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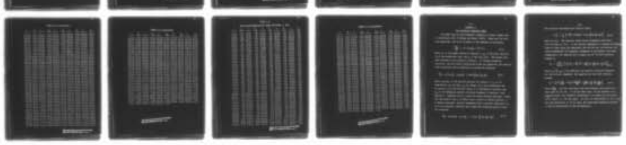

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CALCULATIONS PERTAINING TO THE ENERGY BALANCE AND PLASMA MOTIONS IN THE IONOSPHERE

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Under the present contract, a research effort was undertaken to develop theoretical and computational techniques pertaining to the energy balance and plasma motions in the ionosphere. Emphasis has been placed on the utilization of available satellite data as input to the calculations and as a test of the validity of the theoretical methods.

The effect of ambipolar diffusion on the O^{+} concentration profile has been investigated. Calculations show that diffusive transport produces qualitative agreement between observed and calculated profiles. Additional

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) applications are required to produce definitive results.

Procedures for the calculation of the rate of energy deposition by solar EUV flux and of the rate of photoionization of the principal atmospheric constituents have been revised. The associated computer codes have been modified or rewritten. The atomic and molecular cross sections utilized by these codes have been updated. The total photoionization cross section of atomic oxygen was revised significantly. Branching ratios for the photoionization of N_2 and O_2 are substantially different from those used previously.

Future work undertaken under contract F19628-78-C-0047 will incorporate electric fields into the transport equations. The study of the spectrum of secondary electrons produced by energetic precipitating particles will be continued under the new contract.

SECTION I

INTRODUCTION AND SUMMARY

Knowledge of the energy balance and plasma motions in the ionosphere is essential for the accurate prediction of atmospheric effects on radio communications under both normal and disturbed conditions. The major source of energy in the upper atmosphere is the extreme ultraviolet (EUV) solar flux. In addition, the EUV flux is the major source of ionization in the daytime at midlatitudes. At high latitudes, precipitating energetic particles contribute substantially to and at times dominate the energy budget and rate of ionization of the topside ionosphere. Charged particle motions, due primarily to diffusion, electric fields, and neutral winds, play a major role in determining local ion concentrations as well as the rate of energy transport.

A major part of the effort under the present contract was devoted to developing procedures and computer codes for the calculation of the diffusive transport of atomic oxygen ions. The pertinent equations are given in Appendix B, and the results are discussed in Section II. In general the calculations show that diffusive transport produces qualitative agreement between the observed and calculated profiles of atomic oxygen ions.

Procedures for the calculation of the rate of energy deposition by solar EUV flux and of the rate of photoionization of the principal atmospheric constituents have been revised, and the associated computer codes have been modified or rewritten. The necessary atomic and molecular data have been updated and are given in detail in Appendix A.

SECTION II
DIFFUSIVE TRANSPORT OF ATOMIC OXYGEN IONS

A part of the current study pertains to the study of plasma motions in the ionosphere. The agents of ionospheric transport are ambipolar diffusion, electric fields, neutral winds, and to some extent temperature gradients of the ionized components.

For the principal molecular ions, O_2^+, N_2^+. and NO^+, transport processes are unimportant in the daytime. The short chemical reaction times of these ions cause them to be in photochemical equilibrium at all altitudes. This has been demonstrated in a theoretical study by Schunk and Walker (1973), and by a comparison of calculated and observed molecular ion profiles by Oppenheimer et al. (1977). A typical comparison is shown in Figure 1. The principal molecular ions are also insensitive to transport processes in the nighttime ionosphere above about 200 kilometers (cf. Schunk and Walker, 1973). Below this altitude, the time scales associated with transport due to neutral winds and electric fields are comparable to photochemical times, and photochemical equilibrium no longer prevails.

In contrast to the molecular ions, O^+ ceases to be in photochemical equilibrium at altitudes above the F_2 peak (~250 km) even in daytime. The departure from photochemical equilibrium is clearly demonstrated by Figure 2. This departure is thought to be primarily due to the effects of ambipolar diffusion. Accordingly an effort was undertaken to study these effects in situations where both the neutral and ionized ionospheric constituents are known.

The formulation of the equations for diffusive transport is outlined in Appendix B. Since the electric field is not among the observed quantities, the current formulation eliminates it from the transport equations. In future work, a modified version will study the effects of sample electric fields compatible with those observed by AFGL satellite measurements.

Since the diffusion equation is of second order, two boundary conditions are required for a solution. One of the boundary conditions is chosen to be the O^+ concentration of the lower boundary (200 km in the present calculations). For the second boundary condition two different choices were made. One was to fix the O^+ concentration at some upper boundary (chosen as 470 km in the present calculations), or to fix the O^+ flux at some upper boundary (chosen as 600 km in the present calculations). Figure 3 displays the results of two calculations with fixed concentrations at the upper boundary. Figure 4 displays the results of three calculations with fixed flux at the upper boundary. In both figures the observed O^+ concentration has been plotted as well (in this instance data from orbit 594 of the AE-C satellite were used). For either type of upper boundary condition the altitude profiles are in marked contrast to the profile calculated under the assumption of local photochemical equilibrium. The latter calculation results in a profile which increases exponentially above the F_2 peak. Calculations including diffusion, on the other hand, result in profiles that qualitatively reproduce the observed decline of the concentration above the F_2 peak. The results obtained with fixed upper boundary concentration (Figure 3) are generally less satisfactory in the sense that a reasonable O^+ value at the top of the atmosphere forces very large values at the F_2 peak. The calculations with fixed-flux upper boundary condition are in better qualitative agreement with the observed profile (for the case where the flux is set to zero).

Ideally, a truly vertical O^+ concentration profile is needed for comparison with the calculations. In the absence of such data, however, the closest available approximation to a vertical profile is data from a highly elliptic satellite orbit. Even for such orbits, however, the satellite observations reflect horizontal variations, where such variations exist. The search for orbits which are known to be free from horizontal variations, and which, at the same time, contain all the necessary data has so far been unsuccessful. Diffusive transport calculations for other orbits will, however, serve as a criterion of whether the adopted procedures are valid.

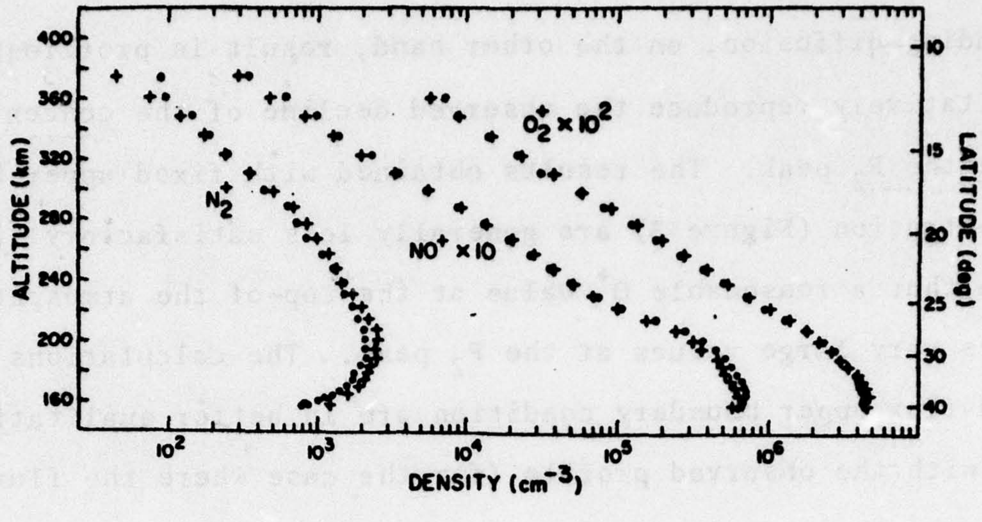

Fig. 1. The densities of the molecular ions plotted against altitude and latitude. Dots indicate measurements by the MIMS experiment for the upleg of orbit 594 of the AE-C satellite. Pluses indicate theoretical values (Oppenheimer et al., 1977).

