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THE UNIVERSITY OF
WESTERN ONTARIO
Department of Physics
Molecular Excitation Group

Identification Atlas of Molecular Spectra

2: The $N_2 C^3\Pi_u-B^3\Pi_g$ Second Positive System

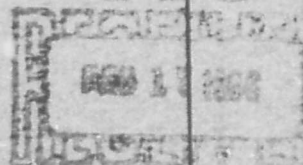
by
D. C. TYTE and R. W. NICHOLLS
October 31, 1964

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ABSTRACT

This report contains a set of vibrationally identified spectrograms of the Second Positive ($C^3\Pi_u - B^3\Pi_g$) system of N_2 . A compilation of all the available molecular data on the states involved, a brief description of the appearance, occurrence and history of the system and a selected bibliography are also included.

ACKNOWLEDGEMENTS

Research grants from The Ontario Research Foundation for the past few years have maintained the continuing "Identification Atlas of Molecular Spectra" project and made possible the production of this report.

The work has been assisted in part by research grants from The National Aeronautics and Space Administration (NsG349), The Air Force Office of Scientific Research (AF-AFOSR-62-236A) and the National Research Council of Canada and in part by contracts with The Air Force Cambridge Research Laboratories (AF 19(628)-2820) and The Defence Research Board of Canada (MM-69-300002).

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PREFACE

During the past decade, spectroscopic methods and techniques have been increasingly employed for a variety of research purposes in many branches of physics, chemistry, aeronomy and astronomy, and a need for a working knowledge of spectroscopic methods has been felt by many whose main field of research is not spectroscopy *per se*.

Positive identification of spectroscopic features is the first and most common requirement in any application of spectroscopy to research, whatever its orientation. Wavelength lists of many atomic lines and some molecular bands are of course available and well known. Wavelength coincidence alone, however, is not always sufficient for positive identifications and photographic atlases for direct comparison with experimental spectra are always extremely useful.

Such atlases are neither common nor comprehensive. The purpose of the present series of reports is thus to provide photographs (at two or three commonly used dispersions) of important band systems, to each set of which vibrational numbering and a wavelength scale have been added for direct comparisons with experimental spectra for which identifications are sought. The reciprocal dispersions most commonly used in the reports are: high (~ 150 A/mm), medium (~ 15 A/mm) and low (~ 5 A/mm). In addition to the identified photographs each report includes brief comments on the character of the spectrum, its common conditions of occurrence and excitation, some historical background of the relevant research, a bibliography of papers which have been found most valuable in the compilation of

the atlas, and a tabulation of essential molecular data. Emphasis is placed on vibrational rather than on rotational structure as it is with vibrational structure of band systems that the first problems of identification usually arise in practice.

The most valuable single aid to identification of molecular spectra is, of course, Pearse and Gaydon's indispensable work "The Identification of Molecular Spectra" (1941, 1950, 1963). The tables in this are arranged with the practical spectroscopist in mind, and the photographic reproductions of a number of common and important molecular spectra are particularly useful. The comparable work "Données Spectroscopiques" edited by Rosen (1951) presents the wavelengths of many band systems in Deslandres tables, essential molecular constants and a very complete bibliography (up to 1950). Two significant compilations of molecular spectra which are important in astronomical and aeronomical applications have recently been published by Wallace (1962a, b). He has the user very much in mind and gives very useful bibliographies.

Phillips and his colleagues at Berkeley (1963) are making distinguished contributions to the detailed compilation of rotational structure (to high quantum numbers) of band systems important in astronomy. Bass and Broida (1953, 1961) have produced valuable spectrophotometric atlases of OH and CH in which the rotational structure is clearly identified. Dieke and his colleagues (1959, 1962) have done a similar service to N_2 and OH band systems. Herman and Hornbeck (1951) published an article some years

ago in which vibrational identifications were made of many of the spectra commonly met in combustion spectroscopy.

The important "Molecular Spectra of Metallic Oxides" produced by Fr. Junkes and his colleagues at the Vatican Observatory is a most useful identification aid for metallic oxide spectra, especially those of astrophysical interest.

While the present series of reports is not as ambitious as some of the above works, it is hoped that it will fill a gap which many have felt existed in the reference literature of molecular spectroscopy.

R. W. NICHOLLS, *Editor*.

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N₂ C³Π_u-B³Π_g SECOND POSITIVE SYSTEM

1. INTRODUCTION

Nitrogen is one of the major constituents of the terrestrial atmosphere and an important constituent of the atmospheres of other planets. Its spectrum is easily excited and nitrogen bands make up an important part of the spectra of all luminescent atmospheric phenomena. Hence the N₂ spectrum has been extensively studied for many years. The most studied band system of nitrogen is the Second Positive (C³Π_u-B³Π_g) system.

The second positive system of Nitrogen extends throughout the wavelength region 2950-5000Å and is very easily excited, occurring particularly readily in discharges through pure nitrogen or air. It frequently appears as an impurity in discharge systems. All the bands of the system are blue degraded, having very definite heads, the wavelengths of which are listed in Table II. The most conspicuous features of the system are four well-defined sequences the most pronounced bands of which are:

Band	Wavelength	Approximate Relative Intensity
0, 2	3805Å	3
0, 1	3568	7
0, 0	3371	10
1, 0	3159	7

The transition giving rise to the system is C³Π_u-B³Π_g. Because of its triplet nature, under medium and high resolution all the bands ex-

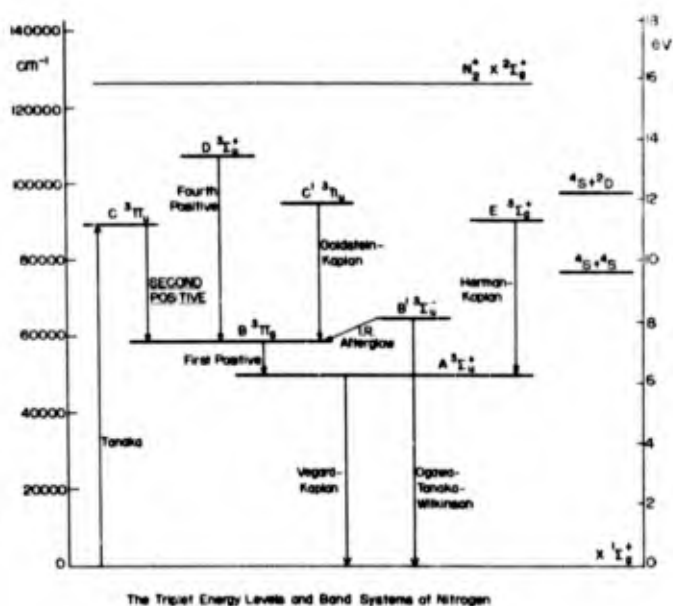


FIGURE 1

hibit three heads, one being stronger than the other two. Both these levels lie well above the X¹Σ ground state of nitrogen, and their positions relative to it and to the other triplet states of nitrogen are illustrated in the energy level diagram Figure 1.

