6)	5.01(+6)
11^e – 6^o	3/2	1/2	E1	3761.21	3402.74	4.78(+5)	6.73(+5)	6.45(+5)	7.44(+5)
14^e – 17^o	3/2	5/2	E1	3765.57	3398.78	1.08(+5)	1.99(+5)	1.46(+5)	2.20(+5)
9^e – 2^o	5/2	5/2	E1	3669.43	3374.94	8.62(+5)	1.16(+6)	1.11(+6)	1.26(+6)
14^e – 18^o	3/2	3/2	E1	3714.91	3374.39	1.76(+4)	5.02(+4)	2.35(+4)	5.53(+4)
10^e – 5^o	3/2	3/2	E1	3631.99	3351.38	4.37(+5)	5.65(+5)	5.57(+5)	6.13(+5)
13^e – 9^o	5/2	5/2	E1	3700.13	3335.30	3.13(+1)	9.15(+1)	4.27(+1)	1.02
11^e – 9^o	3/2	5/2	E1	3677.73	3307.92	4.12(+3)	4.01(+3)	5.67(+3)	4.46(+3)
13^e – 11^o	5/2	7/2	E1	3630.84	3291.48	7.45(+4)	1.35(+5)	9.99(+4)	1.49(+5)
10^e – 6^o	3/2	1/2	E1	3573.88	3291.03	2.02(+5)	2.96(+5)	2.59(+5)	3.21(+5)
9^e – 5^o	5/2	3/2	E1	3534.23	3275.86	1.96(+5)	2.82(+5)	2.47(+5)	3.05(+5)
13^e – 12^o	5/2	5/2	E1	3534.78	3221.77	3.39(+3)	3.64(+3)	4.48(+3)	3.99(+3)
9^e – 7^o	5/2	7/2	E1	3486.64	3209.82	3.86(+4)	4.83(+4)	4.95(+4)	5.25(+4)
10^e – 9^o	3/2	5/2	E1	3498.41	3202.82	2.24(+3)	6.84(+3)	2.92(+3)	7.47(+3)
11^e – 12^o	3/2	5/2	E1	3514.06	3196.21	8.38(+4)	1.08(+5)	1.11(+5)	1.19(+5)
13^e – 13^o	5/2	7/2	E1	3511.36.	3191.32	7.08(+3)	4.62(+3)	9.43(+3)	5.08(+3)
13^e – 14^o	5/2	3/2	E1	3494.39	3185.92	2.70(+3)	4.24(+3)	3.56(+3)	4.65(+3)
12^e – 14^o	1/2	3/2	E1	3464.89	3165.70	1.72(+4)	1.89(+4)	2.25(+4)	2.06(+4)
9^e – 9^o	5/2	5/2	E1	3407.11	3133.77	6.93(+3)	1.06(+4)	8.91(+3)	1.15(+4)
13^e – 15^o	5/2	7/2	E1	3417.59	3120.69	4.98(+4)	4.15(+4)	6.54(+4)	4.55(+4)
11^e – 14^o	3/2	3/2	E1	3474.14	3110.93	8.21(+1)	5.63(−1)	1.14(+2)	6.29(−1)
10^e – 12^o	3/2	5/2	E1	3350.00	3097.98	3.13(+3)	2.43(+3)	3.96(+3)	2.63(+3)
9^e – 11^o	5/2	7/2	E1	3348.28	3095.06	2.42(+4)	1.69(+4)	3.06(+4)	1.82(+4)
13^e – 16^o	5/2	5/2	E1	3385.85	3087.97	1.58(+6)	2.15(+6)	2.08(+6)	2.36(+6)
10^e – 14^o	3/2	3/2	E1	3313.46	3064.82	2.08(+5)	2.67(+5)	2.64(+5)	2.88(+5)
11^e – 16^o	3/2	5/2	E1	3366.83	3064.48	4.05(+4)	6.62(+4)	5.37(+4)	7.27(+4)
9^e – 12^o	5/2	5/2	E1	3266.42	3033.34	9.19(+4)	1.20(+5)	1.15(+5)	1.29(+5)
9^e – 13^o	5/2	7/2	E1	3246.41	3006.33	1.03(+4)	5.30(+3)	1.30(+4)	5.72(+3)
9^e – 14^o	5/2	3/2	E1	3231.90	3001.54	2.90(+4)	3.72(+4)	3.62(+4)	4.00(+4)
13^e – 17^o	5/2	5/2	E1	3256.85	2988.93	4.52(+5)	5.51(+5)	5.84(+5)	6.00(+5)
10^e – 16^o	3/2	5/2	E1	3215.59	2974.07	4.16(+4)	2.69(+4)	5.25(+4)	2.91(+4)
13^e – 18^o	5/2	3/2	E1	3218.89	2970.04	2.67(+5)	3.10(+5)	3.40(+5)	3.36(+5)
11^e – 17^o	3/2	5/2	E1	3239.25	2966.92	9.50(+3)	2.76(+4)	1.23(+4)	3.01(+4)
12^e – 18^o	1/2	3/2	E1	3194.07	2952.46	3.68(+4)	5.33(+4)	4.66(+4)	5.77(+4)
11^e – 18^o	3/2	3/2	E1	3201.91	2948.31	9.76(+5)	1.20(+6)	1.25(+6)	1.30(+6)
9^e – 15^o	5/2	7/2	E1	3166.10	2943.58	9.18(+4)	1.96(+5)	1.14(+5)	2.11(+5)
17^e – 19^o	7/2	5/2	E1	3069.68	2937.05	5.32(+4)	8.63(+4)	6.08(+4)	9.02(+4)
9^e – 16^o	5/2	5/2	E1	3138.84	2914.44	1.53(+6)	1.96(+6)	1.91(+6)	2.11(+6)
10^e – 17^o	3/2	5/2	E1	3099.13	2882.09	1.32(+5)	2.53(+5)	1.64(+5)	2.72(+5)
10^e – 18^o	3/2	3/2	E1	3064.94	2864.53	5.03(+6)	5.85(+6)	6.16(+6)	6.27(+6)
17^e – 22^o	7/2	5/2	E1	2972.75	2843.24	4.65(+6)	7.36(+6)	5.32(+6)	7.70(+6)
9^e – 17^o	5/2	5/2	E1	3027.66	2826.06	5.32(+5)	6.20(+5)	6.55(+5)	6.64(+5)

TABLE III. Wavelengths and E1 Transition Probabilities for the $3d^9$–$3d^84p$ and $3d^84s$–$3d^84p$ Transition Arrays in Ni II