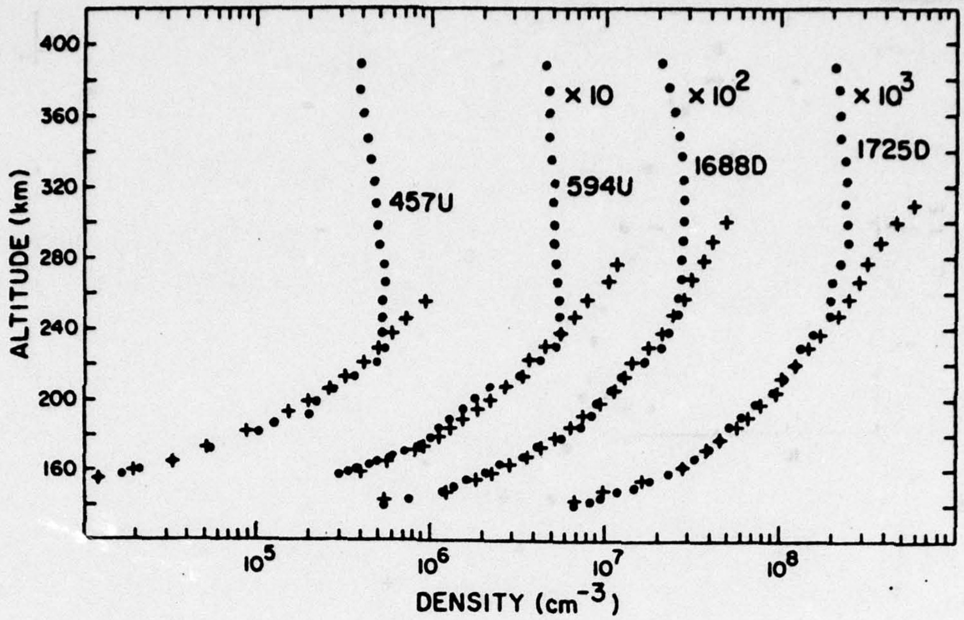

Fig. 2. The density of O^+ plotted against altitude. Dots indicate measurements by the MIMS experiment for four orbits of the AE-C satellite. Pluses indicate theoretical values calculated on the assumption of local photochemical equilibrium (Oppenheimer et al., 1977). The divergence of the theoretical and measured profiles above the F_2 peak demonstrates the breakdown of local photochemical equilibrium.

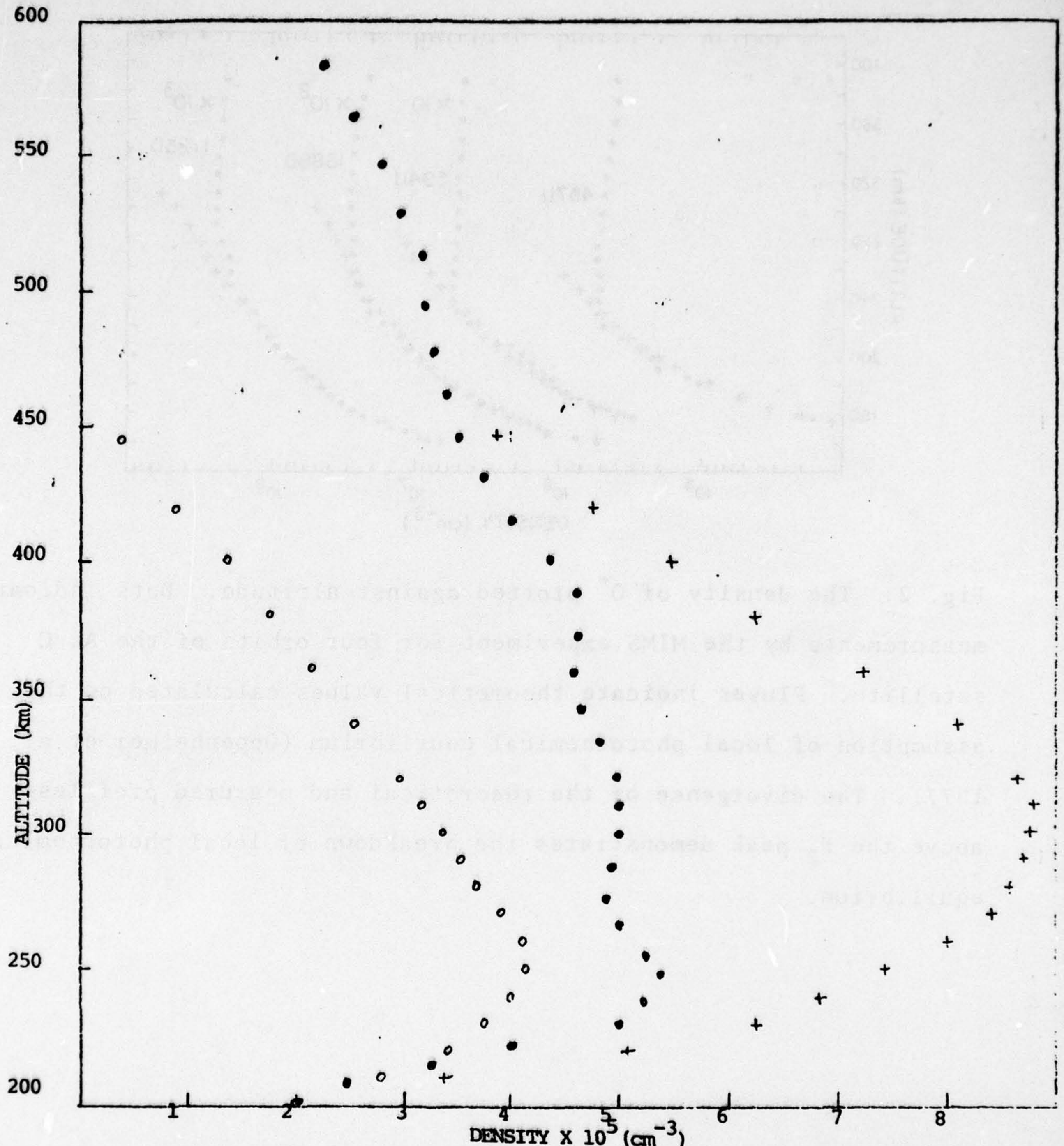

Fig. 3. The density of O^+ plotted against altitude. Filled circles indicate measurements by the BIMS experiment for orbit 594, upleg, of the AE-C satellite. Also shown, as open circles and pulses, are the results of two calculations based on a "fixed density" boundary condition at 470 km.