2. SPECTRAL FEATURES

The appearance of the system depends on the conditions of excitation. In a discharge through nitrogen at pressures of a few mm of mercury the appearance is as illustrated in Plates I-IV. In an arc-type discharge (at ½ atmosphere or greater), the vibrational structure is considerably

suppressed while the rotational structure of the remaining bands is greatly enhanced. This effect is particularly marked in the $\Delta v = 0$ sequence (Feast 1950).

About 50 bands of the system are commonly observed, and they lie within a range of vibrational quantum numbers which is rather restricted compared with that of other major nitrogen systems. These limits ($v' \leq 4$; $v'' \leq 11$) occur because:

(a) The predissociation of the $C^3\Pi_u$ state above $v' = 4$ by the $^4S + ^2D$ dissociation limit precludes all bands with $v' > 4$ except under very special excitation conditions (Tanaka and Jursa 1961).

(b) The predissociation of the $B^3\Pi_g$ state at $v = 12$ by the $^4S + ^4S$ dissociation limit (which is observed in the N_2 First Positive System) implies that bands with $12 \leq v'' \leq 14$ are most unlikely to be excited (Kaplan 1931, van der Ziel 1934), further, bands with $v'' > 14$ have a very small band strength.

Recently some bands with $v' = 5$ have been reported in afterglow sources. Four bands with $v' = 5$ ($5, 2; 5, 3; 5, 4; 5, 5$) were first observed by Tanaka and Jursa (1961). Subsequently Stoebner, Delbourgo and Laffitte (1962) reported observing the $5, 7$ band. Tanaka and Jursa observed that the ΔG_{v+1} value for $v = 5$ indicated that the level was considerably perturbed and concluded that the state causing this perturbation is strongly inter-related with the $C^3\Pi_u$ state but that it is not the same as the one which causes the predissociation of the $v' = 3, 4$ levels.

The rotational structure is that typical of a $^3\Pi-^3\Pi$ transition (Herzberg 1950). The bands are blue degraded with the heads in the P branch. There are three heads to each band, one for each of the three P branches. The most obvious head is that of P_3 branch. The rotational analysis has established that the coupling approaches Hund's case (a) at low J values and case (b) for high J values. The intensity alternation characteristic of the rotational structure of homonuclear molecules can only be observed if the Λ type doubling is resolved (Herzberg 1950, p. 271).

Dieke and Heath (1959) report a very detailed high resolution study of the system and include an exhaustive discussion of the many small perturbations in the rotational terms of the $C^3\Pi_u$ state. These perturbations, which have been recognized by earlier authors and which manifest themselves either as a shift in the rotational

structure or as an intensity anomaly, occur in all the vibrational levels. Dieke and Heath conclude that present knowledge is insufficient to identify conclusively all the perturbing states. In addition to these rotational perturbations there is a strong vibrational perturbation arising from the interaction between the $C^3\Pi_u$ state and a $^3\Pi_u$ state which also causes the observed predissociation (Büttenbender and Herzberg 1934, Mulliken 1957).

Apart from the predissociation mentioned above there appear to be no perturbations in the $B^3\Pi_g$ levels.

3. OCCURRENCE

The nitrogen second positive system is very easily excited in almost any type of discharge through pure Nitrogen or through a gas containing a trace of nitrogen.

As its name implies, it occurs most strongly in the positive column of a discharge. A particularly good source of the system is a heavy current water-cooled discharge tube of the "Hunter-Pearse" type. It is difficult to observe the system completely free from the N_2^+ First negative system, which overlaps it in part, but by avoiding the emission from the negative glow regions of the discharge or by using microwave excitation this interference can be minimized.

The occurrence of the system in the many different types of afterglow spectra is of particular interest. The detailed interpretation of these observations is too complex and controversial to be discussed here, but a number of references to its occurrence under these conditions are given in section (f) of the references.

The second positive system is also an important contributor to the auroral spectrum (Chamberlain, J. W. 1961).

4. HISTORICAL SURVEY

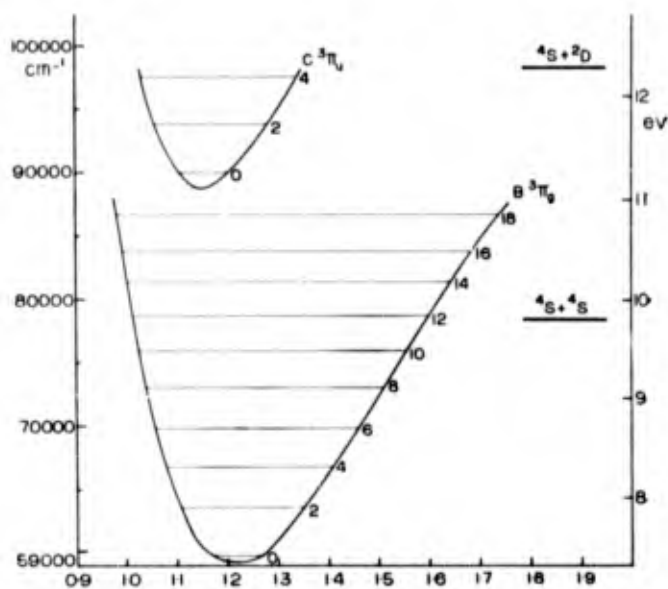
Since the second positive system is easily excited it has become one of the most studied of all band systems. It has been known since about 1870, and band head measurements were made by Hermesdorf (1903) and Lawton (1907). The vibrational numbering was not established until the 1920's when Mecke and Lindau (1924), Lindau (1924 a, b, c) and Hulthén and Johansson (1924) all measured band heads and proposed a vibrational scheme. Later Herzberg (1930) and Coster, Brons and van der Ziel (1933) measured

band heads due to the isotopic molecule N¹⁴N¹⁵ and from the isotope shift confirmed the earlier vibrational numbering. All these workers observed a sudden cut-off of the rotational lines in the $v' = 4$ bands and none observed bands with $v' > 4$. Herzberg (1931) attributed this to predissociation. Pankhurst (1940) gave a list of band heads, accurate to 0.1Å and Carroll and Sayers (1953) reported some new bands in the green. For many years it was accepted that there were no bands of the system with $v' > 4$, but in 1961 Tanaka and Jursa reported observing (in an auroral type afterglow at liquid nitrogen temperatures) four new weak red-degraded bands which they considered as originating from the $v' = 5$ level.