See page 161 for Explanation of Tables

Ni II Emission Lines				Wavelength (Å)		A (1/s)			
Trans.	J_F	J_I	Type	Calc.	Exp.	Length(T)	Velocity(T)	Length(E)	Velocity(E)
$9^e - 18^o$	5/2	3/2	E1	2995.02	2809.17	3.58(+5)	3.65(+5)	4.34(+5)	3.89(+5)
$17^e - 23^o$	7/2	7/2	E1	2940.10	2808.38	1.13(+5)	1.88(+5)	1.29(+5)	1.97(+5)
$16^e - 23^o$	9/2	7/2	E1	2933.01	2806.49	5.94(+6)	9.56(+6)	6.78(+6)	9.99(+6)
$17^e - 26^o$	7/2	5/2	E1	2856.64	2761.48	5.57(+5)	8.47(+5)	6.17(+5)	8.77(+5)
$8^e - 1^o$	5/2	7/2	E1	2818.82	2735.06	3.15(+3)	1.71(+3)	3.44(+3)	1.76(+3)
$15^e - 20^o$	1/2	3/2	E1	2790.85	2703.71	5.05(+5)	6.98(+5)	5.56(+5)	7.20(+5)
$15^e - 21^o$	1/2	1/2	E1	2746.43	2671.11	1.04(+7)	1.21(+7)	1.13(+7)	1.24(+7)
$14^e - 19^o$	3/2	5/2	E1	2749.75	2666.64	9.59(+5)	1.25(+6)	1.05(+6)	1.29(+6)
$14^e - 20^o$	3/2	3/2	E1	2742.63	2666.04	6.97(+6)	8.36(+6)	7.59(+6)	8.60(+6)
$8^e - 2^o$	5/2	5/2	E1	2706.94	2649.51	4.85(+5)	5.60(+5)	5.18(+5)	5.72(+5)
$14^e - 21^o$	3/2	1/2	E1	2699.89	2634.35	1.47(+6)	1.62(+6)	1.58(+6)	1.66(+6)
$7^e - 1^o$	7/2	7/2	E1	2686.40	2630.27[a]	1.10(+6)	1.39(+6)	1.17(+6)	1.42(+6)
$17^e - 28^o$	7/2	5/2	E1	2691.76	2623.85	1.45(+6)	2.03(+6)	1.57(+6)	2.08(+6)
$17^e - 31^o$	7/2	7/2	E1	2686.06	2614.07	8.18(+4)	1.19(+5)	8.88(+4)	1.22(+5)
$16^e - 31^o$	9/2	7/2	E1	2680.48	2612.43	4.26(+6)	6.09(+6)	4.60(+6)	9.25(+6)
$15^e - 24^o$	1/2	3/2	E1	2667.92	2593.30	3.85(+5)	3.52(+5)	4.19(+5)	3.62(+5)
$14^e - 22^o$	3/2	5/2	E1	2671.71	2589.08	6.43(+5)	8.81(+5)	7.07(+5)	9.09(+5)
$8^e - 5^o$	5/2	3/2	E1	2632.65	2588.06	1.76(+5)	2.19(+5)	1.85(+5)	2.23(+5)
$15^e - 25^o$	1/2	1/2	E1	2652.42	2584.77	2.27(+7)	2.64(+7)	2.46(+7)	2.71(+7)
$14^e - 24^o$	3/2	3/2	E1	2623.86	2558.03	1.57(+6)	1.79(+6)	1.70(+6)	1.84(+6)
$7^e - 2^o$	7/2	5/2	E1	2584.42	2551.80	6.70(+5)	8.00(+5)	6.96(+5)	8.10(+5)
$14^e - 25^o$	3/2	1/2	E1	2608.83	2550.32	1.38(+7)	1.49(+7)	1.48(+7)	1.53(+7)
$17^e - 32^o$	7/2	5/2	E1	2614.67	2547.95	7.76(+5)	1.05(+6)	8.39(+5)	1.08(+6)
$8^e - 7^o$	5/2	7/2	E1	2606.15	2545.90[a]	1.21(+7)	1.13(+7)	1.30(+7)	1.16(+7)
$15^e - 27^o$	1/2	3/2	E1	2607.34	2539.86	1.33(+7)	1.46(+7)	1.44(+7)	1.50(+7)
$14^e - 26^o$	3/2	5/2	E1	2577.55	2521.11	1.07(+5)	1.76(+5)	1.14(+5)	1.80(+5)
$7^e - 3^o$	7/2	9/2	E1	2570.42	2510.87[a]	5.78(+7)	5.27(+7)	6.20(+7)	5.39(+7)
$14^e - 27^o$	3/2	3/2	E1	2565.22	2506.60	4.18(+7)	4.73(+7)	4.48(+7)	4.85(+7)
$8^e - 9^o$	5/2	5/2	E1	2561.46	2498.55	6.72(+5)	6.68(+5)	7.24(+5)	6.85(+5)
$8^e - 11^o$	5/2	7/2	E1	2528.06	2473.88	4.92(+6)	4.96(+6)	5.25(+6)	5.04(+6)
$7^e - 7^o$	7/2	7/2	E1	2492.34	2456.26	2.54(+6)	2.77(+6)	2.65(+6)	2.81(+6)
$7^e - 8^o$	7/2	9/2	E1	2489.53	2437.89[a]	5.74(+7)	4.95(+7)	6.11(+7)	5.05(+7)
$8^e - 12^o$	5/2	5/2	E1	2481.12	2433.56[a]	4.93(+6)	5.35(+6)	5.22(+6)	5.45(+6)
$15^e - 29^o$	1/2	3/2	E1	2475.59	2432.30	4.45(+6)	4.23(+6)	4.69(+6)	4.30(+6)
$15^e - 30^o$	1/2	1/2	E1	2486.81	2429.82	3.32(+6)	3.59(+6)	3.56(+6)	3.68(+6)
$8^e - 13^o$	5/2	7/2	E1	2469.56	2416.13[a]	2.43(+8)	2.19(+8)	2.59(+8)	2.24(+8)
$8^e - 14^o$	5/2	3/2	E1	2461.02	2413.04[a]	7.62(+6)	8.90(+6)	8.08(+6)	9.08(+6)
$5^e - 1^o$	5/2	7/2	E1	2469.83	2412.27[a]	2.86(+5)	3.57(+5)	3.06(+5)	3.65(+5)
$7^e - 9^o$	7/2	5/2	E1	2451.49	2410.74[a]	4.28(+5)	4.09(+5)	4.50(+5)	4.15(+5)
$13^e - 19^o$	5/2	5/2	E1	2468.35	2407.61	3.74(+6)	3.53(+6)	4.03(+6)	3.62(+6)
$13^e - 20^o$	5/2	3/2	E1	2462.48	2407.13	1.42(+6)	8.35(+5)	1.52(+6)	8.54(+5)
$14^e - 28^o$	3/2	5/2	E1	2442.55	2405.90	4.24(+7)	4.09(+7)	4.44(+7)	4.15(+7)
$14^e - 29^o$	3/2	3/2	E1	2437.58	2401.78	4.52(+5)	4.60(+5)	4.72(+5)	4.67(+5)
$12^e - 20^o$	1/2	3/2	E1	2447.93	2395.57	5.35(+7)	5.80(+7)	5.71(+7)	5.93(+7)
$7^e - 10^o$	7/2	9/2	E1	2421.39	2394.52[a]	2.08(+8)	1.77(+8)	2.16(+8)	1.10(+8)
$14^e - 30^o$	3/2	1/2	E1	2448.45	2393.36	7.43(+5)	7.24(+5)	7.96(+5)	7.44(+5)
$11^e - 19^o$	3/2	5/2	E1	2458.23	2393.31	2.69(+7)	2.81(+7)	2.91(+7)	2.88(+7)
$11^e - 20^o$	3/2	3/2	E1	2452.24	2392.83	9.74(+6)	9.55(+5)	1.05(+7)	9.79(+6)
$7^e - 11^o$	7/2	7/2	E1	2420.82	2387.76[a]	2.70(+7)	2.72(+7)	2.81(+7)	2.78(+7)

TABLE III. Wavelengths and E1 Transition Probabilities for the $3d^9$–$3d^8 4p$ and $3d^8 4s$–$3d^8 4p$ Transition Arrays in Ni II

See page 161 for Explanation of Tables

Ni II Emission Lines				Wavelength (Å)		A (1/s)			
Trans.	J_F	J_I	Type	Calc.	Exp.	Length(T)	Velocity(T)	Length(E)	Velocity(E)
6^e – 2^o	3/2	5/2	E1	2407.15	2376.73	9.57(+5)	1.18(+6)	9.94(+5)	1.20(+6)
8^e – 15^o	5/2	7/2	E1	2422.81	2375.42[a]	5.37(+7)	5.12(+7)	5.69(+7)	5.22(+7)
12^e – 21^o	1/2	1/2	E1	2413.69	2369.24	3.28(+7)	3.45(+7)	3.46(+7)	3.52(+7)
4^e – 1^o	7/2	7/2	E1	2412.71	2367.39[a]	6.96(+6)	9.39(+6)	7.36(+6)	9.57(+6)
11^e – 21^o	3/2	1/2	E1	2418.18	2367.27	7.78(+7)	7.44(+7)	8.29(+7)	7.60(+7)
11^e – 27^o	3/2	3/2	E1	2309.69	2363.60	1.72(+6)	2.02(+6)	1.61(+6)	1.97(+6)
8^e – 16^o	5/2	5/2	E1	2406.81	2356.40[a]	1.95(+7)	1.84(+7)	2.08(+7)	1.88(+7)
7^e – 12^o	7/2	5/2	E1	2377.79	2351.57	3.28(+5)	3.08(+5)	3.39(+5)	3.12(+5)
5^e – 2^o	5/2	5/2	E1	2334.43	2346.16	2.45(+7)	3.10(+7)	2.57(+7)	3.15(+7)
17^e – 38^o	7/2	9/2	E1	2384.27	2345.99	3.42(+8)	2.60(+8)	3.59(+8)	2.65(+8)
16^e – 38^o	9/2	9/2	E1	2379.62	2344.67	1.55(+7)	1.28(+7)	1.62(+7)	1.30(+7)
13^e – 22^o	5/2	5/2	E1	2383.52	2344.21	2.89(+7)	2.78(+7)	3.12(+7)	2.85(+7)
14^e – 32^o	3/2	5/2	E1	2378.91	2341.93	2.94(+8)	2.80(+8)	3.08(+8)	2.85(+8)
10^e – 19^o	3/2	5/2	E1	2376.68	2337.81	1.83(+6)	2.84(+6)	1.92(+6)	2.89(+6)
15^e – 33^o	1/2	3/2	E1	2386.89	2337.43	1.76(+8)	1.65(+8)	1.87(+8)	1.68(+8)
10^e – 20^o	3/2	3/2	E1	2371.36	2337.35	5.05(+7)	4.94(+7)	5.27(+7)	5.02(+7)
7^e – 13^o	7/2	7/2	E1	2367.06	2334.58[a]	6.18(+7)	5.69(+7)	6.44(+7)	5.77(+7)
11^e – 22^o	3/2	5/2	E1	2395.67	2330.65	7.13(+6)	5.30(+6)	7.75(+6)	5.45(+6)
6^e – 5^o	3/2	3/2	E1	2348.38	2326.45[a]	4.35(+7)	5.12(+7)	4.47(+7)	5.17(+7)
13^e – 23^o	5/2	7/2	E1	2383.89	2320.46	5.98(+7)	5.19(+7)	6.48(+7)	5.33(+7)
13^e – 24^o	5/2	3/2	E1	2366.44	2319.22	7.84(+7)	8.00(+7)	8.32(+7)	8.16(+7)
16^e – 40^o	9/2	7/2	E1	2331.52	2316.04[a]	3.52(+8)	4.22(+8)	3.59(+8)	4.25(+8)
16^e – 39^o	9/2	11/2	E1	2357.82	2313.63	3.64(+8)	2.89(+8)	3.85(+8)	2.94(+8)
11^e – 25^o	3/2	1/2	E1	2345.00	2312.95	2.17(+8)	2.22(+8)	2.26(+8)	2.25(+8)
14^e – 33^o	3/2	3/2	E1	2351.54	2309.23	1.61(+8)	1.55(+8)	1.70(+8)	1.58(+8)
12^e – 24^o	1/2	3/2	E1	2352.87	2308.49	4.48(+7)	4.57(+7)	4.76(+7)	4.66(+7)
11^e – 24^o	3/2	3/2	E1	2357.13	2305.95	6.81(+7)	6.92(+7)	7.28(+7)	7.08(+7)
15^e – 34^o	1/2	3/2	E1	2362.14	2304.56	1.50(+8)	1.49(+8)	1.62(+8)	1.53(+8)
17^e – 40^o	7/2	7/2	E1	2336.09	2304.46	4.09(+6)	5.27(+6)	4.26(+6)	5.35(+6)
3^e – 1^o	9/2	7/2	E1	2338.62	2303.19	3.53(+8)	4.00(+8)	3.69(+8)	4.06(+8)
4^e – 2^o	7/2	5/2	E1	2330.37	2303.00[a]	3.42(+8)	3.76(+8)	3.54(+8)	3.80(+8)
12^e – 25^o	1/2	1/2	E1	2340.78	2301.72	2.15(+7)	2.20(+7)	2.26(+7)	2.23(+7)
9^e – 19^o	5/2	5/2	E1	2405.29	2300.80	3.32(+8)	3.31(+8)	3.47(+8)	3.36(+8)
9^e – 20^o	5/2	3/2	E1	2329.30	2300.36	2.31(+8)	2.34(+8)	2.40(+8)	2.37(+8)
10^e – 21^o	3/2	1/2	E1	2339.22	2299.20	2.30(+8)	2.37(+8)	2.42(+8)	2.41(+8)
8^e – 17^o	5/2	5/2	E1	2340.90	2298.27[a]	3.29(+8)	3.44(+8)	3.48(+8)	3.50(+8)
6^e – 6^o	3/2	1/2	E1	2323.83	2298.20	3.62(+8)	4.03(+8)	3.74(+8)	4.08(+8)
5^e – 5^o	5/2	3/2	E1	2325.73	2297.14[a]	3.18(+8)	3.55(+8)	3.30(+8)	3.60(+8)
7^e – 15^o	7/2	7/2	E1	2324.17	2296.55[a]	2.74(+8)	2.70(+8)	2.84(+8)	2.73(+8)
13^e – 26^o	5/2	5/2	E1	2328.70	2288.35	2.75(+8)	2.79(+8)	2.89(+8)	2.84(+8)
8^e – 18^o	5/2	3/2	E1	2321.34	2287.09[a]	3.46(+8)	3.91(+8)	3.61(+8)	3.97(+8)
7^e – 16^o	7/2	5/2	E1	2309.46	2279.47	3.54(+8)	3.87(+8)	3.68(+8)	3.92(+8)
17^e – 41^o	7/2	5/2	E1	2311.45	2278.77[a]	3.76(+8)	4.37(+8)	3.93(+8)	4.43(+8)
10^e – 22^o	3/2	5/2	E1	2318.16	2277.93	3.21(+8)	2.82(+8)	3.39(+8)	2.87(+8)
14^e – 34^o	3/2	3/2	E1	2327.51	2277.14	1.32(+8)	1.36(+8)	1.41(+8)	1.39(+8)
13^e – 27^o	5/2	3/2	E1	2318.62	2276.39	1.35(+8)	1.44(+8)	1.43(+8)	1.46(+8)
11^e – 26^o	3/2	5/2	E1	2319.69	2275.43	6.83(+7)	6.67(+7)	7.23(+7)	6.80(+7)
4^e – 3^o	7/2	9/2	E1	2318.98	2270.21[a]	1.94(+8)	1.49(+8)	2.07(+8)	1.53(+8)
12^e – 27^o	1/2	3/2	E1	2305.60	2266.05	2.54(+7)	2.62(+7)	2.67(+7)	2.67(+7)