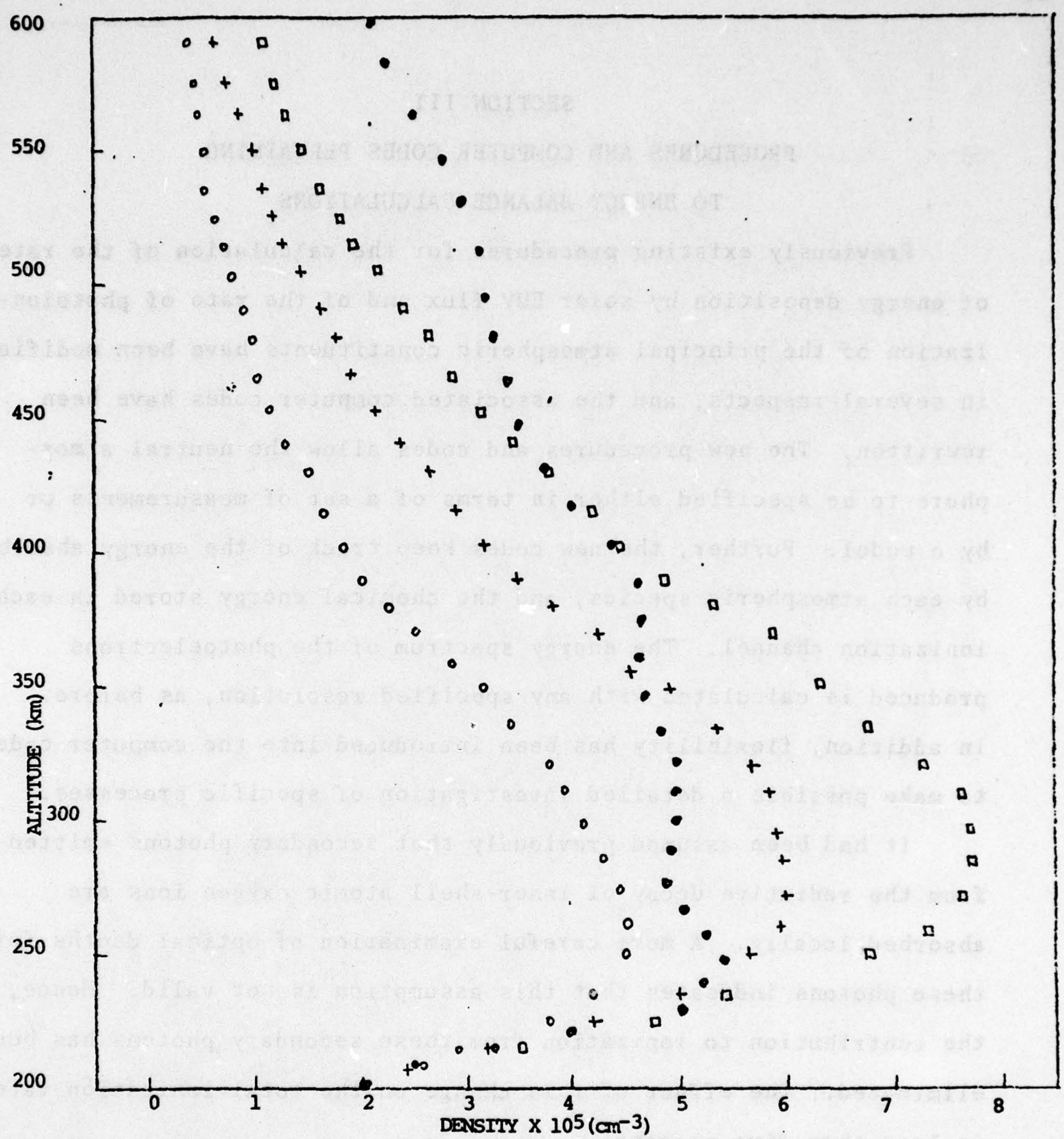

Fig. 4. The density of O^+ plotted against altitude. Filled circles indicate measurements by the BIMS experiment for orbit 594, upleg, of the AE-C satellite. Also shown are the results of three calculations based on a fixed flux boundary condition at 600 km: 000 $\phi = 5x10^8$, +++ $\phi = 0$, □□□ $\phi = 5x10^8$. Flux is in units of $cm^{-2}\ sec^{-1}$.

SECTION III

PROCEDURES AND COMPUTER CODES PERTAINING TO ENERGY BALANCE CALCULATIONS

Previously existing procedures for the calculation of the rate of energy deposition by solar EUV flux and of the rate of photoionization of the principal atmospheric constituents have been modified in several respects, and the associated computer codes have been rewritten. The new procedures and codes allow the neutral atmosphere to be specified either in terms of a set of measurements or by a model. Further, the new codes keep track of the energy absorbed by each atmospheric species, and the chemical energy stored in each ionization channel. The energy spectrum of the photoelectrons produced is calculated with any specified resolution, as before. In addition, flexibility has been introduced into the computer codes to make possible a detailed investigation of specific processes.

It had been assumed previously that secondary photons emitted from the radiative decay of inner-shell atomic oxygen ions are absorbed locally. A more careful examination of optical depths for these photons indicates that this assumption is not valid. Hence, the contribution to ionization from these secondary photons has been eliminated. The effect of this change on the total ionization rate is less than five percent.

The atomic and molecular cross sections utilized by those codes have been revised significantly. A detailed description of the cross sections currently in use is given in Appendix A.

The code that calculates the equilibrium electron flux has been modified to some extent in order to make it suitable for execution on a CDC system. A listing and a punched-card copy of this code, together with the necessary input files, is being submitted separately. A sample execution on a CDC-6400 system is also being submitted.

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APPENDIX A

Atomic and Molecular Cross Sections

The extreme ultraviolet (EUV) solar flux supplies the major energy input in the upper atmosphere. In addition, the EUV flux is the major source of ionization in the daytime at midlatitudes. To account properly for the rates of energy deposition and ionization in the upper atmosphere accurate photoabsorption and photoionization cross sections are required. This appendix contains cross sections for the most important atmospheric constituents. These cross sections are based on critical reviews and evaluations of laboratory and theoretical data. A considerable body of new data has become available recently. The agreement among results reported by various investigators is good (generally within 10% or better). Consequently the present body of cross section data may be considered complete insofar as aeronomic calculations are concerned, at least at wavelengths longer than 300 Å.

A.1 Atomic Oxygen Cross Sections

The photionization of atomic oxygen through the removal of the 2p valence shell electron leads to $O^+(^4S^o)$, $O^+(^2D^o)$, and $O^+(^2P^o)$ with thresholds at 910.4 Å, 732 Å, and 665 Å respectively. The partial cross sections for these processes as calculated by Henry (1970) have been renormalized using the total ionization cross section calculated by Taylor and Burke (1976). Ionization through the removal of a 2s inner shell electron gives rise to $O^+(^4P^e)$ and $O^+(^2P^e)$ with thresholds at 435 Å and 315 Å respectively. The partial cross sections for these processes were obtained from a calculation by Dalgarno, Henry and Stewart (1964) as modified by Henry (1967). The total ionization cross sections at wavelengths shorter than 435 Å were obtained by adding the partial cross sections for inner shell ionization to the total ionization cross sections of Taylor and Burke.

Table A-1 displays the total and partial ionization cross sections at selected wavelengths between 14.25 Å and 910 Å. Cross sections at other wavelengths can be obtained by linear interpolation.

A. 2 Molecular Oxygen Cross Sections

Total absorption (and ionization) cross sections in the region 14 Å - 662 Å were derived from the data of Lee, Carlson, Judge and Ogawa (1973), Samson, Gardner and Haddad (1977), Mehlman, Ederer and Saloman (1978), and Huffman (1963). In the region 662 Å - 870 Å a least squares fit to the values of Cook and Metzger (1964) was used. The 870 Å - 1030 Å region is marked by wider, well separated peaks. Using data from Huffman (1963) a background cross section σ_b was obtained by drawing in a baseline, upon which the peak cross section σ_p was superimposed. Each peak area was approximated as a square wave over the same wavelength interval as the actual triangular line shape. Total abosrption and total ionization cross sections are displayed in Tables A-2 and A-3 respectively.

Branching ratios as a function of wavelength were assigned on the basis of the results of Samson, Gardner and Haddad (1977), and of Fryar and Browning (1973). Samson et al. detected nine photoionization channels, of which the last five are predissociating states. Fryar and Browning have measured the total cross section for dissociative ionization.

Between the threshold for photoionization at 1026 Å and the threshold for dissociative ionization at 662 Å, we have used the branching ratios of Samson et al. with the following exception: Samson et al. give combined values for the $a^4\Pi_u$ and $A^2\Pi_u$ states. We have assigned the (small) branching ratios for the $A^2\Pi_u$ state on the basis of earlier work by Schoen (1969), and thus derived branching ratios for the $a^4\Pi_u$ state from the combined values of Samson et al.

In the region between 303 Å and 662 Å, the total cross section for dissociative ionization of Fryar and Browning (1973) exceeds the sum of the partial cross sections for the predissociating states observed by Samson et al. To reconcile this difference we have postulated the existence of a single additional predissociating branch with threshold at 662 Å. A straightforward algorithm yields branching ratios for this (tenth) additional branch as well as renormalized branching ratios for the branches observed by Samson et al.

No measurements of the branching ratios have been reported at wavelengths shorter than 303 Å. We have arbitrarily assumed that branching ratios remain constant short of 303 Å. This assumption is of minor importance for most aeronomic applications.

Table A-4 displays branching ratios at selected wavelengths between 14 Å and 1026 Å for each of ten branches. At other wavelengths the branching ratios can be obtained by linear interpolation. It should be kept in mind that the last six branches represent dissociative ionization.