Following the establishment of the vibrational analysis, attention was turned to the rotational analysis of the system. In 1924 Hulthén and Johansson, and Lindau had measured rotational lines and established the basic rotational structure and combination differences, although at that time the general theory of the rotational structure of bands was not well understood. Coster, Brons and van der Ziel (1933) analysed some bands and established that the transition was a ³Π-³Π type. Guntzsch (1933) analysed 18 bands and obtained rotational and vibrational constants. Büttnerbender and Herzberg (1934) analysed the structure of several bands with $v' = 3,4$ in order to study the predissociation more fully whereas Coster, van Dijk and Lameris (1935) observed, under very high resolution, the structure of the (0,0) band to high J values. All the above workers observed and discussed perturbations in the upper (C³Π_u) state. More recently Janin (1946) has observed new branches in some bands, and Dieke and Heath (1959) have made a complete new high resolution study of the system analysing 9 bands, improving the molecular constants and discussing in great detail the observed perturbations.

The intensity distribution of the system varies markedly with discharge conditions. Some of the earliest work on the intensity distribution in the system was done by Smythe and Arnot (1930) while in 1933 Okubo and Hamada discussed the relative intensities of the first and second positive systems. More recently intensity measurements have been made by a number of workers including Tawde and Patankar (1944, 1947), Wallace and Nicholls (1955) and Tyte (1962a, b). Some

qualitative discussion of intensities is also included in a number of the afterglow references (section 6f).



Rydberg-Klein-Rees Potential Curves for the C³Π and B³Π States of Nitrogen

FIGURE 2

Lifetime measurements have been made on the $v' = 0$ level of the upper state by Bennett and Dalby (1959) they find $\tau_{v=0}(N_2 C^3\Pi_u) = 4.45 \times 10^{-8}$ sec.

The presence of the system in the spectrum of the aurora has long been recognized (Sommer 1929) and recently Omholt (1954) measured its auroral intensity.

5. MOLECULAR STRUCTURE

The molecular structure of nitrogen has been studied very fully. Some 48 systems have been observed involving 32 singlet states and 7 triplet states. Three of the observed systems have not as yet been definitely assigned and there is still some uncertainty about the electronic assignment of 8 of the singlet states. A very complete discussion of the observed states and systems of nitrogen is given by Lofthus (1960).

The potential energy curves have been calculated for the B³Π_g and C³Π_u levels using a modified Rydberg-Klein-Rees method (Vanderslice, Mason, and Lippincott 1959, Jarman 1960). These are shown in Figure 2.

As already mentioned, Figure 1 shows the triplet energy levels and demonstrates the relationship of the second positive system to the

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TABLE II
 Wavelengths (Å) (in air) and Wavenumbers (cm⁻¹) (in vacuo) of the Observed Bandheads

<i>r'</i> \ <i>r''</i>	0	1	2	3	4	5	6	7	8	9	10	11
0	3371.4*	3576.9*	3804.9*	4059.4*	4343.6*	4667.3	5031.5	5452.0				
	29652.8	28049.2	26274.5	24627.3	23015.9	21419.7	19869.3	18336.8				
1	3159.3*	3338.9	3536.7*	3755.5*	3998.4*	4269.7	4574.3	4916.8*	5309.3			
	31643.5	29941.4	28266.9	26620.1	25003.0	23414.3	21855.2	20332.8	18829.7			
2	2976.8*	3136.0	3309	3500.5*	3710.6*	3943.0*	4200.5	4490.2	4814.7	5179.3		
	35583.3	31878.5	30211.9	28559.2	26942.2	25354.2	23800.0	22264.5	20763.9	19302.3		
3	2819.8	2962.0*	3116.7	3285.3*	3469	3671.9*	3894.6	4141.8*	4416.7	4723.5	5066.0	
	35453.1	33751.1	32075.9	30429.9	28818.5	27226.1	25669.3	24137.3	22635.0	21164.8	19734.0	
4	2687	2814.3	2953.2*	3104.0	3268.1*	3446	3641.7*	3857.9	4094.8*	4355.0	4649.4	4976.4
	37205.2	35522.4	33851.7	32207.2	30590.0	29010.9	27451.9	25913.5	24414.4	22955.7	21502.2	20089.3
5			2804.6	2940.3	3087.8	3246.5		3616				
			35645	34000	32376	30794		27655				

The bandheads listed here are the principal (*P*₂) bandheads as recorded by Dieke and Heath (1959) except those with *r'* = 5, which are from Tanaka and Jursa (1961) and Stoebner, Delbourgo, and Laffitte (1962).

*Signifies that the rotational structure of the band has been analysed.

TABLE III
 Observed Vibrational Energy Levels and Intervals, and Rotational Constants C³Π_u State

<i>v</i>	<i>G_v</i> (cm ⁻¹)	Δ <i>G_{v+1}</i> (cm ⁻¹)	<i>B_v</i> (cm ⁻¹)	<i>D_v</i> (cm ⁻¹)
0	88978.7	1994.34	1.8149	0.67 × 10 ⁻⁶
1	90973.1	1940.72	1.7933	0.68
2	92913.9	1873.95	1.7694	0.73
3	94787.9	1781.21	1.7404	0.85
4	96569.1	1790	1.6999	1.25
5	98365			

Data from Dieke and Heath (1959), Lofthus (1960), and Tanaka and Jursa (1961).

other triplet systems of Nitrogen and a very good, more complete energy level diagram is given in Pearse and Gaydon (1963).