TABLE III. Wavelengths and E1 Transition Probabilities for the $3d^9$–$3d^8 4p$ and $3d^8 4s$–$3d^8 4p$ Transition Arrays in Ni II

See page 161 for Explanation of Tables

Ni II Emission Lines				Wavelength (Å)		A (1/s)			
Trans.	J_F	J_I	Type	Calc.	Exp.	Length(T)	Velocity(T)	Length(E)	Velocity(E)
$5^e - 7^o$	5/2	7/2	E1	2305.02	2264.46[a]	1.55(+8)	1.19(+8)	1.63(+8)	1.21(+8)
$15^e - 35^o$	1/2	1/2	E1	2298.97	2256.84	2.93(+8)	2.96(+8)	3.10(+8)	3.02(+8)
$10^e - 24^o$	3/2	3/2	E1	2282.05	2254.38	1.72(+8)	1.69(+8)	1.78(+8)	1.71(+8)
$6^e - 9^o$	3/2	5/2	E1	2291.57	2253.85[a]	2.64(+8)	2.09(+8)	2.77(+8)	2.13(+8)
$10^e - 26^o$	3/2	5/2	E1	2246.93	2252.20	1.76(+7)	1.59(+7)	1.75(+7)	1.59(+7)
$10^e - 25^o$	3/2	1/2	E1	2270.67	2247.93	8.08(+7)	8.82(+7)	8.34(+7)	8.91(+7)
$9^e - 22^o$	5/2	5/2	E1	2277.94	2242.84	4.97(+5)	1.83(+5)	5.21(+5)	1.86(+5)
$15^e - 36^o$	1/2	1/2	E1	2265.59	2237.64	3.69(+7)	3.73(+7)	3.83(+7)	3.78(+7)
$15^e - 37^o$	1/2	3/2	E1	2260.54	2236.76	1.07(+5)	9.41(+4)	1.11(+5)	9.51(+4)
$14^e - 35^o$	3/2	1/2	E1	2266.15	2230.53	2.28(+7)	2.23(+7)	2.39(+7)	2.27(+7)
$5^e - 9^o$	5/2	5/2	E1	2269.99	2226.33[a]	1.25(+8)	1.08(+8)	1.32(+8)	1.10(+8)
$4^e - 7^o$	7/2	7/2	E1	2255.26	2224.86[a]	2.23(+8)	1.93(+8)	2.32(+8)	1.96(+8)
$7^e - 17^o$	7/2	5/2	E1	2248.71	2224.36[a]	2.30(+7)	2.73(+7)	2.21(+7)	2.70(+7)
$3^e - 3^o$	9/2	9/2	E1	2250.27	2222.96[a]	1.20(+8)	1.06(+8)	1.25(+8)	1.08(+8)
$9^e - 23^o$	5/2	7/2	E1	2258.74	2220.40[a]	3.16(+8)	2.71(+8)	3.32(+8)	2.76(+8)
$9^e - 24^o$	5/2	3/2	E1	2243.06	2219.95	6.20(+5)	4.45(+5)	6.40(+5)	4.50(+5)
$3^e - 4^o$	9/2	11/2	E1	2256.88	2216.48[a]	4.13(+8)	3.32(+8)	4.35(+8)	3.38(+8)
$10^e - 27^o$	3/2	3/2	E1	2237.55	2213.88	1.08(+8)	1.07(+8)	1.12(+8)	1.08(+8)
$14^e - 36^o$	3/2	1/2	E1	2233.71	2211.78	3.54(+8)	3.45(+8)	3.65(+8)	3.49(+8)
$14^e - 37^o$	3/2	3/2	E1	2228.80	2210.92	8.27(+6)	7.84(+6)	8.47(+6)	7.91(+6)
$4^e - 8^o$	7/2	9/2	E1	2252.86	2210.38[a]	5.46(+7)	4.84(+7)	5.78(+7)	4.94(+7)
$5^e - 11^o$	5/2	7/2	E1	2243.73	2206.72[a]	2.15(+8)	1.87(+8)	2.25(+8)	1.90(+8)
$6^e - 12^o$	3/2	5/2	E1	2227.17	2201.41[a]	1.31(+8)	1.19(+8)	1.35(+8)	1.20(+8)
$13^e - 28^o$	5/2	5/2	E1	2217.95	2193.03	6.36(+7)	5.48(+7)	6.58(+7)	5.55(+7)
$9^e - 26^o$	5/2	5/2	E1	2209.13	2191.65	1.66(+7)	1.72(+7)	1.70(+7)	1.73(+7)
$13^e - 29^o$	5/2	3/2	E1	2213.86	2189.60	1.28(+7)	1.11(+7)	1.32(+7)	1.13(+7)
$4^e - 9^o$	7/2	5/2	E1	2221.73	2188.05[a]	5.23(+6)	3.99(+6)	5.47(+6)	4.05(+6)
$13^e - 31^o$	5/2	7/2	E1	2214.28	2186.19	3.29(+8)	2.81(+8)	3.42(+8)	2.85(+8)
$6^e - 14^o$	3/2	3/2	E1	2210.95	2184.61[a]	3.55(+8)	3.34(+8)	3.68(+8)	3.38(+8)
$11^e - 28^o$	3/2	5/2	E1	2209.77	2181.16	2.56(+8)	2.21(+8)	2.66(+8)	2.26(+8)
$9^e - 27^o$	5/2	3/2	E1	2200.06	2180.67	4.11(+7)	4.49(+7)	4.22(+7)	4.53(+7)
$3^e - 7^o$	9/2	7/2	E1	2190.30	2180.13	2.82(+6)	1.87(+6)	2.86(+6)	1.88(+6)
$12^e - 29^o$	1/2	3/2	E1	2201.98	2180.03	1.88(+8)	1.68(+8)	1.94(+8)	1.69(+8)
$12^e - 30^o$	1/2	1/2	E1	2210.84	2178.04	3.33(+8)	2.92(+8)	3.48(+8)	2.96(+8)
$11^e - 29^o$	3/2	3/2	E1	2205.71	2177.77	1.78(+8)	1.50(+8)	1.85(+8)	1.52(+8)
$11^e - 30^o$	3/2	1/2	E1	2214.60	2175.78	4.63(+7)	3.85(+7)	4.88(+7)	3.92(+7)
$5^e - 12^o$	5/2	5/2	E1	2206.27	2175.15[a]	2.56(+8)	2.53(+8)	2.67(+8)	2.57(+8)
$4^e - 10^o$	7/2	9/2	E1	2196.88	2174.67[a]	1.67(+8)	1.29(+8)	1.72(+8)	1.30(+8)
$4^e - 11^o$	7/2	7/2	E1	2196.53	2169.10[a]	1.62(+8)	1.57(+8)	1.68(+8)	1.58(+8)
$3^e - 8^o$	9/2	9/2	E1	2188.03	2165.55[a]	2.98(+8)	2.80(+8)	3.07(+8)	2.83(+8)
$5^e - 13^o$	5/2	7/2	E1	2197.52	2161.22[a]	1.00(+7)	7.21(+6)	1.05(+7)	7.33(+6)
$5^e - 14^o$	5/2	3/2	E1	2190.86	2158.74[a]	4.98(+7)	4.44(+7)	5.20(+7)	4.50(+7)
$13^e - 32^o$	5/2	5/2	E1	2165.35	2139.75	5.07(+6)	4.56(+6)	5.25(+6)	4.62(+6)
$6^e - 16^o$	3/2	5/2	E1	2167.00	2138.75	6.17(+5)	4.24(+5)	6.42(+5)	4.29(+5)
$4^e - 12^o$	7/2	5/2	E1	2161.04	2138.58[a]	2.66(+7)	2.21(+7)	2.74(+7)	2.23(+7)
$10^e - 28^o$	3/2	5/2	E1	2143.65	2134.96	3.45(+7)	2.36(+7)	2.39(+7)	2.14(+7)
$10^e - 29^o$	3/2	3/2	E1	2139.83	2131.71	1.71(+7)	1.30(+7)	1.73(+7)	1.31(+7)
$3^e - 10^o$	9/2	9/2	E1	2135.20	2131.28[a]	8.23(+6)	9.56(+6)	8.27(+6)	9.57(+6)
$10^e - 30^o$	3/2	1/2	E1	2148.20	2129.81	1.45(+7)	1.18(+7)	1.48(+7)	1.19(+7)