- A-5 -

Table A-4

Branching Ratios for the Photoionization of O_2

Branch	1	2	3	4	5	6	7	8	9	10
Deisgnation	$X^2\Pi_g$	$a^4\Pi_u$	$A^2\Pi_u$	$b^4\Sigma_g^-$	$B^2\Sigma_g^-$	$^2\Pi_u$	$c^4\Sigma_u^-$	$^2\Sigma_u^-$	$^{2,4}\Sigma_g^-$	662 Å
λ(Å)	Branching Ratios									
14	0.365	0.185	0.020	0.125	0.055	0.060	0.035	0.030	0.125	0.000
303	0.365	0.185		0.125					0.125	0.000
323								0.030	0.000	0.112
454								0.000		0.055
461	0.435	0.225		0.120	0.055	0.060	0.035			0.050
504							0.000			0.115
537	0.345	0.270		0.130		0.000				0.137
556		0.210		0.225						
573	0.365	0.250								0.030
584		0.310		0.210	0.125					0.030
598	0.[illegible]30	0.275		0.375						0.045
610		0.365		0.305	0.000					0.075
637	0.245	0.330		0.370						
645	0.340	0.285		0.330						
662	0.270		0.020	0.345						0.000
684		0.468	0.050	0.000						
704	0.675	0.275								
720	0.565	0.385	0.050							
737	0.565	0.435	0.000							
774	1.000	0.000								
1026	1.000									

A.3 Molecular Nitrogen Cross Sections

Total absorption (and ionization) cross sections in the region 100 Å - 650 Å were derived from the data of Lee, Carlson, Judge and Ogawa (1973) and of Samson, Haddad and Gardner (1977). The data were extrapolated from 100 Å to 14 Å so that consistency was obtained with the cross section measurements by Huffman (1969) at 100 Å, 68 Å, 44.6 Å and 13.4 Å. From 650 Å to 734 Å total absorption cross sections were obtained from Huffman (1969) by superimposing peak values on a baseline representing the continuum, as for molecular oxygen. From 734 Å to 986 Å cross sections were derived from the tabulated oscillator strengths of Carter (1972). Ionization yields from 650 Å to the photoionization threshold at 796 Å were obtained by a least squares fit to the data of Cook and Metzger (1964). Above 1000 Å no detectable absorption was observed by Huffman, Tanaka and Larrabee (1963). Thus from 986 Å to 1030 Å the absorption cross section has been set to zero. Total absorption and total ionization cross sections are displayed in Tables A-5 and A-6 respectively.

Dissociative ionization of N_2 is assumed to occur through a single channel with threshold at 509 Å. The partial cross section for dissociative ionization is obtained by multiplying the total ionization cross section by the fractional yield for dissociative ionization. The remaining part of the total ionization cross section is apportioned among five branches of N_2^+. Fractional yields for dissociative ionization are displayed in Table A-7 for wavelengths between 14 Å and 509 Å. At other wavelengths the yield can be obtained by linear interpolation, with one exception: between 387 Å and 477 Å the yield, Y, is given by

$$Y = 0.0329 + 8.13\text{x}10^{-6} \text{ x } (\lambda-442)^2 \quad .$$

Values for the yield for dissociative ionization were derived from the data of Wight, Van der Wiel and Brion (1976), and of Fryar and Browning (1973).

Branching ratios as a function of wavelength for five N_2^+ branches were derived from the data of Samson, Haddad and Gardner (1977), Plummer, Gustafson, Gudat and Eastman (1977), Hamnet, Stoll and Brion (1976), and Lee (1977). The agreement among the results published by these investigators is good (generally within 10%). No measurements have been reported at wavelengths shorter than 210 Å. We have arbitrarily assumed that branching ratios remain constant short of 210 Å. This assumption is of minor importance for most aeronomic calculations. Table A-8 displays branching ratios between 14 Å and 795 Å for each of five branches. At other wavelengths the branching ratios can be obtained by linear interpolation.

Table A-7

Fractional Yield for Dissociative Ionization of N_2

λ(Å)	Yield
14	0.360
210	0.360
240	0.346
302	0.202
387*	0.033
477*	0.041
496	0.024
509	0.000

*See text

Table A-8

Branching Ratios for the Photionization of N_2

Branch	1	2	3	4	5
Designation	$X^2\Sigma_g^+$	$A^2\Pi_u$	$B^2\Sigma_u^+$	$F^2\Sigma_u$	$^2\Sigma_g^+$
λ (Å)	Branching Ratios				
14	0.271	0.275	0.110	0.064	0.278
210		0.275			0.278
240		0.345	0.110	0.064	0.210
280		0.470	0.095	0.040	0.124
300	0.271	0.470	0.110	0.074	0.075
332	0.300	0.520	0.120	0.060	0.000
428	0.460	0.460	0.080	0.000	
500	0.404	0.506	0.090		
600	0.308	0.589	0.103		
660	0.308	0.589	0.103		
660.01		0.692	0.000		
720	0.420	0.580			
747	1.000	0.000			
795	1.000				

A.4 Helium Cross Sections

For helium, with a photionization threshold at 504 Å, we have used the cross sections given by Jacobs (1971). These are displayed in Table A-9.

TABLE A-1

TOTAL AND PARTIAL PHOTOIONIZATION CROSS SECTIONS FOR ATOMIC OXYGEN (IN MEGABARNS)

λ(Å)	Total	$^4S^o$	$^2D^o$	$^2P^o$	$^4P^e$	$^2P^e$
14.25	0.322	0.095	0.102	0.063	0.031	0.025
30.02	0.277	0.083	0.088	0.058	0.027	0.021
46.40	0.261	0.078	0.083	0.055	0.025	0.020
60.30	0.423	0.123	0.140	0.088	0.040	0.032
75.03	0.824	0.245	0.263	0.173	0.079	0.063
90.14	1.527	0.455	0.486	0.321	0.147	0.117
105.23	2.310	0.689	0.736	0.486	0.222	0.176
127.65	3.714	1.108	1.184	0.782	0.357	0.284
150.10	4.789	1.372	1.562	1.025	0.460	0.370
180.40	5.920	1.611	1.981	1.293	0.571	0.465
200.00	6.633	1.759	2.253	1.465	0.650	0.510
220.08	7.345	1.905	2.531	1.640	0.725	0.544
243.03	8.087	2.064	2.844	1.836	0.763	0.561
256.37	8.432	2.154	3.023	1.947	0.818	0.556
270.50	8.906	2.245	3.210	2.061	0.958	0.532
284.15	9.262	2.332	3.387	2.168	0.969	0.487
303.78	9.719	2.451	3.633	2.316	0.914	0.405
315.02	9.573	2.507	3.755	2.398	0.923	0.000
335.39	10.127	2.636	4.014	2.540	0.938	
349.85	10.456	2.713	4.173	2.631	0.940	
366.07	10.837	2.811	4.371	2.740	0.915	
401.70	11.266	2.930	4.529	2.873	0.835	
413.00	11.435	2.935	4.740	2.925	0.785	
435.00	11.609	3.049	4.359	2.981	0.720	
452.00	10.900	3.052	4.964	2.984	0.000	
453.00	11.100	3.109	4.967	3.025		
454.00	11.307	3.167	5.060	3.081		
455.00	11.895	3.331	5.234	3.240		
456.00	11.765	3.295	5.265	3.204		
457.00	11.603	3.252	5.196	3.150		
458.00	11.503	3.222	5.150	3.131		
459.00	11.425	3.201	5.116	3.108		
460.00	11.373	3.186	5.092	3.093		
462.00	11.320	3.177	5.071	3.077		
464.00	11.263	3.159	5.049	3.061		
466.00	11.242	3.132	5.038	3.052		
467.00	11.163	3.131	5.006	3.031		
468.00	11.077	3.106	4.965	3.006		
470.00	11.000	3.085	4.932	2.987		
471.00	10.917	3.062	4.396	2.959		
472.00	10.783	3.025	4.935	2.922		
473.00	10.553	2.961	4.733	2.859		
474.00	9.991	2.803	4.482	2.706		
475.00	9.412	2.641	4.222	2.548		
476.00	11.447	3.213	5.136	3.096		

TABLE A-2

MOLECULAR OXYGEN ABSORPTION CROSS SECTIONS σ_T (Mb)