Mulliken (1957) has treated the problem of the energy levels of nitrogen theoretically and using a molecular orbital approach has predicted all the possible states of the N_2 molecule and indicates whether they should be attractive or repulsive.

6. MOLECULAR DATA

The fundamental constants of the $B^3\Pi_g$ and $C^3\Pi_u$ states of N_2 are displayed in Table I. The wavelengths (in air) and the wavenumbers (in *vacuo*) of the observed P_3 heads are shown in

TABLE I
Constants of the $B^3\Pi_g$ and $C^3\Pi_u$ States of N_2

$\mu_A = 7.00377$	
$B^3\Pi_g$	$C^3\Pi_u$
$T_e = 59626.3 \text{ cm}^{-1}$	$T_e = 89147.3 \text{ cm}^{-1}$
$\omega_e = 1735.42 \text{ cm}^{-1}$	$\omega_e = 2047.09 \text{ cm}^{-1}$
$\omega_e x_e = 15.198 \text{ cm}^{-1}$	$\omega_e x_e = 28.446 \text{ cm}^{-1}$
$\omega_e y_e = 0.178 \text{ cm}^{-1}$	$\omega_e y_e = 2.085 \text{ cm}^{-1}$
$\omega_e z_e = 0.0158 \text{ cm}^{-1}$	$\omega_e z_e = 0.535 \text{ cm}^{-1}$
$B_e = 1.63748 \text{ cm}^{-1}$	$B_e = 1.8247 \text{ cm}^{-1}$
$\alpha_e = 0.01794 \text{ cm}^{-1}$	$\alpha_e = 0.01868 \text{ cm}^{-1}$
$r_e = 1.2125 \text{ \AA}$	$r_e = 1.1487 \text{ \AA}$
$A_e = 42.3 \text{ cm}^{-1}$	$A_e = 39.2 \text{ cm}^{-1}$

(1) Nomenclature as used by Herzberg (1950).

(2) These constants are taken from Budó, (1935), Dieke and Heath (1959), Herzberg (1950) and Lofthus (1960).

(3) The $B^3\Pi_g$ state is predissociated by a $5^2\Sigma^+$ state from $^1S + ^1S$ at 78719 cm^{-1} (9.756 eV) ($v = 12$).

The $C^3\Pi_u$ state is predissociated by a $3\Pi_u$ state from $^1S + ^2D$ at 97942 cm^{-1} (12.139 eV) ($v = 4$).

The dissociation energy of nitrogen has long been a subject of disagreement. It is generally accepted that there are two possible values 59488 cm^{-1} (7.373 eV) or 78719 cm^{-1} (9.756 eV) and the higher value is regarded as the more probable one. Thus $D_0^0 = 78719 \pm 40 \text{ cm}^{-1} = 9.756 \text{ eV}$. (For a full discussion of this problem see Gaydon (1953).)

(4) The ionization potential, based on spectroscopic data, is 15.580 eV.

Table II. The positions of the band origins are best represented by the formula

$$\begin{aligned} \nu = & 29521.0 + 2047.09 (v' + \frac{1}{2}) - 28.446 \\ & \times (v' + \frac{1}{2})^2 + 2.085 (v' + \frac{1}{2})^3 - 0.535 (v' + \frac{1}{2})^4 \\ & - 1735.42 (v'' + \frac{1}{2}) + 15.198 (v'' + \frac{1}{2})^2 \\ & - 0.178 (v'' + \frac{1}{2})^3 + 0.0158 (v'' + \frac{1}{2})^4 \end{aligned}$$

while the band heads are best represented by

$$\begin{aligned} \nu = & 29653.1 + 2044.7 (v' + \frac{1}{2}) \\ & - 26.047 (v' + \frac{1}{2})^2 - 1732.84 (v'' + \frac{1}{2}) \\ & + 14.437 (v'' + \frac{1}{2})^2 \end{aligned}$$

The observed positions of the vibrational

energy levels (G_r), the separation between the levels (ΔG_{r+1}) and the rotational constants (B_r , D_r) for the two states are shown in Tables III and IV. Arrays of Franck-Condon factors and r -centroids appropriate to the Klein-Dunham and Morse potentials respectively are displayed in Tables V and VI. Table VII lists the Einstein A coefficients, oscillator strengths and band strengths for the system, while Table VIII compares the relative intensities of the main bands of the system as reported by various workers. The numerical values of the potential function plotted in fig. 2 are listed in Table IX.

7. BIBLIOGRAPHY

While not claiming to be exhaustive, it is hoped that most of the relevant papers are included in this list.

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TABLE IV
Observed Vibrational Energy Levels and Intervals, and
Rotational Constants $B^2\Pi_v$ State

v	$G_v(\text{cm}^{-1})$	$\Delta G_{v+1}(\text{cm}^{-1})$	$B_v(\text{cm}^{-1})$	$D_v(\text{cm}^{-1})$
0	59307.8	1705.55	1.62849	0.64×10^{-5}
1	61013.3	1676.32	1.61047	0.65
2	62689.7	1647.36	1.59218	0.67
3	64337.1	1618.34	1.57365	0.68
4	67955.4	1589.25	1.55509	0.69
5	67544.7	1560.26	1.53676	0.70
6	69105.0	1530.95	1.51787	0.72
7	70636.0	1501.72	1.49896	0.73
8	72137.7	1472.40	1.47940	0.75
9	73610.0	1442.69	1.46016	
10	75052.7	1412.91	1.44124	
11	76465.7	1383.08	1.42132	
12	77848.7		1.40150	

Data from Dieke and Heath (1959) and Lofthus (1960).