TABLE III. Wavelengths and E1 Transition Probabilities for the $3d^9$–$3d^84p$ and $3d^84s$–$3d^84p$ Transition Arrays in Ni II

See page 161 for Explanation of Tables

Ni II Emission Lines				Wavelength (Å)		A (1/s)			
Trans.	J_F	J_I	Type	Calc.	Exp.	Length(T)	Velocity(T)	Length(E)	Velocity(E)
$5^e - 15^o$	5/2	7/2	E1	2160.42	2128.58[a]	2.66(+7)	2.32(+7)	2.78(+7)	2.35(+7)
$11^e - 32^o$	3/2	5/2	E1	2157.56	2128.45	3.99(+7)	3.45(+7)	4.17(+7)	3.50(+7)
$3^e - 11^o$	9/2	7/2	E1	2134.87	2125.91[a]	3.75(+6)	2.81(+6)	3.79(+6)	2.82(+6)
$4^e - 13^o$	7/2	7/2	E1	2152.19	2125.12[a]	1.42(+7)	1.17(+7)	1.48(+7)	1.19(+7)
$17^e - 42^o$	7/2	7/2	E1	2129.79	2114.19	4.61(+8)	4.07(+8)	1.62(+7)	1.48(+7)
$5^e - 16^o$	5/2	5/2	E1	2147.69	2113.96	2.28(+5)	2.97(+5)	2.39(+5)	3.02(+5)
$16^e - 42^o$	9/2	7/2	E1	2126.06	2113.12	4.80(+6)	3.64(+6)	4.89(+6)	3.66(+6)
$14^e - 41^o$	3/2	5/2	E1	2125.26	2112.78	2.10(+6)	1.85(+6)	2.14(+6)	1.86(+6)
$13^e - 33^o$	5/2	3/2	E1	2142.64	2112.42	8.63(+5)	8.04(+5)	9.00(+5)	8.16(+5)
$17^e - 43^o$	7/2	9/2	E1	2124.87	2109.69	2.15(+7)	1.81(+7)	2.20(+7)	1.82(+7)
$16^e - 43^o$	9/2	9/2	E1	2121.27	2108.62	4.42(+8)	4.02(+8)	4.50(+8)	4.04(+8)
$9^e - 28^o$	5/2	5/2	E1	2109.22	2104.06	1.36(+7)	1.52(+7)	1.37(+7)	1.05(+7)
$12^e - 33^o$	1/2	3/2	E1	2131.52	2103.51	5.64(+6)	5.12(+6)	5.86(+6)	5.19(+6)
$11^e - 33^o$	3/2	3/2	E1	2135.01	2101.44	1.44(+6)	1.47(+6)	1.51(+6)	1.49(+6)
$9^e - 29^o$	5/2	3/2	E1	2105.52	2100.91	4.75(+6)	3.52(+6)	4.79(+6)	3.53(+6)
$9^e - 31^o$	5/2	7/2	E1	2105.90	2097.76	8.64(+7)	7.34(+7)	8.74(+7)	7.37(+7)
$4^e - 15^o$	7/2	7/2	E1	2116.67	2094.22	1.64(+7)	1.48(+7)	4.71(+8)	4.10(+8)
$6^e - 17^o$	3/2	5/2	E1	2113.43	2090.10[a]	5.08(+6)	4.26(+6)	5.25(+6)	4.31(+6)
$13^e - 34^o$	5/2	3/2	E1	2122.58	2085.54	2.87(+7)	2.71(+7)	3.02(+7)	2.76(+7)
$10^e - 32^o$	3/2	5/2	E1	2094.48	2084.43	6.42(+6)	4.88(+6)	6.52(+6)	4.91(+6)
$3^e - 13^o$	9/2	7/2	E1	2092.95	2084.31	1.29(+6)	1.06(+6)	1.30(+6)	1.06(+6)
$6^e - 18^o$	3/2	3/2	E1	2097.47	2080.85[a]	1.11(+7)	1.09(+7)	1.14(+7)	1.10(+7)
$4^e - 16^o$	7/2	5/2	E1	2104.44	2079.43	8.33(+5)	8.96(+5)	8.63(+5)	9.07(+5)
$12^e - 34^o$	1/2	3/2	E1	2111.76	2076.86	2.41(+5)	2.68(+5)	2.53(+5)	2.72(+5)
$11^e - 34^o$	3/2	3/2	E1	2115.19	2074.80	3.94(+6)	3.44(+6)	4.18(+6)	3.50(+6)
$5^e - 17^o$	5/2	5/2	E1	2095.06	2067.07	2.36(+6)	2.33(+6)	2.46(+6)	2.36(+6)
$10^e - 33^o$	3/2	3/2	E1	2073.23	2058.49	8.61(+5)	7.70(+5)	8.80(+5)	7.76(+5)
$5^e - 18^o$	5/2	3/2	E1	2079.38	2058.02	3.33(+6)	3.12(+6)	3.44(+6)	3.15(+6)
$9^e - 32^o$	5/2	5/2	E1	2061.60	2054.97	1.34(+7)	1.05(+7)	1.35(+7)	1.05(+7)
$3^e - 15^o$	9/2	7/2	E1	2059.35	2053.30[a]	4.38(+6)	3.79(+6)	4.41(+6)	3.80(+6)
$12^e - 35^o$	1/2	1/2	E1	2061.13	2039.02	4.91(+6)	4.24(+6)	5.07(+6)	4.29(+6)
$11^e - 35^o$	3/2	1/2	E1	2064.39	2036.04	2.24(+7)	2.02(+7)	2.34(+7)	2.05(+7)
$4^e - 17^o$	7/2	5/2	E1	2053.88	2034.05[a]	3.54(+6)	3.38(+6)	3.65(+6)	3.41(+6)
$10^e - 34^o$	3/2	3/2	E1	2054.53	2032.96	2.33(+7)	2.12(+7)	2.41(+7)	2.14(+7)
$13^e - 37^o$	5/2	3/2	E1	2040.27	2029.86	1.51(+8)	1.38(+8)	1.53(+8)	1.38(+8)
$9^e - 33^o$	5/2	3/2	E1	2041.00	2029.75	1.47(+7)	1.30(+7)	1.49(+7)	1.30(+7)
$12^e - 36^o$	1/2	1/2	E1	2034.25	2022.35	5.22(+4)	3.74(+4)	5.31(+4)	3.76(+4)
$12^e - 37^o$	1/2	3/2	E1	2030.18	2021.63	8.82(+7)	8.41(+7)	8.93(+7)	8.44(+7)
$11^e - 36^o$	3/2	1/2	E1	2037.44	2020.40	5.89(+6)	5.49(+6)	6.05(+6)	5.54(+6)
$11^e - 37^o$	3/2	3/2	E1	2033.35	2019.68	1.62(+8)	1.45(+8)	1.66(+8)	1.46(+8)
$9^e - 34^o$	5/2	3/2	E1	2022.88	2004.92	4.80(+7)	4.38(+7)	4.93(+7)	4.42(+7)
$10^e - 35^o$	3/2	1/2	E1	2006.57	1995.73	5.72(+7)	5.22(+7)	5.81(+7)	5.25(+7)
$10^e - 36^o$	3/2	1/2	E1	1981.10	1980.70	2.56(+6)	2.49(+6)	2.57(+6)	2.49(+6)
$10^e - 37^o$	3/2	3/2	E1	1977.23	1980.01	2.14(+7)	1.85(+7)	2.13(+7)	1.84(+7)
$13^e - 40^o$	5/2	7/2	E1	1970.73	1965.36	1.97(+7)	1.63(+7)	1.98(+7)	1.63(+7)
$9^e - 37^o$	5/2	3/2	E1	1947.90	1953.40	6.90(+7)	5.93(+7)	6.84(+7)	5.91(+7)
$2^e - 2^o$	3/2	5/2	E1	2027.15	1951.92	2.04(+5)	4.46(+5)	2.95(+5)	5.05(+5)
$13^e - 41^o$	5/2	5/2	E1	1953.16	1946.83	2.67(+5)	1.99(+5)	2.68(+5)	2.00(+5)
$1^e - 1^o$	5/2	7/2	E1	2025.61	1939.57	1.03(+2)	1.27(+4)	1.52(+2)	1.44(+4)