λ	σ_T	λ	σ_T	λ	σ_T	λ	σ_T	λ	σ_T
14.25	.29	14.40	.29	15.01	.29	15.26	.29	16.01	.29
16.77	.29	17.05	.29	17.11	.29	18.62	.29	18.97	.29
21.40	.29	21.80	.29	22.10	.29	28.47	.30	28.79	.30
29.52	.30	30.02	.30	30.43	.30	33.74	.30	40.95	.31
43.76	.31	44.02	.31	44.16	.31	45.66	.33	46.40	.35
46.67	.36	47.87	.39	49.22	.42	50.36	.45	50.52	.45
50.69	.46	52.30	.50	52.91	.51	54.15	.54	54.42	.55
54.70	.56	55.06	.57	55.34	.57	56.09	.59	56.92	.61
57.76	.62	57.56	.63	57.69	.64	58.96	.66	59.62	.68
60.30	.70	60.65	.71	61.07	.72	61.63	.73	61.90	.74
62.30	.75	62.35	.75	62.77	.76	62.92	.76	63.16	.77
63.30	.77	63.65	.78	63.72	.78	64.11	.79	64.60	.80
65.21	.82	65.71	.83	65.85	.84	66.30	.85	67.14	.87
67.35	.87	68.35	.91	69.65	.95	70.00	.96	70.54	.98
70.75	.98	71.00	.99	71.94	1.01	72.31	1.02	72.63	1.03
72.80	1.04	72.95	1.04	73.55	1.06	74.21	1.08	74.44	1.08
74.83	1.10	75.03	1.10	75.29	1.11	75.46	1.11	75.73	1.12
76.01	1.13	76.46	1.14	76.63	1.15	76.98	1.15	77.30	1.16
77.74	1.19	78.56	1.20	78.70	1.20	79.08	1.21	79.46	1.23
79.76	1.23	80.00	1.24	80.21	1.25	80.55	1.26	80.94	1.27
81.16	1.27	81.58	1.28	81.94	1.29	82.43	1.31	82.67	1.31
83.25	1.33	83.42	1.34	83.67	1.34	84.00	1.35	84.26	1.36
84.50	1.37	84.72	1.37	84.86	1.38	85.16	1.38	85.50	1.39
85.67	1.40	85.87	1.40	86.23	1.41	86.40	1.42	86.77	1.43
86.98	1.44	87.30	1.44	87.61	1.45	88.10	1.47	88.11	1.47
88.14	1.47	88.42	1.48	88.64	1.48	88.90	1.49	89.14	1.50
89.70	1.51	90.14	1.52	90.45	1.53	90.71	1.54	91.00	1.55
91.48	1.56	91.65	1.57	91.81	1.57	92.09	1.58	92.55	1.59
92.81	1.60	93.61	1.62	94.07	1.63	94.25	1.64	94.35	1.64
94.81	1.65	94.90	1.66	95.07	1.67	95.51	1.67	95.81	1.68
96.05	1.69	96.49	1.70	96.63	1.71	97.12	1.72	97.51	1.73
97.87	1.74	98.12	1.75	98.23	1.75	98.50	1.76	98.86	1.77
99.44	1.79	99.71	1.79	99.99	1.80	100.54	1.84	100.96	1.86
101.57	1.90	102.15	1.94	103.01	2.00	103.15	2.01	103.17	2.01
103.56	2.04	103.94	2.06	104.23	2.08	104.76	2.11	105.23	2.15
106.25	2.21	106.27	2.23	106.93	2.26	108.05	2.33	108.45	2.36
109.50	2.47	109.56	2.46	110.36	2.50	110.62	2.50	110.76	2.51
111.16	2.54	111.25	2.54	113.80	2.71	114.09	2.73	114.24	2.74
115.39	2.82	115.82	2.84	116.75	2.91	117.20	2.94	120.40	3.15
121.15	3.20	121.79	3.24	122.70	3.30	123.50	3.35	127.65	3.62
129.67	3.77	130.30	3.92	131.02	3.96	[illegible]	3.97	134.21	4.26
136.28	4.27	[illegible]	4.27	136.45	4.23	136.49	4.29	144.21	4.79
145.00	4.83	148.56	5.05	150.10	5.21	152.15	5.33	152.84	5.38
154.20	5.46	157.70	5.56	158.38	5.70	159.79	5.80	164.13	6.03
167.50	6.32	168.17	6.37	168.55	6.40	169.92	6.42	171.06	6.53
172.12	6.65	172.92	6.71	173.10	6.72	174.53	6.82	175.24	6.87
175.47	6.89	177.22	7.01	178.02	7.06	179.78	7.13	180.40	7.22
180.71	7.24	181.14	7.27	182.16	7.33	182.39	7.34	183.91	7.44
184.10	7.45	184.52	7.47	184.75	7.49	185.21	7.52	186.60	7.60
186.87	7.62	188.20	7.70	188.70	7.72	190.00	7.80	191.29	7.87
192.36	7.93	192.30	7.96	193.50	8.00	195.14	8.05	196.63	8.13

TABLE A-2 (continued)

λ	σ_T	λ	σ_T	λ	σ_T	λ	σ_T	λ	σ_T
197.41	8.27	198.53	8.30	200.00	8.40	201.10	8.48	202.64	8.60
203.78	8.67	204.89	8.78	206.26	8.90	206.38	8.91	207.46	9.00
208.35	9.07	209.63	9.17	209.78	9.18	209.93	9.19	211.32	9.30
212.15	9.36	214.75	9.54	215.16	9.57	216.70	9.68	218.21	9.77
219.07	9.83	220.08	9.91	221.26	9.99	221.51	10.01	223.26	10.15
223.72	10.19	224.81	10.27	225.12	10.30	227.01	10.45	227.47	10.49
228.79	10.60	230.65	10.75	231.55	10.83	232.60	10.91	233.84	11.01
234.35	11.05	235.55	11.15	237.36	11.29	239.97	11.49	240.75	11.56
243.03	11.74	245.94	11.97	246.24	12.00	246.71	12.05	247.13	12.07
249.25	12.24	251.10	12.39	251.96	12.46	252.17	12.48	253.80	12.61
256.37	12.82	256.69	12.34	257.48	12.91	258.40	12.98	259.50	13.06
261.08	13.18	262.95	13.32	264.27	13.41	264.80	13.44	270.50	13.83
271.99	13.94	272.70	13.99	274.24	14.09	275.35	14.17	275.76	14.20
276.15	14.23	276.77	14.27	277.00	14.29	277.27	14.31	278.40	14.39
281.41	14.60	284.15	14.80	285.65	14.92	288.36	15.09	289.17	15.14
290.72	15.25	291.63	15.31	292.00	15.33	292.37	15.36	295.57	15.55
296.17	15.58	299.50	15.77	303.73	16.00	315.02	16.51	315.05	16.51
316.20	16.55	319.83	16.69	335.05	17.31	335.39	17.32	345.13	17.66
345.74	17.69	347.42	17.73	349.85	17.00	353.86	17.91	356.07	17.98
360.75	18.12	364.00	18.25	368.07	18.35	401.70	19.14	405.00	19.21
406.00	19.23	407.00	19.25	408.00	19.27	409.00	19.29	410.00	19.30
411.00	19.31	412.00	19.32	413.00	19.33	414.00	19.34	415.00	19.35
416.00	19.35	417.00	19.36	417.24	19.37	417.71	19.37	418.00	19.37
419.00	19.39	420.00	19.40	421.00	19.42	422.00	19.44	423.00	19.46
424.00	19.48	425.00	19.50	426.00	19.53	427.00	19.55	428.00	19.57
429.00	19.59	430.00	19.60	430.50	19.61	431.00	19.61	432.00	19.62
433.00	19.63	434.00	19.64	435.00	19.64	436.00	19.65	436.10	19.65
437.00	19.66	438.00	19.67	439.00	19.69	440.00	19.70	441.00	19.72
442.00	19.75	443.00	19.78	444.00	19.81	445.00	19.84	446.00	19.88
447.00	19.91	448.00	19.94	449.00	19.97	450.00	20.00	451.00	20.02
452.00	20.04	453.00	20.06	454.00	20.08	455.00	20.10	456.00	20.11
457.00	20.13	458.00	20.15	459.00	20.17	460.00	20.20	461.00	20.23
462.00	20.26	463.00	20.30	464.00	20.34	465.00	20.38	465.92	20.39
466.00	20.43	467.00	20.47	468.00	20.51	469.00	20.56	469.80	20.59
470.00	20.60	471.00	20.64	472.00	20.68	473.00	20.72	474.00	20.76
475.00	20.80	476.00	20.84	477.00	20.88	478.00	20.92	479.00	20.96
480.00	21.00	481.00	21.04	482.00	21.09	482.10	21.09	483.00	21.14
484.00	21.19	485.00	21.23	486.00	21.28	487.00	21.34	488.00	21.39
489.00	21.44	489.50	21.47	490.00	21.50	491.00	21.56	492.00	21.61
493.00	21.67	494.00	21.73	495.00	21.79	496.00	21.85	497.00	21.91
498.00	21.97	499.00	22.04	499.27	22.05	500.00	22.10	501.00	22.16
502.00	22.23	503.00	22.30	504.00	22.37	507.90	22.68	515.60	23.57
521.10	23.92	525.00	23.85	537.03	25.20	542.30	25.62	550.00	25.40
554.51	25.56	558.60	25.76	562.80	25.71	568.50	25.35	572.30	25.23
580.40	24.03	584.32	22.01	599.60	26.62	608.00	26.56	609.00	26.32
609.85	26.17	610.00	26.10	611.00	25.73	612.00	25.75	613.00	25.70
614.00	25.63	615.00	25.60	616.00	25.59	616.60	25.59	617.00	25.60
618.00	25.62	619.00	25.66	620.00	25.70	621.00	25.75	622.00	25.79
623.00	25.83	624.00	25.87	625.00	25.89	625.33	25.90	626.00	25.91
627.00	25.91	628.00	25.90	629.00	25.86	629.73	25.82	630.00	25.80
631.00	25.72	632.00	25.61	633.00	25.50	634.00	25.37	635.00	25.24