TABLE V
Franck-Condon Factors Appropriate to Klein-Dunham Potentials

$v' \setminus v''$	0	1	2	3	4	5	6	7	8	9	10	11	12
0	4.55-1	3.31-1	1.45-1	4.94-2	1.45-2	3.87-3	9.68-4	2.31-4	5.36-5	1.21-5	2.61-6	5.23-7	9.10-8
1	3.88-1	2.29-2	2.12-1	2.02-1	1.09-1	4.43-2	1.52-2	4.68-3	1.33-3	3.57-4	9.15-5	2.25-5	5.22-6
2	1.34-1	3.35-1	2.30-2	6.91-2	1.69-1	1.41-1	7.72-2	3.32-2	1.23-2	4.12-3	1.27-3	3.69-4	1.03-4
3	2.16-2	2.52-1	2.04-1	8.81-2	6.56-3	1.02-1	1.37-1	9.93-2	5.26-2	2.31-2	8.95-3	3.16-3	1.03-3
4	1.16-3	5.66-2	3.26-1	1.13-1	1.16-1	2.45-3	4.70-2	1.09-1	1.04-1	6.67-2	3.40-2	1.50-2	5.97-3

Data from Zare, Larson, Berg (1964). (The authors are grateful to Dr. Zare for a pre-publication copy of this paper.)
In each entry, the sign and last digit denotes the power of ten by which the preceding number should be multiplied.

TABLE VI
 r -Centroids (A) Appropriate to Morse Potentials

$v' \setminus v''$	0	1	2	3	4	5	6	7	8	9
0	1.182	1.148	1.116	1.086	1.058	1.032				
1	1.228	1.189	1.154	1.122	1.092	1.056	1.039	1.104		
2	1.280	1.234	1.195	1.160	1.129	1.099	1.072	1.046	1.021	
3	1.344	1.287	1.241	1.202	1.166	1.135	1.106	1.079	1.064	1.029
4	1.426	1.351	1.294	1.247	1.208	1.173	1.141	1.113	1.086	1.069

Data from Wallace and Nicholls (1955)

TABLE VII
Einstein A Coefficients ($A_{v'v''}$), Oscillator Strengths ($f_{v'v''}$) and Band Strengths ($S_{v'v''}$)

$v' \setminus v''$	0	1	2	3	4	5	6	7	8	9
0	1.11+7*	7.27+6	2.83+6	9.33+5	2.54+5	5.11+4				
	1.90-2†	1.40-2	6.15-3	2.31-3	7.18-4	1.67-4				
	1.1+0‡	9.65-1	4.52-1	1.82-1	0.03-2	1.5-2				
1	1.02+7	5.59+5	4.70+6	3.93+6	1.95+6	6.68+5	2.17+5	8.75+4		
	1.53-2	9.34-4	8.82-3	8.31-3	4.68-3	1.83-3	6.82-4	3.17-4		
	9.35-1	6.03-2	6.03-1	6.03-1	3.62-1	1.55-1	6.03-2	3.02-2		
2	3.55+6	8.43+6	8.61+5	1.45+6	3.26+6	2.54+6	1.26+6	4.69+5	1.86+5	
	4.72-3	1.24-2	1.41-3	2.67-3	6.73-3	5.93-3	3.35-3	1.39-3	6.48-4	
	2.72-1	7.53-1	9.05-2	1.82-1	4.82-1	4.52-1	2.72-1	1.21-1	6.03-2	
3	4.64+5	6.40+3	4.47+6	2.93+6		1.89+6	2.64+6	1.61+6	7.24+5	2.96+5
	5.53-4	8.43-3	6.51-3	4.75-3		3.82-3	6.01-3	4.14-3	2.12-3	9.91-4
	3.02-2	4.82-1	3.92-2	3.02-1		2.72-1	4.52-1	3.32-1	1.82-1	9.05-2
4		1.40+6	7.27+6	1.39+6	3.87+6	5.08+5	6.46+5	1.81+6	1.82+6	1.0+7
		1.66-3	9.51-3	2.01-3	6.21-3	9.05-4	1.29-3	4.04-3	4.57-3	2.87-2
		9.03-2	5.43-1	1.21-1	3.92-1	6.03-2	9.05-2	3.02-1	3.62-1	2.42-1

* $A_{v'v''}(\text{sec}^{-1})$

† $f_{v'v''}$

‡ $S_{v'v''}$

Data from Nicholls (1963, 1964).

TABLE VIII
Relative Intensities as Measured by Various Workers

Band	Symthe and Arnot (1930)	Omholt (1954)	Wallace and Nicholls (1955, 1962)	Steers (1957)	Tyte (1962)
0,0	100	100	100	100	100 *
0,1	61	66	59	63	67
0,2	67	20	22	24	22
0,3	44	4.8	5.2	7.5	7.0
0,4	—	—	—	1.8	1.8
1,0	75	97	69	—	67
1,1	15	2.4	2.8	2.4	3.7
1,2	30	30	30	30	30 *
1,3	60	21	22	23	25
1,4	50	8.3	10	10	12
1,6	—	—	1.2	1.5	0.9
2,0	15	—	—	—	12
2,1	18	46	41	—	29
2,2	7.5	1.4	3.3	3.4	1.9
2,3	5	5	5	5	5 *
2,4	12.5	8.5	13.2	11.8	8.6
2,5	11	6.3	8.1	8.7	6.3
2,6	—	—	4.8	5.8	3.8
2,7	5	—	1.5	2.2	1.1
3,1	17	—	—	—	23
3,2	14	—	17	—	18
3,3	8.4	—	8.7	7.6	7.5
3,5	5	—	5	5	5 *
3,7	—	—	3.8	4.3	3.9
3,8	—	—	1.6	2.2	1.5
4,2	4.5	—	—	—	19.6
4,3	2.6	—	—	—	6.1
4,4	2.3	—	6.9	6.0	6.0
4,6	1.5	—	1.5	1.5	1.5 *
4,7	—	—	3.5	3.4	—
4,8	—	—	2.8	2.9	2.4
4,9	—	—	—	2.2	0.8

*Set equal for comparison.

TABLE IX
Tabulation of Rydberg-Klein-Rees Potential Energy Functions

$C^2\Pi_u$	v	$V(\text{cm}^{-1})$	$V(\text{eV})$	$r_{\text{max}}(\text{Å})$	$r_{\text{min}}(\text{Å})$
0		1013	0.1256	1.202	1.104
1		3006	0.3727	1.246	1.074
2		4946	0.6133	1.279	1.056
3		6820	0.8457	1.310	1.042
4		8602	1.067	1.342	1.033
$B^2\Pi_g$	v	$V(\text{cm}^{-1})$	$V(\text{eV})$	$r_{\text{max}}(\text{Å})$	$r_{\text{min}}(\text{Å})$
0		863.4	0.1071	1.271	1.165
1		2569	0.3186	1.316	1.132
2		4246	0.5265	1.351	1.111
3		5894	0.7309	1.381	1.095
4		7512	0.9315	1.409	1.082
5		9010	1.129	1.436	1.071
6		10661	1.322	1.460	1.061
7		12191	1.512	1.484	1.052
8		13693	1.698	1.508	1.044
9		15165	1.880	1.531	1.037
10		16608	2.059	1.554	1.030
11		18021	2.235	1.577	1.024
12		19404	2.406	1.599	1.018

The potential energy, V , is given relative to the bottom of the potential curve.