TABLE III. Wavelengths and E1 Transition Probabilities for the $3d^9$–$3d^8 4p$ and $3d^8 4s$–$3d^8 4p$ Transition Arrays in Ni II

See page 161 for Explanation of Tables

Ni II Emission Lines				Wavelength (Å)		A (1/s)			
Trans.	J_F	J_I	Type	Calc.	Exp.	Length(T)	Velocity(T)	Length(E)	Velocity(E)
$8^e - 19^o$	5/2	5/2	E1	1903.78	1938.89	4.10(+5)	4.13(+5)	3.88(+5)	4.06(+5)
$8^e - 20^o$	5/2	3/2	E1	1900.37	1938.58	5.96(+6)	5.72(+6)	5.61(+6)	5.60(+6)
$11^e - 41^o$	3/2	5/2	E1	1946.82	1937.47	4.87(+6)	4.04(+6)	4.94(+6)	4.06(+6)
$2^e - 5^o$	3/2	3/2	E1	1985.11	1918.37	3.54(+5)	3.79(+5)	5.03(+5)	4.26(+5)
$10^e - 41^o$	3/2	5/2	E1	1895.31	1900.93	1.26(+7)	1.05(+7)	1.25(+7)	1.04(+7)
$2^e - 6^o$	3/2	1/2	E1	1967.53	1898.64	5.93(+5)	4.36(+5)	8.43(+5)	4.90(+5)
$5^e - 22^o$	5/2	5/2	E1	1866.05	1897.57	7.39(+5)	5.37(+5)	6.72(+5)	4.48(+5)
$1^e - 2^o$	5/2	5/2	E1	1967.20	1896.15	1.44(+6)	3.22(+6)	2.05(+6)	3.63(+6)
$9^e - 40^o$	5/2	7/2	E1	1884.42	1893.16	6.40(+6)	5.33(+6)	6.31(+6)	5.30(+6)
$15^e - 45^o$	1/2	1/2	E1	1285.75	1886.68	1.16(+6)	6.56(+5)	3.66(+5)	4.47(+5)
$7^e - 19^o$	7/2	5/2	E1	1842.36	1886.05	8.11(+6)	6.99(+6)	7.56(+6)	6.83(+6)
$8^e - 23^o$	5/2	7/2	E1	1853.15	1881.98	3.63(+5)	2.43(+5)	3.47(+5)	2.39(+5)
$8^e - 24^o$	5/2	3/2	E1	1842.58	1881.16	2.18(+7)	1.98(+7)	2.05(+7)	1.93(+7)
$9^e - 41^o$	5/2	5/2	E1	1868.34	1876.39	2.72(+4)	1.93(+4)	2.68(+4)	1.92(+4)
$2^e - 9^o$	3/2	5/2	E1	1944.34	1868.75	2.20(+5)	1.29(+5)	3.16(+5)	1.45(+5)
$1^e - 5^o$	5/2	3/2	E1	1927.67	1864.47	9.28(+4)	1.37(+5)	1.30(+5)	1.53(+5)
$8^e - 26^o$	5/2	5/2	E1	1819.62	1860.80	1.76(+6)	1.52(+6)	1.67(+6)	1.49(+6)
$8^e - 27^o$	5/2	3/2	E1	1813.46	1852.88	3.27(+6)	2.83(+6)	3.09(+6)	2.77(+6)
$7^e - 22^o$	7/2	5/2	E1	1806.99	1846.92	3.84(+5)	2.64(+5)	3.60(+5)	2.58(+5)
$1^e - 7^o$	5/2	7/2	E1	1913.42	1842.89	1.48(+6)	2.70(+6)	2.10(+6)	3.03(+6)
$2^e - 12^o$	3/2	5/2	E1	1897.71	1832.57	4.52(+5)	8.86(+5)	6.36(+5)	9.93(+5)
$7^e - 23^o$	7/2	7/2	E1	1794.84	1832.15	9.99(+5)	5.80(+5)	9.39(+5)	5.68(+5)
$13^e - 42^o$	5/2	7/2	E1	1821.88	1825.26	2.33(+4)	1.57(+4)	2.31(+4)	1.55(+4)
$2^e - 14^o$	3/2	3/2	E1	1886.02	1820.91	2.23(+6)	4.04(+6)	3.14(+6)	4.53(+6)
$1^e - 9^o$	5/2	5/2	E1	1889.22	1817.56	1.79(+6)	1.52(+6)	8.45(+5)	8.59(+5)
$7^e - 26^o$	7/2	5/2	E1	1763.42	1812.07	1.44(+7)	1.20(+7)	1.33(+7)	1.17(+7)
$1^e - 11^o$	5/2	7/2	E1	1870.99	1804.47	6.08(+6)	1.11(+7)	8.56(+6)	1.25(+7)
$8^e - 28^o$	5/2	5/2	E1	1751.29	1797.27	5.18(+4)	2.51(+4)	4.79(+4)	2.44(+4)
$8^e - 29^o$	5/2	3/2	E1	1748.74	1794.97	5.89(+5)	5.14(+5)	5.44(+5)	5.01(+5)
$8^e - 31^o$	5/2	7/2	E1	1748.94	1792.68	8.84(+3)	3.01(+3)	8.21(+3)	2.94(+3)
$6^e - 19^o$	3/2	5/2	E1	1750.55	1788.67	9.31(+3)	6.34(+3)	8.73(+3)	6.21(+3)
$2^e - 16^o$	3/2	5/2	E1	1853.93	1788.49	2.43(+7)	4.31(+7)	3.42(+7)	4.82(+7)
$6^e - 20^o$	3/2	3/2	E1	1747.66	1788.40	8.60(+4)	5.41(+4)	8.02(+4)	5.28(+4)
$1^e - 12^o$	5/2	5/2	E1	1845.15	1783.32	2.75(+5)	2.75(+5)	3.83(+5)	3.07(+5)
$6^e - 21^o$	3/2	1/2	E1	1730.14	1774.08	3.95(+4)	2.91(+4)	3.66(+4)	2.84(+4)
$1^e - 13^o$	5/2	7/2	E1	1838.75	1773.95	1.08(+6)	2.03(+6)	1.51(+6)	2.27(+6)
$1^e - 14^o$	5/2	3/2	E1	1834.08	1772.28	1.57(+5)	1.82(+5)	2.19(+5)	2.03(+5)
$5^e - 19^o$	5/2	5/2	E1	1737.93	1771.30	3.07(+5)	2.49(+5)	2.90(+5)	2.45(+5)
$5^e - 20^o$	5/2	3/2	E1	1735.08	1771.04	4.49(+5)	4.01(+5)	4.22(+5)	3.93(+5)
$9^e - 42^o$	5/2	7/2	E1	1747.86	1763.21	8.74(+3)	5.18(+3)	8.51(+3)	5.14(+3)
$8^e - 32^o$	5/2	5/2	E1	1708.33	1761.33	2.22(+5)	1.66(+5)	2.06(+5)	1.62(+5)
$2^e - 17^o$	3/2	5/2	E1	1814.58	1754.81	1.68(+7)	2.84(+7)	2.33(+7)	3.17(+7)
$6^e - 22^o$	3/2	5/2	E1	1718.59	1753.44	1.77(+4)	1.28(+4)	1.66(+4)	1.25(+4)
$1^e - 15^o$	5/2	7/2	E1	1812.79	1751.92[a]	3.47(+7)	5.78(+7)	4.83(+7)	6.44(+7)
$7^e - 28^o$	7/2	5/2	E1	1699.17	1751.77	7.67(+5)	6.54(+5)	6.70(+5)	6.34(+5)
$2^e - 18^o$	3/2	3/2	E1	1802.81	1748.28	1.08(+8)	1.96(+8)	1.48(+8)	2.18(+8)
$7^e - 31^o$	7/2	7/2	E1	1697.01	1747.40	8.07(+4)	3.85(+4)	7.39(+4)	3.74(+4)
$4^e - 19^o$	7/2	5/2	E1	1709.50	1746.99	1.91(+6)	1.63(+6)	1.79(+6)	1.59(+6)
$8^e - 33^o$	5/2	3/2	E1	1704.00	1742.77	1.09(+5)	2.98(+4)	1.03(+5)	2.91(+4)

TABLE III. Wavelengths and E1 Transition Probabilities for the $3d^9$–$3d^8 4p$ and $3d^8 4s$–$3d^8 4p$ Transition Arrays in Ni II