TABLE A-2 (continued)

λ	σ_T	λ	σ_T	λ	σ_T	λ	σ_T	λ	σ_T
868.00	11.97	869.00	11.94	870.00	12.00	871.00	12.09	872.00	10.50
873.00	9.09	874.00	7.50	875.00	6.02	876.00	5.84	877.00	5.65
878.00	9.48	879.00	9.31	880.00	9.15	881.00	9.01	882.00	8.90
883.00	8.89	884.00	11.41	885.00	11.35	886.00	11.31	887.00	11.29
888.00	11.28	889.00	11.27	890.00	11.28	891.00	7.59	892.00	7.61
893.00	7.64	894.00	7.68	895.00	7.71	896.00	7.74	897.00	4.79
898.00	4.82	899.00	4.34	900.00	17.57	901.00	17.56	902.00	17.58
903.00	17.59	904.00	17.57	904.10	17.57	905.00	17.55	906.00	4.82
907.00	17.75	908.00	17.72	909.00	17.69	910.00	17.65	911.00	17.60
912.00	17.55	913.00	17.50	914.00	17.45	915.00	4.43	916.00	4.38
917.00	14.36	918.00	14.30	919.00	14.24	920.00	14.18	921.00	14.12
922.00	14.06	923.00	3.96	923.10	3.95	924.00	13.52	925.00	13.47
926.00	13.41	926.20	13.40	927.00	13.35	928.00	13.30	929.00	13.25
930.00	3.59	930.70	3.54	931.00	25.74	932.00	25.69	933.00	25.64
933.40	25.62	934.00	25.60	935.00	25.55	936.00	25.51	937.00	3.27
937.80	3.24	938.00	23.56	939.00	23.53	940.00	23.50	941.00	23.47
942.00	23.44	943.00	23.42	944.00	23.40	944.50	23.39	945.00	30.16
946.00	30.14	947.00	30.13	948.00	30.11	949.00	30.10	949.74	30.09
950.00	30.08	951.00	30.07	952.00	2.95	953.00	2.94	954.00	2.93
955.00	28.57	956.00	28.52	957.00	28.51	958.00	28.50	959.00	28.48
960.00	28.46	961.00	27.11	962.00	27.09	963.00	27.07	964.00	27.04
965.00	27.02	966.00	27.00	967.00	26.97	968.00	26.95	969.00	26.92
970.00	26.89	971.00	25.36	972.00	21.96	972.50	21.95	973.00	21.93
974.00	21.90	975.00	21.87	976.00	21.84	977.00	21.80	977.03	21.80
978.00	21.77	979.00	21.74	980.00	21.71	981.00	21.67	982.00	21.64
983.00	22.89	984.00	22.84	985.00	22.81	986.00	22.78	987.00	22.74
988.00	22.71	989.00	22.68	990.00	22.64	991.00	1.93	991.00	1.93
992.00	1.39	993.00	1.37	994.00	13.07	995.00	13.04	996.00	13.01
997.00	12.98	998.00	1.72	999.00	1.69	1000.00	1.66	1001.00	1.64
1002.00	1.61	1003.00	1.59	1004.00	3.78	1005.00	3.76	1006.00	3.74
1007.00	3.71	1008.00	1.47	1009.00	1.45	1010.00	1.42	1010.20	1.42
1011.00	1.40	1012.00	1.38	1013.00	1.36	1014.00	1.34	1015.00	1.32
1016.00	1.29	1017.00	1.27	1018.00	1.25	1019.00	1.23	1020.00	1.21
1021.00	1.13	1021.00	1.18	1022.00	1.15	1023.00	1.14	1024.00	1.12
1025.00	1.09	1025.72	1.58	1026.00	1.07	1027.00	1.04	1028.00	1.02
1029.00	1.00	1030.00	.97						

TABLE A-3

MOLECULAR OXYGEN PHOTOIONIZATION CROSS SECTIONS σ_I (Mb)

λ	σ_I	λ	σ_I	λ	σ_I	λ	σ_I	λ	σ_I
14.25	.29	14.40	.29	15.01	.29	15.26	.29	16.01	.29
16.77	.29	17.05	.29	17.11	.29	18.62	.29	18.97	.29
21.60	.29	21.80	.29	22.10	.29	28.47	.30	28.79	.30
29.52	.30	30.02	.30	30.43	.30	33.74	.30	40.95	.31
43.78	.31	44.02	.31	44.16	.31	45.66	.33	46.40	.35
46.67	.36	47.87	.39	49.22	.42	50.36	.45	50.52	.45
50.69	.46	52.30	.50	52.91	.51	54.15	.54	54.42	.55
54.70	.56	55.06	.57	55.34	.57	56.08	.59	56.92	.61
57.36	.62	57.56	.63	57.88	.64	58.96	.66	59.62	.68
60.30	.70	60.35	.71	61.07	.72	61.63	.73	61.90	.74
62.30	.75	62.55	.75	62.77	.76	62.92	.76	63.16	.77
63.30	.77	63.65	.78	63.72	.78	64.11	.79	64.60	.80
65.21	.82	65.71	.83	65.85	.84	66.30	.85	67.14	.87
67.35	.87	68.35	.91	69.65	.95	70.00	.96	70.54	.98
70.75	.98	71.00	.99	71.94	1.01	72.31	1.02	72.63	1.03
72.80	1.04	72.95	1.04	73.55	1.06	74.21	1.08	74.44	1.08
74.83	1.10	75.03	1.10	75.29	1.11	75.46	1.11	75.73	1.12
76.01	1.13	76.48	1.14	76.63	1.15	76.94	1.15	77.30	1.16
77.74	1.18	78.56	1.20	78.70	1.20	79.08	1.21	79.43	1.23
79.76	1.23	80.00	1.24	80.21	1.25	80.55	1.26	80.94	1.27
81.16	1.27	81.56	1.28	81.94	1.29	82.43	1.31	82.67	1.31
83.25	1.33	83.42	1.34	83.67	1.34	84.00	1.35	84.26	1.36
84.50	1.37	84.72	1.37	84.86	1.38	85.16	1.38	85.50	1.39
85.69	1.40	85.87	1.40	86.23	1.41	86.40	1.42	86.77	1.43
86.96	1.44	87.30	1.44	87.61	1.45	88.10	1.47	88.11	1.47
88.14	1.47	88.42	1.46	88.64	1.48	88.90	1.49	89.14	1.50
89.70	1.51	90.14	1.52	90.45	1.53	90.71	1.54	91.00	1.55
91.46	1.56	91.69	1.57	91.81	1.57	92.09	1.58	92.55	1.59
92.81	1.60	93.61	1.62	94.07	1.63	94.25	1.64	94.37	1.64
94.81	1.65	94.90	1.66	95.07	1.67	95.31	1.67	95.81	1.69
96.05	1.69	96.49	1.70	96.83	1.71	97.12	1.72	97.51	1.73
97.87	1.74	98.12	1.75	98.23	1.75	98.50	1.76	98.83	1.77
99.44	1.78	99.71	1.79	99.99	1.80	100.34	1.84	100.95	1.86
101.57	1.90	102.15	1.94	103.01	2.00	103.15	2.01	103.17	2.01
103.58	2.04	103.94	2.06	104.23	2.08	104.76	2.11	105.23	2.15
106.25	2.21	106.57	2.23	106.93	2.26	108.05	2.33	108.46	2.35
109.50	2.43	109.96	2.46	110.55	2.50	110.62	2.50	110.76	2.51
111.16	2.54	111.25	2.54	113.80	2.71	114.09	2.73	114.24	2.74
115.39	2.82	115.52	2.84	116.75	2.91	117.20	2.94	120.40	3.15
121.15	3.20	121.75	3.24	122.70	3.30	123.50	3.35	127.65	3.62
129.57	3.77	130.50	3.92	131.02	3.96	131.21	3.97	136.21	4.25
136.28	4.27	136.34	4.27	136.45	4.28	136.49	4.28	144.21	4.79
145.06	4.85	148.58	5.09	150.10	5.21	152.13	5.32	152.94	5.39
154.20	5.45	157.73	5.66	158.38	5.70	159.94	5.80	164.15	6.08
167.50	6.32	168.17	6.37	168.55	6.40	168.72	6.42	171.05	6.58
172.12	6.65	172.92	6.71	173.10	6.72	174.33	6.82	175.24	6.87
175.47	6.89	177.22	7.01	178.02	7.05	179.74	7.10	180.40	7.22
180.71	7.24	181.14	7.27	182.16	7.33	182.59	7.34	183.91	7.44
184.10	7.45	184.52	7.47	184.76	7.49	185.21	7.52	186.60	7.60
186.97	7.62	188.22	7.70	188.70	7.72	190.00	7.80	191.29	7.87
192.36	7.93	192.80	7.96	193.50	8.00	195.10	8.09	196.65	8.15