Data from Vanderslice, Mason, and Lippincott (1959).

8. SPECTRA

Description of the Plates

Plate I shows the appearance of the system under small dispersion. The spectrogram was taken on a Hilger f/4 small quartz prism spectrograph with a dispersion of approximately 30 Å/mm at 2950Å and 100 Å/mm at 4500Å. The source was a Geisler tube containing low pressure nitrogen. Band sequences and a wavelength scale are indicated.

Plate II shows the appearance of the system under moderate dispersion. The spectrogram was taken on a Hilger medium quartz prism spectrograph with a dispersion of 15 Å/mm at 2950Å and 35 Å/mm at 4500Å. The source was the same as for Plate I. The vibrational quantum numbers of the bands and a wavelength scale are indicated.

Plates III and IV show the appearance of the system under moderately high dispersion. The spectrograms were taken in the first order of a 3m concave grating in a Wadsworth mounting with a dispersion of approximately 5 Å/mm. The source used was a microwave discharge through nitrogen at approx. 5 mm Hg pressure.

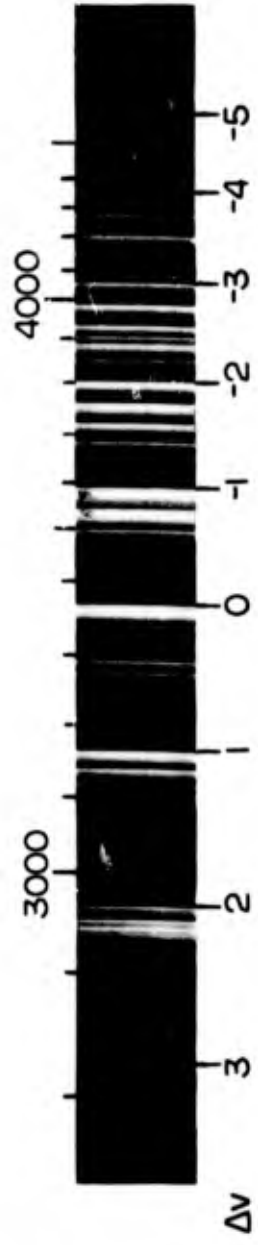


Plate I

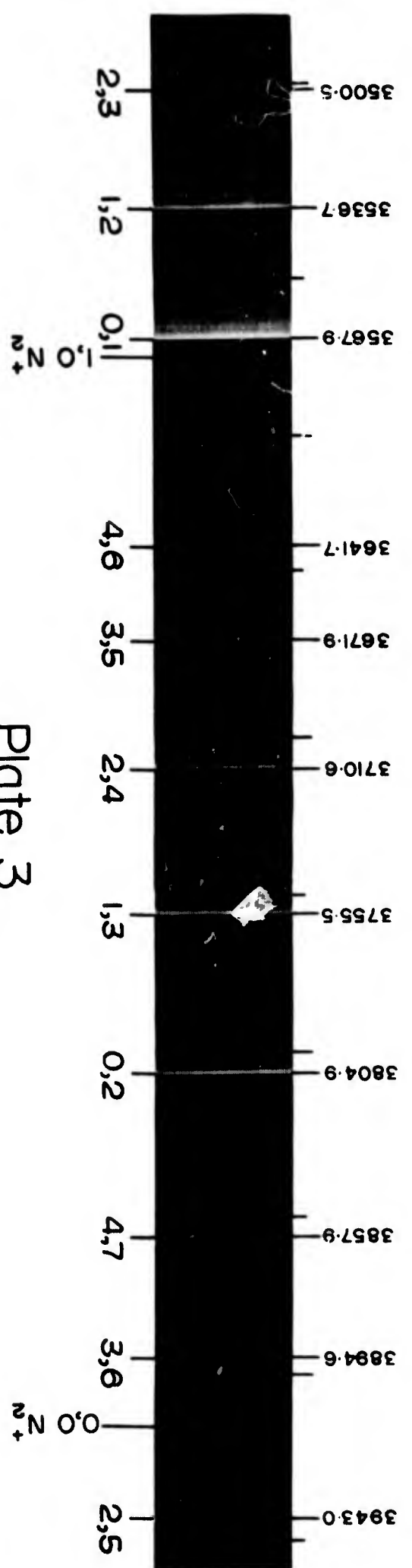
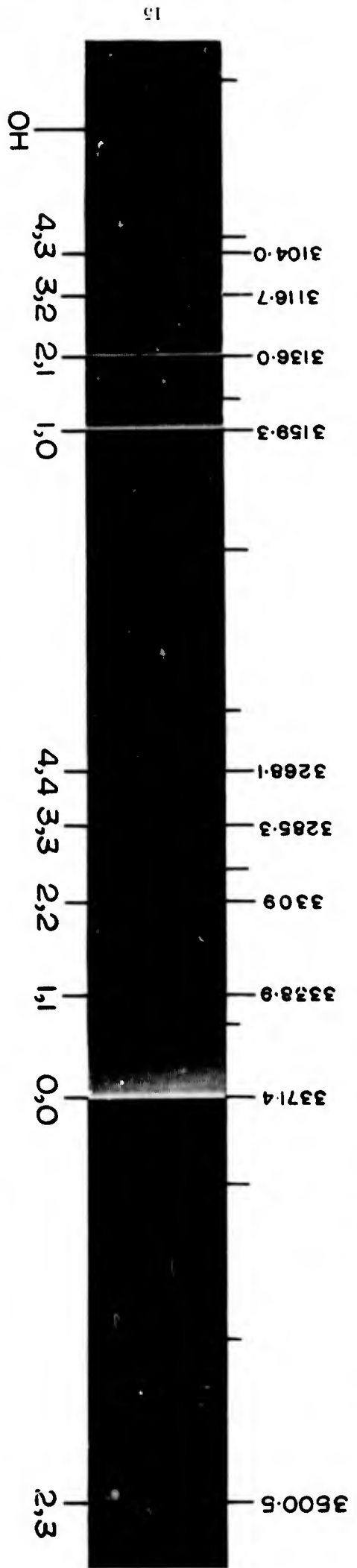
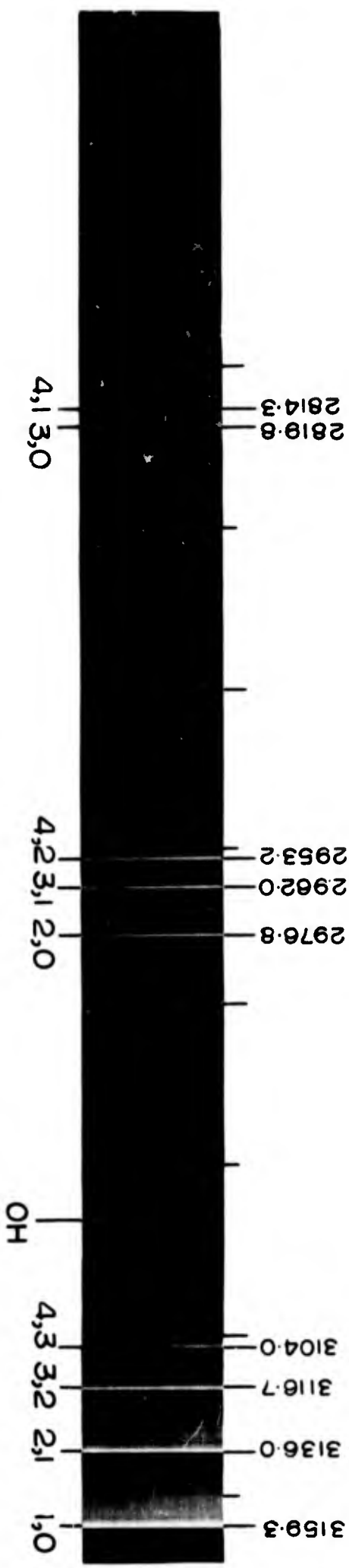