See page 161 for Explanation of Tables

Ni II Emission Lines				Wavelength (Å)		A (1/s)			
Trans.	J_F	J_I	Type	Calc.	Exp.	Length(T)	Velocity(T)	Length(E)	Velocity(E)
$1^e - 16^o$	5/2	5/2	E1	1803.73	1741.55	8.40(+7)	1.52(+8)	1.17(+8)	1.70(+8)
$6^e - 24^o$	3/2	3/2	E1	1698.66	1739.42	2.01(+4)	5.45(+4)	1.88(+4)	5.33(+4)
$5^e - 22^o$	5/2	5/2	E1	1706.43	1736.74	7.39(+4)	5.37(+4)	7.01(+4)	5.28(+4)
$6^e - 25^o$	3/2	1/2	E1	1692.35	1735.58	7.78(+3)	4.99(+3)	7.21(+3)	4.86(+3)
$8^e - 34^o$	5/2	3/2	E1	1691.35	1724.43	4.04(+5)	3.50(+5)	3.81(+5)	3.43(+5)
$5^e - 23^o$	5/2	7/2	E1	1695.63	1723.68	3.86(+2)	8.66(+0)	3.67(+2)	8.52(+0)
$5^e - 24^o$	5/2	3/2	E1	1686.78	1722.99	3.12(+5)	3.09(+5)	2.93(+5)	3.02(+5)
$6^e - 26^o$	3/2	5/2	E1	1679.13	1722.00	4.05(+2)	3.49(+1)	3.76(+2)	3.40(+1)
$7^e - 32^o$	7/2	5/2	E1	1668.13	1717.61	2.21(+6)	1.51(+6)	2.03(+6)	1.47(+6)
$6^e - 27^o$	3/2	3/2	E1	1673.89	1715.21	8.44(+2)	6.03(+2)	7.85(+2)	5.89(+2)
$4^e - 22^o$	7/2	5/2	E1	1679.01	1713.37	6.50(+5)	5.14(+5)	6.12(+5)	5.04(+5)
$1^e - 17^o$	5/2	5/2	E1	1766.46	1709.60	4.91(+7)	8.55(+7)	6.75(+7)	9.51(+7)
$5^e - 26^o$	5/2	5/2	E1	1667.52	1705.89	8.80(+3)	3.91(+3)	8.22(+3)	3.83(+3)
$1^e - 18^o$	5/2	3/2	E1	1755.30	1703.40	1.61(+7)	2.67(+7)	2.19(+7)	2.96(+7)
$4^e - 23^o$	7/2	7/2	E1	1668.63	1700.65	2.06(+5)	1.55(+5)	1.95(+5)	1.52(+5)
$5^e - 27^o$	5/2	3/2	E1	1662.35	1699.24	2.16(+4)	2.67(+4)	2.02(+4)	2.61(+4)
$15^e - 44^o$	1/2	3/2	E1	1275.46	1695.24	3.49(+5)	1.80(+5)	1.48(+5)	1.36(+5)
$8^e - 37^o$	5/2	3/2	E1	1638.62	1686.19	1.36(+3)	1.99(+3)	1.25(+3)	1.94(+3)
$4^e - 26^o$	7/2	5/2	E1	1641.33	1683.33	3.56(+5)	3.13(+5)	3.30(+5)	3.05(+5)
$14^e - 44^o$	3/2	3/2	E1	1265.30	1680.36	1.75(+6)	7.98(+5)	7.49(+5)	6.01(+5)
$3^e - 23^o$	9/2	7/2	E1	1632.70	1674.00	3.16(+6)	2.48(+6)	2.93(+6)	2.42(+6)
$14^e - 45^o$	3/2	1/2	E1	1275.42	1671.94	5.01(+4)	7.73(+3)	2.22(+4)	5.90(+3)
$6^e - 28^o$	3/2	5/2	E1	1620.78	1667.46	2.54(+5)	2.31(+5)	2.33(+5)	2.25(+5)
$6^e - 29^o$	3/2	3/2	E1	1618.59	1665.48	4.21(+6)	3.46(+6)	3.87(+6)	3.36(+6)
$6^e - 30^o$	3/2	1/2	E1	1623.37	1664.31	2.11(+7)	1.65(+7)	1.95(+7)	1.61(+7)
$5^e - 28^o$	5/2	5/2	E1	1609.95	1652.35	2.99(+6)	2.59(+6)	2.77(+6)	2.53(+6)
$5^e - 29^o$	5/2	3/2	E1	1607.79	1650.41	1.49(+7)	1.20(+7)	1.38(+7)	1.17(+7)
$5^e - 31^o$	5/2	7/2	E1	1608.02	1648.47	1.73(+5)	1.45(+5)	1.60(+5)	1.42(+5)
$8^e - 40^o$	5/2	7/2	E1	1593.46	1641.44	9.18(+4)	6.71(+4)	8.40(+4)	6.51(+4)
$6^e - 32^o$	3/2	5/2	E1	1592.51	1636.48	2.08(+4)	1.22(+4)	1.92(+5)	1.19(+5)
$4^e - 28^o$	7/2	5/2	E1	1585.53	1631.18	1.22(+7)	9.24(+6)	1.12(+7)	8.98(+6)
$8^e - 41^o$	5/2	5/2	E1	1581.95	1628.49	8.61(+6)	6.53(+6)	5.16(+6)	5.50(+6)
$4^e - 31^o$	7/2	7/2	E1	1583.65	1627.39	2.10(+6)	1.57(+6)	1.93(+6)	1.53(+6)
$7^e - 38^o$	7/2	9/2	E1	1571.26	1623.40	1.23(+4)	3.81(+3)	1.12(+4)	3.69(+3)
$5^e - 32^o$	5/2	5/2	E1	1582.06	1621.92	4.44(+5)	3.57(+5)	4.03(+5)	3.48(+5)
$6^e - 33^o$	3/2	3/2	E1	1580.19	1620.44	2.88(+3)	1.36(+4)	2.67(+3)	1.33(+4)
$5^e - 33^o$	5/2	3/2	E1	1569.90	1606.17	9.79(+4)	7.21(+4)	9.14(+4)	7.04(+4)
$6^e - 34^o$	3/2	3/2	E1	1569.31	1604.58	1.59(+4)	1.93(+4)	1.49(+4)	1.89(+4)
$7^e - 40^o$	7/2	7/2	E1	1550.16	1603.40	8.26(+6)	5.94(+6)	7.46(+6)	5.75(+6)
$3^e - 31^o$	9/2	7/2	E1	1551.34	1602.97	1.32(+7)	1.00(+7)	1.20(+7)	9.72(+6)
$4^e - 32^o$	7/2	5/2	E1	1558.47	1601.52	1.95(+6)	1.44(+6)	1.79(+6)	1.40(+6)
$7^e - 41^o$	7/2	5/2	E1	1539.30	1591.05	5.76(+5)	3.66(+5)	5.21(+5)	3.54(+5)
$5^e - 34^o$	5/2	3/2	E1	1559.16	1590.58	3.44(+4)	4.16(+4)	3.24(+4)	4.08(+4)
$6^e - 35^o$	3/2	1/2	E1	1541.17	1581.29	4.02(+5)	4.37(+5)	2.72(+5)	4.26(+5)
$13^e - 44^o$	5/2	3/2	E1	1202.23	1573.67	3.08(+6)	1.98(+6)	1.37(+6)	1.51(+6)
$6^e - 36^o$	3/2	1/2	E1	1526.10	1571.85	2.53(+2)	3.08(+3)	2.32(+2)	2.99(+3)
$6^e - 37^o$	3/2	3/2	E1	1523.81	1571.41	5.30(+1)	1.19(+2)	4.83(+1)	1.15(+2)
$12^e - 44^o$	1/2	3/2	E1	1198.72	1568.72	2.96(+2)	1.51(+3)	1.32(+2)	1.15(+3)
$11^e - 44^o$	3/2	3/2	E1	1199.83	1567.55	1.09(+5)	8.53(+4)	4.89(+4)	6.53(+4)

TABLE III. Wavelengths and E1 Transition Probabilities for the $3d^9$–$3d^84p$ and $3d^84s$–$3d^84p$ Transition Arrays in Ni II