TABLE A-3 (continued)

λ	σ_I	λ	σ_I	λ	σ_I	λ	σ_I	λ	σ_I
197.41	8.23	198.53	8.30	200.00	8.40	201.10	8.46	202.64	8.60
203.78	8.69	204.69	8.78	206.26	8.90	206.38	8.91	207.46	9.00
208.35	9.07	209.63	9.17	209.73	9.18	209.93	9.19	211.32	9.30
212.15	9.36	214.75	9.54	215.16	9.57	216.90	9.68	218.21	9.77
219.09	9.83	220.08	9.91	221.26	9.99	221.51	10.01	223.26	10.15
223.72	10.19	224.81	10.27	225.12	10.30	227.01	10.45	227.47	10.49
228.79	10.69	230.65	10.75	231.55	10.83	232.60	10.91	233.84	11.01
234.38	11.05	235.55	11.15	237.16	11.29	239.87	11.49	240.73	11.56
243.03	11.74	245.94	11.97	246.24	12.00	246.91	12.05	247.13	12.07
249.23	12.24	251.10	12.39	251.96	12.46	252.17	12.48	253.80	12.61
256.37	12.82	256.65	12.84	257.48	12.91	258.40	12.98	259.50	13.06
261.08	13.19	262.99	13.32	264.27	13.41	264.30	13.44	270.50	13.83
271.99	13.94	272.70	13.99	274.24	14.09	275.35	14.17	275.76	14.20
276.15	14.23	276.77	14.27	277.00	14.29	277.27	14.31	278.40	14.39
281.41	14.60	284.15	14.80	285.85	14.92	288.36	15.09	289.17	15.14
290.72	15.25	291.63	15.31	292.00	15.33	292.37	15.38	295.57	15.55
296.17	15.59	299.50	15.77	303.78	16.00	313.02	16.51	315.05	16.51
316.20	16.55	319.93	16.69	335.05	17.31	335.39	17.32	345.13	17.66
345.74	17.69	347.42	17.73	349.85	17.80	353.86	17.91	356.07	17.98
360.76	18.12	364.80	18.25	368.07	18.35	401.70	19.14	405.00	19.21
406.00	19.23	407.00	19.25	408.00	19.27	409.00	19.29	410.00	19.30
411.00	19.31	412.00	19.32	413.00	19.33	414.00	19.34	415.00	19.35
416.00	19.36	417.00	19.36	417.24	19.37	417.71	19.37	418.00	19.37
419.00	19.39	420.00	19.40	421.00	19.42	422.00	19.44	423.00	19.46
424.00	19.48	425.00	19.50	426.00	19.53	427.00	19.55	428.00	19.57
429.00	19.59	430.00	19.60	430.50	19.61	431.00	19.61	432.00	19.62
433.00	19.63	434.00	19.64	435.00	19.64	436.00	19.65	436.10	19.65
437.00	19.66	438.00	19.67	439.00	19.68	440.00	19.70	441.00	19.72
442.00	19.75	443.00	19.78	444.00	19.81	445.00	19.84	446.00	19.88
447.00	19.91	448.00	19.94	449.00	19.97	450.00	20.00	451.00	20.02
452.00	20.04	453.00	20.06	454.00	20.08	455.00	20.10	456.00	20.11
457.00	20.13	458.00	20.15	459.00	20.17	460.00	20.20	461.00	20.23
462.00	20.26	463.00	20.30	464.00	20.34	465.00	20.38	465.22	20.39
466.00	20.43	467.00	20.47	468.00	20.51	469.00	20.56	469.80	20.59
470.00	20.60	471.00	20.64	472.00	20.68	473.00	20.72	474.00	20.76
475.00	20.80	476.00	20.84	477.00	20.88	478.00	20.92	479.00	20.96
480.00	21.00	481.00	21.04	482.00	21.05	482.10	21.09	483.00	21.14
484.00	21.19	485.00	21.23	486.00	21.28	487.00	21.34	488.00	21.39
489.00	21.44	489.50	21.47	490.00	21.50	491.00	21.56	492.00	21.61
493.00	21.67	494.00	21.73	495.00	21.79	496.00	21.85	497.00	21.91
498.00	21.97	499.00	22.04	499.27	22.05	500.00	22.10	501.00	22.16
502.00	22.23	503.00	22.30	504.00	22.37	507.50	22.68	515.60	23.57
521.10	23.92	525.20	23.95	537.03	23.20	542.80	25.68	550.00	25.40
554.51	25.56	558.60	25.72	562.80	25.71	568.50	25.35	572.30	25.28
580.40	24.03	584.30	22.01	589.60	26.62	608.00	26.56	609.00	26.32
609.05	26.13	610.00	26.10	611.00	25.93	612.00	25.79	613.00	25.70
614.00	25.63	615.00	25.60	616.00	25.57	616.60	25.55	617.00	25.60
618.00	25.62	619.00	25.66	620.00	25.70	621.00	25.75	622.00	25.79
623.00	25.83	624.00	25.87	625.00	25.89	625.29	25.90	626.00	25.91
627.00	25.91	628.00	25.90	629.00	25.86	629.73	25.82	630.00	25.80
631.00	25.72	632.00	25.61	633.00	25.50	634.00	25.37	635.00	25.24

TABLE A-3 (continued)