Plate 3

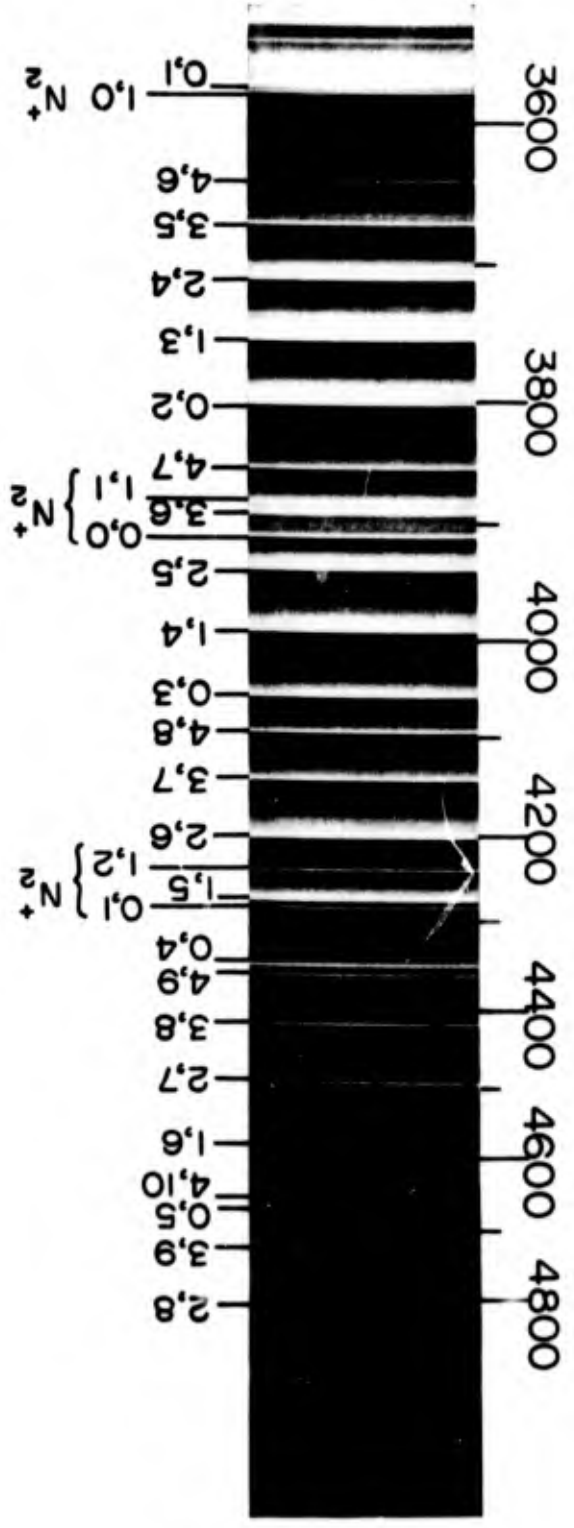
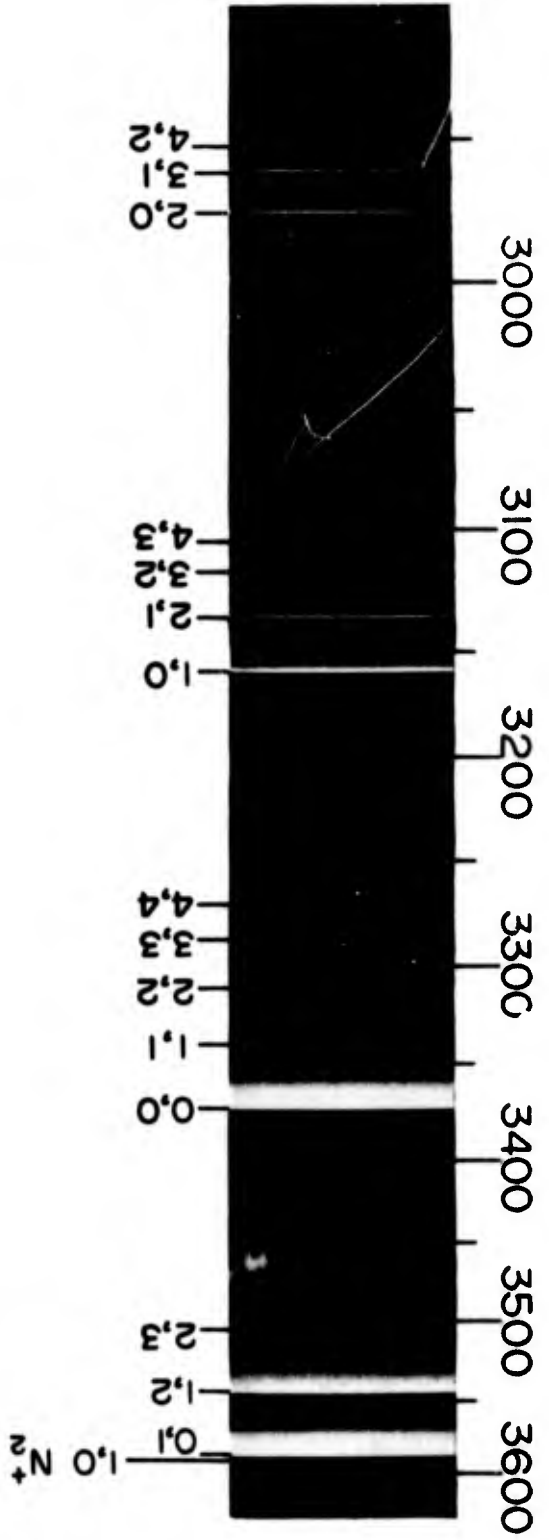