See page 161 for Explanation of Tables

Ni II Emission Lines				Wavelength (Å)		A (1/s)			
Trans.	J_F	J_I	Type	Calc.	Exp.	Length(T)	Velocity(T)	Length(E)	Velocity(E)
$12^e - 45^o$	1/2	1/2	E1	1207.80	1561.39	3.17(+3)	1.54(+3)	1.47(+3)	1.19(+3)
$11^e - 45^o$	3/2	1/2	E1	1208.92	1560.22	1.32(+6)	8.02(+5)	6.14(+5)	6.22(+5)
$5^e - 37^o$	5/2	3/2	E1	1514.24	1557.99	2.01(+3)	1.29(+3)	1.85(+3)	1.25(+3)
$10^e - 44^o$	3/2	3/2	E1	1180.06	1543.55	2.15(+5)	1.58(+5)	9.60(+4)	1.21(+5)
$8^e - 42^o$	5/2	7/2	E1	1494.71	1542.56	2.39(+5)	5.95(+5)	2.17(+5)	5.76(+5)
$2^e - 19^o$	3/2	5/2	E1	1540.42	1536.94	5.20(+6)	7.86(+6)	6.33(+6)	8.39(+6)
$2^e - 20^o$	3/2	3/2	E1	1538.18	1536.74	1.34(+7)	2.15(+7)	1.63(+7)	2.29(+7)
$10^e - 45^o$	3/2	1/2	E1	1188.86	1536.44	5.25(+6)	3.31(+6)	2.43(+6)	2.56(+6)
$9^e - 44^o$	5/2	3/2	E1	1169.55	1527.33	2.14(+6)	1.39(+6)	9.60(+5)	1.07(+6)
$2^e - 21^o$	3/2	1/2	E1	1524.59	1526.16	2.15(+4)	1.52(+4)	2.59(+4)	1.62(+4)
$6^e - 41^o$	3/2	5/2	E1	1474.69	1521.27	1.27(+5)	1.43(+5)	1.16(+5)	1.39(+5)
$5^e - 40^o$	5/2	7/2	E1	1475.59	1519.71	2.99(+4)	3.08(+4)	2.74(+4)	2.99(+4)
$4^e - 38^o$	7/2	9/2	E1	1473.59	1519.31	1.19(+3)	1.74(+3)	1.09(+3)	1.70(+3)
$2^e - 22^o$	3/2	5/2	E1	1515.62	1510.85	2.18(+7)	2.86(+7)	2.66(+7)	3.08(+7)
$7^e - 42^o$	7/2	7/2	E1	1456.54	1508.92	1.20(+5)	7.90(+4)	1.08(+5)	7.62(+4)
$5^e - 41^o$	5/2	5/2	E1	1465.72	1508.61	1.16(+4)	5.84(+3)	1.07(+4)	5.68(+3)
$7^e - 43^o$	7/2	9/2	E1	1454.30	1506.63	1.32(+4)	2.77(+4)	1.19(+4)	2.68(+4)
$1^e - 19^o$	5/2	5/2	E1	1505.61	1502.15	1.42(+7)	2.44(+7)	1.72(+7)	2.60(+7)
$1^e - 20^o$	5/2	3/2	E1	1503.47	1501.96	8.82(+5)	1.76(+6)	1.07(+6)	1.88(+6)
$4^e - 40^o$	7/2	7/2	E1	1455.03	1501.78	1.93(+5)	1.27(+5)	1.75(+5)	1.23(+5)
$2^e - 24^o$	3/2	3/2	E1	1500.10	1500.43	3.39(+7)	5.82(+7)	4.07(+7)	6.19(+7)
$3^e - 38^o$	9/2	9/2	E1	1445.58	1498.00	5.10(+1)	7.06(+1)	4.58(+1)	6.81(+1)
$2^e - 25^o$	3/2	1/2	E1	1495.17	1497.57	5.53(+4)	5.22(+4)	6.63(+4)	5.54(+4)
$4^e - 41^o$	7/2	5/2	E1	1445.44	1490.94	3.99(+4)	1.94(+4)	3.63(+4)	1.89(+4)
$2^e - 26^o$	3/2	5/2	E1	1484.85	1487.45	9.56(+5)	2.07(+6)	1.14(+6)	2.20(+6)
$3^e - 39^o$	9/2	11/2	E1	1437.49	1485.27	1.62(+4)	1.77(+4)	1.47(+4)	1.72(+4)
$2^e - 27^o$	3/2	3/2	E1	1480.74	1482.39	5.82(+5)	1.14(+6)	6.96(+5)	1.21(+6)
$3^e - 40^o$	9/2	7/2	E1	1427.71	1480.96	2.81(+4)	1.06(+4)	2.51(+4)	1.02(+4)
$1^e - 22^o$	5/2	5/2	E1	1481.90	1477.22	5.66(+6)	8.23(+6)	6.87(+6)	8.78(+6)
$1^e - 23^o$	5/2	7/2	E1	1473.75	1467.76	2.72(+7)	3.48(+7)	3.30(+7)	3.71(+7)
$1^e - 24^o$	5/2	3/2	E1	1467.06	1467.26	2.18(+7)	3.22(+7)	2.61(+7)	3.42(+7)
$1^e - 26^o$	5/2	5/2	E1	1452.47	1454.84	5.58(+7)	8.55(+7)	6.65(+7)	9.06(+7)
$1^e - 27^o$	5/2	3/2	E1	1448.55	1450.00	8.70(+6)	9.90(+6)	1.04(+7)	1.05(+7)
$2^e - 28^o$	3/2	5/2	E1	1439.03	1446.58	7.01(+6)	9.59(+6)	8.24(+6)	1.01(+7)
$2^e - 29^o$	3/2	3/2	E1	1437.31	1445.09	1.69(+6)	2.61(+6)	1.99(+6)	2.76(+6)
$2^e - 30^o$	3/2	1/2	E1	1423.19	1444.22	4.29(+6)	6.11(+6)	5.09(+6)	6.46(+6)
$5^e - 42^o$	5/2	7/2	E1	1390.53	1434.57	7.52(+1)	5.07(+1)	6.85(+1)	4.92(+1)
$2^e - 32^o$	3/2	5/2	E1	1416.71	1423.21	6.51(+6)	8.61(+6)	7.65(+6)	9.09(+6)
$4^e - 42^o$	7/2	7/2	E1	1372.23	1418.58	7.31(+3)	5.08(+3)	6.62(+3)	4.92(+3)
$4^e - 43^o$	7/2	9/2	E1	1370.24	1416.55	4.06(+0)	5.14(+2)	3.68(+0)	4.97(+2)
$1^e - 28^o$	5/2	5/2	E1	1408.60	1415.72	7.55(+6)	1.05(+7)	8.85(+6)	1.10(+7)
$1^e - 29^o$	5/2	3/2	E1	1406.95	1414.29	1.65(+6)	1.96(+6)	1.94(+6)	2.07(+6)
$1^e - 31^o$	5/2	7/2	E1	1407.12	1412.87	8.58(+6)	1.09(+7)	1.01(+7)	1.16(+7)
$2^e - 33^o$	3/2	3/2	E1	1404.05	1411.06	7.89(+7)	1.09(+8)	9.31(+7)	1.15(+8)
$3^e - 42^o$	9/2	7/2	E1	1347.91	1399.99	3.54(+2)	1.71(+2)	3.16(+2)	1.66(+2)
$2^e - 34^o$	3/2	3/2	E1	1398.31	1399.02	2.32(+7)	2.84(+7)	2.75(+7)	3.01(+7)
$3^e - 43^o$	9/2	9/2	E1	1345.99	1398.02	4.87(+3)	3.33(+3)	4.35(+3)	3.21(+3)
$1^e - 32^o$	5/2	5/2	E1	1387.20	1393.32	2.22(+7)	3.06(+7)	2.60(+7)	3.22(+7)
$1^e - 33^o$	5/2	3/2	E1	1377.84	1381.68	8.39(+6)	9.09(+6)	9.86(+6)	9.60(+6)

TABLE III. Wavelengths and E1 Transition Probabilities for the $3d^9$–$3d^8 4p$ and $3d^8 4s$–$3d^8 4p$ Transition Arrays in Ni II

See page 161 for Explanation of Tables

Ni II Emission Lines				Wavelength (Å)		A (1/s)			
Trans.	J_F	J_I	Type	Calc.	Exp.	Length(T)	Velocity(T)	Length(E)	Velocity(E)
$2^e - 35^o$	3/2	1/2	E1	1375.93	1381.29	3.12(+8)	3.74(+8)	3.66(+8)	3.95(+8)
$2^e - 36^o$	3/2	1/2	E1	1363.90	1374.07	5.78(+7)	6.74(+7)	6.69(+7)	7.07(+7)
$2^e - 37^o$	3/2	3/2	E1	1362.07	1373.74	2.54(+6)	3.26(+6)	2.93(+6)	3.42(+6)
$1^e - 34^o$	5/2	3/2	E1	1369.56	1370.13	3.00(+8)	3.59(+8)	3.55(+8)	3.80(+8)
$8^e - 44^o$	5/2	3/2	E1	1050.50	1358.95	3.24(+4)	2.16(+4)	1.50(+4)	1.67(+4)
$1^e - 37^o$	5/2	3/2	E1	1334.78	1345.88	1.21(+7)	1.34(+7)	1.39(+7)	1.40(+7)
$2^e - 41^o$	3/2	5/2	E1	1322.69	1335.20	1.65(+8)	2.04(+8)	1.88(+8)	2.13(+8)
$1^e - 40^o$	5/2	7/2	E1	1304.66	1317.22	1.71(+8)	2.08(+8)	1.95(+8)	2.17(+8)
$1^e - 41^o$	5/2	5/2	E1	1296.94	1308.87	8.51(+6)	1.07(+7)	9.72(+6)	1.12(+7)
$6^e - 44^o$	3/2	3/2	E1	1002.09	1283.40	7.61(+3)	7.11(+3)	3.62(+3)	5.55(+3)
$6^e - 45^o$	3/2	1/2	E1	1008.44	1278.48	1.05(+5)	9.20(+4)	5.15(+4)	7.26(+4)
$5^e - 44^o$	5/2	3/2	E1	997.949	1274.43	1.54(+4)	1.25(+4)	7.39(+3)	9.80(+3)
$1^e - 42^o$	5/2	7/2	E1	1237.71	1252.77	2.17(+5)	3.97(+5)	2.43(+5)	4.12(+5)
$2^e - 44^o$	3/2	3/2	E1	929.513	1148.43	1.07(+7)	9.28(+6)	6.36(+6)	7.80(+6)
$2^e - 45^o$	3/2	1/2	E1	934.967	1144.50	1.11(+8)	9.66(+7)	6.78(+7)	8.20(+7)
$1^e - 44^o$	5/2	3/2	E1	916.720	1128.90	8.57(+7)	7.15(+7)	5.13(+7)	6.02(+7)