Plate 2

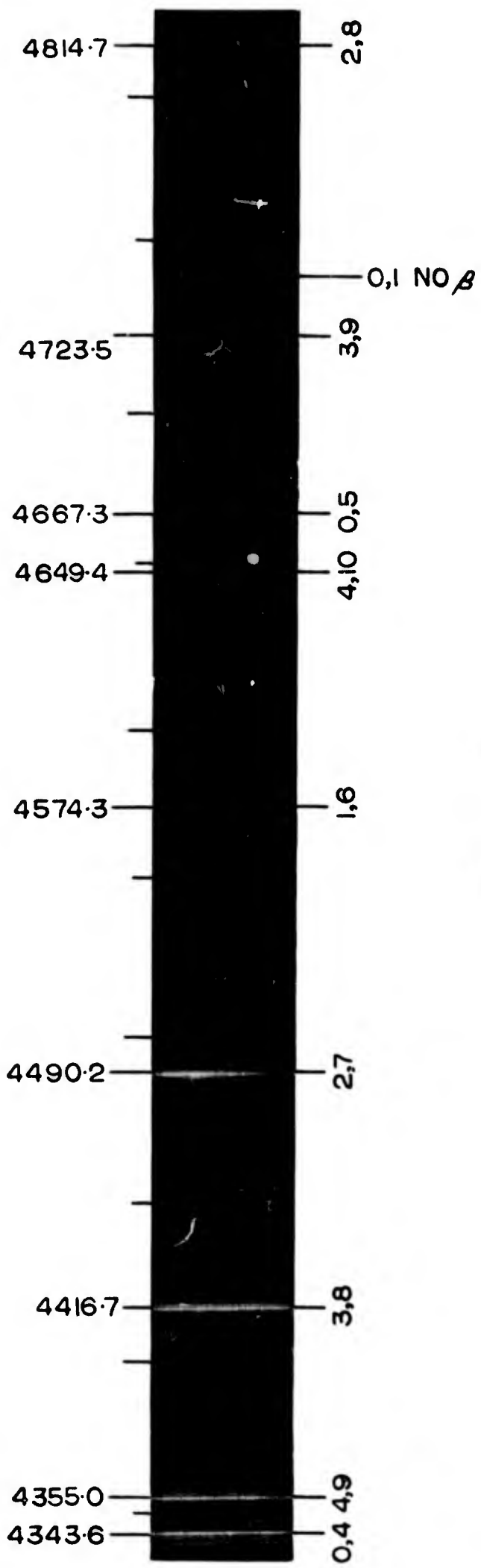
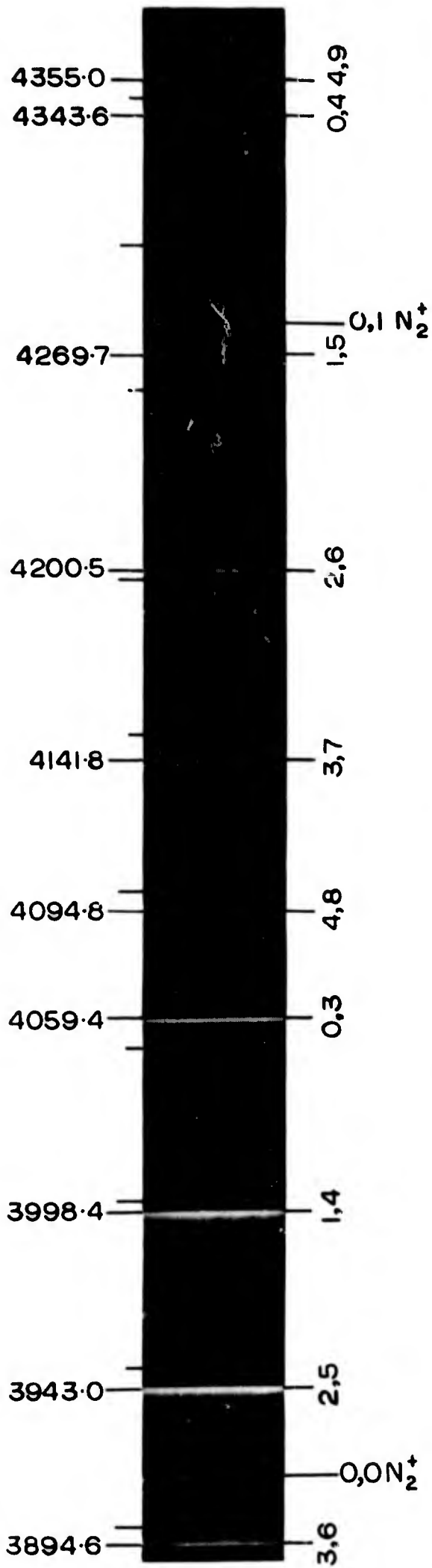


Plate 4