TABLE IV. Comparison of Our *Ab initio* Results with Those of Previous Works

See page 161 for Explanation of Tables

	Wavelength	A (1/s) Present		A (1/s) Previous Works			
Transition	(Å) [15]	Length(E)	Velocity(E)	Ref. [1]	Ref. [3]	Exp. [4]	Theo. [4]
7^e – 1^o	2630.27	1.17(+6)	1.42(+6)		6.8(+5)		
14^e – 24^o	2557.87	1.70(+6)	1.84(+6)			3.4±0.6(+6)	1.29(+7)
14^e – 25^o	2551.04	1.48(+7)	1.53(+7)			1.3±0.09(+7)	1.11(+7)
8^e – 7^o	2545.90	1.30(+7)	1.16(+7)	2.6(+7)	1.56(+7)	5±1(+5)	8.0(+5)
15^e – 27^o	2539.10	1.44(+7)	1.50(+7)			1.48±0.25(+7)	2.04(+7)
7^e – 3^o	2510.87	6.20(+7)	5.39(+7)	9.4(+7)	5.8(+7)	6.09±0.58(+7)	6.48(+7)
8^e – 9^o	2497.80	7.24(+5)	6.85(+5)			6±2(+5)	7.0(+5)
8^e – 11^o	2473.14	5.25(+6)	5.04(+6)			1.3±0.09(+7)	1.11(+7)
7^e – 7^o	2455.52	2.65(+6)	2.85(+6)			1.2±0.3(+6)	1.0(+6)
7^e – 8^o	2437.89	6.11(+7)	5.05(+7)	8.7(+7)	5.4(+7)	7.48±0.92(+7)	6.27(+7)
8^e – 12^o	2433.56	5.22(+6)	5.45(+6)	1.3(+7)	7.3(+6)	9.7±1.7(+6)	8.4(+6)
15^e – 29^o	2431.57	4.69(+6)	4.30(+6)			1.1±0.2(+7)	9.8(+6)
8^e – 13^o	2416.13	2.59(+8)	2.24(+8)	3.3(+8)	2.1(+8)	2.65±0.18(+8)	2.645(+8)
8^e – 14^o	2413.04	8.08(+6)	9.08(+6)	1.3(+7)	8.3(+6)	1.11±0.22(+7)	1.21(+7)
5^e – 1^o	2412.27	3.06(+5)	3.65(+5)		2.4(+5)		
7^e – 9^o	2410.74	4.50(+5)	4.15(+5)	1.8(+6)	1.0(+6)	1.0±0.2(+6)	9.0(+5)
14^e – 28^o	2405.17	4.44(+7)	4.15(+7)			3.7±0.6(+7)	3.49(+7)
7^e – 10^o	2394.52	2.16(+8)	1.77(+8)	2.9(+8)	1.70(+8)	2.30±0.18(+8)	2.541(+8)
11^e – 20^o	2392.59	1.05(+7)	9.79(+6)			4.18±0.78(+7)	4.48(+7)
7^e – 11^o	2387.76	2.81(+7)	2.78(+7)	1.70(+7)	1.59(+7)	1.92±0.39(+7)	1.70(+7)
8^e – 15^o	2375.42	5.69(+7)	5.22(+7)		6.6(+7)		
4^e – 1^o	2367.39	7.36(+6)	9.57(+6)		7.4(+6)		
11^e – 21^o	2366.55	8.29(+7)	7.60(+7)			1.15±0.18(+8)	1.415(+8)
8^e – 16^o	2356.40	2.08(+7)	1.88(+7)	4.5(+7)	2.8(+7)	2.9±0.4(+7)	3.9(+7)
7^e – 12^o	2350.85	3.39(+5)	3.12(+5)			2.3±0.8(+6)	1.9(+6)
17^e – 38^o	2345.99	3.59(+8)	2.65(+8)		1.7(+8)	2.30±0.18(+8)	2.541(+8)
14^e – 32^o	2341.21	3.08(+8)	2.85(+8)			3.96±0.61(+8)	3.762(+8)
7^e – 13^o	2334.58	6.44(+7)	5.77(+7)	1.3(+8)	8.0(+7)	1.00±0.082(+8)	1.107(+8)
6^e – 5^o	2326.45	4.47(+7)	5.17(+7)		3.3(+7)		
13^e – 23^o	2319.76	6.48(+7)	5.33(+7)			7.2±1.2(+7)	8.14(+7)
16^e – 40^o	2316.04	3.59(+8)	4.25(+8)		2.88(+8)		
4^e – 2^o	2303.00	3.54(+8)	3.80(+8)		2.9(+8)		
8^e – 17^o	2298.27	3.48(+8)	3.50(+8)		2.8(+8)	3.93±1.20(+8)	3.840(+8)
6^e – 6^o	2298.20	3.74(+8)	4.08(+8)	4.5(+8)	3.0(+8)		
5^e – 5^o	2297.14	3.30(+8)	3.60(+8)		2.70(+8)		
7^e – 15^o	2296.55	2.84(+8)	2.73(+8)		1.98(+8)	2.64±0.81(+8)	3.036(+8)
8^e – 18^o	2287.09	3.61(+8)	3.97(+8)			4.97±1.6(+8)	4.060(+8)
17^e – 41^o	2278.77	3.93(+8)	4.43(+8)	4.5(+8)	2.8(+8)	4.82±0.85(+8)	3.945(+8)
10^e – 22^o	2277.30	3.39(+8)	2.87(+8)			3.91±0.64(+8)	3.660(+8)
14^e – 34^o	2276.45	1.41(+8)	1.39(+8)			1.61±0.37(+8)	2.035(+8)

TABLE IV. Comparison of Our *Ab initio* Results with Those of Previous Works

See page 161 for Explanation of Tables

	Wavelength	A (1/s) Present		A (1/s) Previous Works			
Transition	(Å) [15]	Length(E)	Velocity(E)	Ref. [1]	Ref. [3]	Exp. [4]	Theo. [4]
$4^e - 3^o$	2270.21	2.07(+8)	1.53(+8)	2.5(+8)	1.56(+8)	2.43±0.15(+8)	2.248(+8)
$5^e - 7^o$	2264.46	1.63(+8)	1.21(+8)	2.4(+8)	1.43(+8)	2.22±0.13(+8)	2.079(+8)
$6^e - 9^o$	2253.85	2.77(+8)	2.13(+8)	3.2(+8)	1.98(+8)	2.90±0.17(+8)	2.715(+8)
$10^e - 25^o$	2247.24	8.34(+7)	8.91(+7)			1.88±0.38(+8)	1.459(+8)
$5^e - 9^o$	2226.33	1.32(+8)	1.10(+8)	2.0(+8)	1.3(+8)	1.79±0.11(+8)	1.983(+8)
$4^e - 7^o$	2224.86	2.32(+8)	1.96(+8)	2.5(+8)	1.55(+8)	2.31±0.13(+8)	2.425(+8)
$7^e - 17^o$	2224.36	2.21(+7)	2.70(+7)		3.2(+7)		
$3^e - 3^o$	2222.96	1.25(+8)	1.08(+8)	1.6(+8)	9.8(+7)	1.47±0.10(+8)	1.618(+8)
$9^e - 23^o$	2220.40	3.32(+8)	2.76(+8)	3.7(+8)	2.3(+8)	4.02±0.79(+8)	3.829(+8)
$3^e - 4^o$	2216.48	4.35(+8)	3.38(+8)	5.5(+8)	3.4(+8)	5.6±1.0(+8)	4.977(+8)
$4^e - 8^o$	2210.38	5.78(+7)	4.94(+7)	6.4(+7)	3.9(+7)	5.86±0.35(+7)	8.58(+7)
$5^e - 11^o$	2206.72	2.25(+8)	1.90(+8)	2.5(+8)	1.66(+8)	2.43±0.15(+8)	2.321(+8)
$6^e - 12^o$	2201.41	1.35(+8)	1.20(+8)	2.1(+8)	1.3(+8)	1.93±0.14(+8)	2.057(+8)
$4^e - 9^o$	2188.05	5.47(+6)	4.05(+6)	9.0(+6)	5.7(+6)	1.00±0.13(+7)	9.1(+6)
$13^e - 31^o$	2185.52	3.42(+8)	2.85(+8)			5.7±1.4(+8)	3.989(+8)
$6^e - 14^o$	2184.61	3.68(+8)	3.38(+8)	4.7(+8)	2.90(+8)	4.54±0.26(+8)	4.458(+8)
$5^e - 12^o$	2175.15	2.67(+8)	2.57(+8)	2.8(+8)	1.77(+8)	2.76±0.18(+8)	2.702(+8)
$4^e - 10^o$	2174.67	1.72(+8)	1.30(+8)	2.4(+8)	1.43(+8)	2.06±0.16(+8)	1.826(+8)
$4^e - 11^o$	2169.10	1.68(+8)	1.58(+8)	2.3(+8)	1.58(+8)	2.22±0.13(+8)	2.384(+8)
$3^e - 8^o$	2165.55	3.07(+8)	2.83(+8)	3.8(+8)	2.4(+8)	3.69±0.21(+8)	3.538(+8)
$5^e - 13^o$	2161.22	1.05(+7)	7.33(+6)	3.2(+7)	2.0(+7)	2.70±0.31(+7)	1.89(+7)
$5^e - 14^o$	2158.74	5.20(+7)	4.50(+7)	5.7(+7)	3.5(+7)	5.00±0.46(+7)	1.89(+7)
$4^e - 12^o$	2138.58	2.74(+7)	2.23(+7)	2.8(+7)	1.77(+7)	3.36±0.22(+7)	2.82(+7)
$10^e - 28^o$	2134.30	2.39(+7)	2.14(+7)			5.5±1.3(+7)	4.04(+7)
$3^e - 10^o$	2131.28	8.27(+6)	9.57(+6)			7.6±1.2(+6)	6.2(+6)
$5^e - 15^o$	2128.58	2.78(+7)	2.35(+7)	4.0(+7)	2.48(+7)	2.69±0.63(+7)	3.29(+7)
$11^e - 32^o$	2127.79	4.17(+7)	3.50(+7)			4.6±1.1(+7)	3.37(+7)
$3^e - 11^o$	2125.91	3.79(+6)	2.82(+6)	7.3(+6)	5.0(+6)	9.2±1.4(+6)	8.0(+6)
$4^e - 13^o$	2125.12	1.48(+7)	1.19(+7)	1.0(+7)	6.4(+6)	1.01±0.19(+7)	8.6(+6)
$6^e - 17^o$	2090.10	5.25(+6)	4.31(+6)		7.0(+6)		
$6^e - 18^o$	2080.85	1.14(+7)	1.10(+7)		8.0(+6)		
$3^e - 15^o$	2053.30	4.41(+6)	3.80(+6)		2.5(+6)		
$4^e - 17^o$	2034.05	3.65(+6)	3.41(+6)		2.3(+6)		
$1^e - 15^o$	1751.92	4.83(+7)	6.44(+7)				