λ	σ_I	λ	σ_I	λ	σ_I	λ	σ_I	λ	σ_I
636.00	25.10	637.00	24.98	638.00	24.87	639.00	24.77	640.00	24.70
641.00	24.65	642.00	24.63	643.00	24.63	644.00	24.64	644.10	24.64
645.00	24.66	646.00	24.69	647.00	24.73	648.00	24.76	649.00	24.78
650.00	23.00	651.00	23.06	652.00	23.11	653.00	23.14	654.00	23.16
655.00	23.16	656.00	23.15	657.00	23.13	657.30	23.12	658.00	23.10
659.00	23.05	660.00	22.99	661.00	22.92	661.40	22.88	662.00	22.83
663.00	22.77	664.00	22.61	665.00	22.49	666.00	22.35	667.00	22.19
668.00	22.03	669.00	21.85	670.00	21.65	671.00	21.45	671.50	21.34
672.00	21.23	673.00	21.00	674.00	20.75	675.00	20.49	676.00	20.22
677.00	19.93	678.00	19.64	679.00	19.32	680.00	19.00	680.94	18.23
681.00	18.23	681.70	18.24	682.00	18.25	683.00	18.28	684.00	18.32
685.00	18.39	685.70	18.43	686.00	14.45	687.00	14.54	688.00	14.65
689.00	14.77	690.00	14.90	691.00	15.05	692.00	15.21	693.00	15.39
694.00	15.58	694.30	15.64	695.00	15.79	696.00	16.01	697.00	16.25
698.00	16.50	699.00	16.77	700.00	17.05	701.00	17.39	702.00	17.69
703.00	17.93	703.40	18.02	704.00	18.15	705.00	18.32	706.00	18.46
707.00	18.56	708.00	18.62	709.00	18.65	710.00	18.63	711.00	18.53
712.00	18.49	712.70	18.40	713.00	18.36	714.00	18.15	715.00	17.99
716.00	17.74	717.00	17.46	718.00	17.14	718.50	16.96	719.00	16.78
720.00	16.39	721.00	18.14	722.00	18.71	723.00	19.21	724.00	19.64
725.00	20.00	726.00	20.29	727.00	20.51	728.00	20.66	729.00	20.74
730.00	20.76	731.00	20.70	732.00	20.57	733.00	20.38	734.00	20.11
735.00	19.78	736.00	19.37	737.00	18.90	738.00	18.36	739.00	17.74
740.00	17.06	741.00	16.31	742.00	15.49	743.00	14.60	744.00	13.64
745.00	12.61	746.00	11.51	747.00	10.34	748.00	9.10	749.00	7.80
750.00	6.42	751.00	8.52	752.00	8.55	753.00	8.50	754.00	8.46
755.00	8.42	756.00	8.39	757.00	8.37	758.00	8.36	758.70	8.36
759.00	8.36	759.40	8.36	760.00	8.37	760.40	8.37	761.00	8.38
762.00	8.41	762.00	8.41	763.00	8.44	764.00	8.48	764.60	8.51
765.00	8.54	766.00	8.60	767.00	8.66	768.00	8.74	769.00	8.83
770.00	8.92	770.40	9.62	771.00	9.68	772.00	9.77	773.00	9.84
774.00	9.90	775.00	9.95	776.00	9.97	776.00	9.99	777.00	10.01
778.00	10.02	779.00	10.02	780.00	10.01	780.30	10.00	781.00	9.98
782.00	9.94	783.00	9.89	784.00	9.83	785.00	9.75	786.00	9.66
786.40	9.61	787.00	9.56	787.71	9.48	788.00	9.45	789.00	9.32
790.00	9.69	790.21	9.65	791.00	9.52	792.00	9.38	793.00	9.26
794.00	9.16	795.00	9.06	796.00	9.03	797.00	8.99	798.00	8.98
799.00	8.99	800.00	9.02	801.00	9.07	802.00	9.15	803.00	9.24
804.00	9.36	805.00	9.50	806.00	9.65	807.00	9.85	808.00	10.05
809.00	10.28	810.00	10.52	811.00	11.85	812.00	11.50	813.00	11.11
814.00	10.72	815.00	10.35	816.00	9.78	817.00	9.67	818.00	9.27
819.00	8.92	820.00	8.59	821.00	8.26	822.00	7.93	823.00	7.62
824.00	7.31	825.00	7.01	826.00	6.72	827.00	6.43	828.00	6.15
829.00	5.68	830.00	5.62	831.00	6.83	832.00	6.71	833.00	6.54
834.00	6.37	834.20	6.34	835.00	6.21	836.00	6.05	837.00	5.90
838.00	5.75	839.00	5.60	840.00	5.46	841.00	5.32	842.00	5.19
843.00	5.05	844.00	4.93	845.00	4.81	846.00	4.69	847.00	4.58
848.00	4.47	849.00	4.36	850.00	4.26	851.00	4.16	852.00	4.07
853.00	3.97	854.00	3.89	855.00	3.80	856.00	3.72	857.00	3.65
858.00	3.59	859.00	3.51	860.00	3.45	861.00	3.00	862.00	3.03
863.00	3.07	864.00	3.07	865.00	3.08	866.00	3.10	867.00	3.12

TABLE A-3 (continued)

λ	σ_I	λ	σ_I	λ	σ_I	λ	σ_I	λ	σ_I
868.00	3.13	869.00	3.15	870.00	3.17	871.00	3.18	872.00	3.20
873.00	3.22	874.00	3.24	875.00	3.25	876.00	3.27	877.00	3.29
878.00	3.30	879.00	3.32	880.00	3.34	881.00	3.36	882.00	3.38
883.00	3.39	884.00	3.41	885.00	3.43	886.00	3.45	887.00	3.46
888.00	3.48	889.00	3.49	890.00	3.50	891.00	3.51	892.00	3.52
893.00	3.53	894.00	3.54	895.00	3.54	896.00	3.54	897.00	3.54
898.00	3.54	899.00	3.53	900.00	3.52	901.00	3.51	902.00	3.50
903.00	3.48	904.00	3.46	904.10	3.46	905.00	3.44	906.00	3.42
907.00	3.39	908.00	3.36	909.00	3.34	910.00	3.31	911.00	3.28
912.00	3.25	913.00	3.21	914.00	3.18	915.00	3.15	916.00	3.12
917.00	3.09	918.00	3.06	919.00	3.03	920.00	3.00	921.00	2.97
922.00	2.95	923.00	2.92	923.10	2.92	924.00	2.90	925.00	2.88
926.00	2.85	926.20	2.85	927.00	2.83	928.00	2.81	929.00	2.79
930.00	2.77	930.70	2.75	931.00	2.75	932.00	2.73	933.00	2.71
933.40	2.70	934.00	2.69	935.00	2.67	936.00	2.65	937.00	2.62
937.80	2.61	938.00	2.60	939.00	2.58	940.00	2.56	941.00	2.53
942.00	2.51	943.00	2.48	944.00	2.45	944.50	2.44	945.00	2.43
946.00	2.40	947.00	2.37	948.00	2.34	949.00	2.32	949.74	2.30
950.00	2.29	951.00	2.26	952.00	2.24	953.00	2.21	954.00	2.19
955.00	2.16	956.00	2.14	957.00	2.12	958.00	2.10	959.00	2.08
960.00	2.06	961.00	2.05	962.00	2.03	963.00	2.02	964.00	2.01
965.00	2.00	966.00	1.99	967.00	1.98	968.00	1.97	969.00	1.96
970.00	1.95	971.00	1.95	972.00	1.94	972.30	1.93	973.00	1.93
974.00	1.92	975.00	1.91	976.00	1.90	977.00	1.89	977.03	1.89
978.00	1.88	979.00	1.87	980.00	1.85	981.00	1.84	982.00	1.82
983.00	1.80	984.00	1.78	985.00	1.76	986.00	1.74	987.00	1.72
988.00	1.69	989.00	1.67	990.00	1.65	991.00	1.63	991.00	1.62
992.00	1.60	993.00	1.58	994.00	1.55	995.00	1.53	996.00	1.50
997.00	1.48	998.00	1.45	999.00	1.44	1000.00	1.42	1001.00	1.40
1002.00	1.38	1003.00	1.36	1004.00	1.35	1005.00	1.33	1006.00	1.32
1007.00	1.30	1008.00	1.29	1009.00	1.27	1010.00	1.26	1010.20	1.26
1011.00	1.25	1012.00	1.24	1013.00	1.23	1014.00	1.21	1015.00	1.20
1016.00	1.19	1017.00	1.18	1018.00	1.17	1019.00	1.16	1020.00	1.15
1021.00	1.17	1021.00	1.13	1022.00	1.12	1023.00	1.11	1024.00	1.10
1025.00	1.08	1025.72	.98	1026.00	1.07	1027.00	1.06	1028.00	.00
1029.00	.00	1030.00	.00						

TABLE A-5

MOLECULAR NITROGEN ABSORPTION CROSS SECTIONS σ_T (Mb)

λ	σ_T	λ	σ_T	λ	σ_T	λ	σ_T	λ	σ_T
14.05	.03	14.40	.03	15.01	.03	15.26	.03	16.01	.04
16.77	.04	17.05	.04	17.11	.04	18.62	.05	18.97	.05
21.60	.06	21.80	.06	22.10	.06	28.47	.09	28.79	.09
29.52	.10	30.02	.10	30.43	.10	33.74	.11	40.95	.14
43.76	.16	44.02	.16	44.16	.16	45.66	.20	46.40	.21
46.67	.21	47.87	.23	49.22	.24	50.36	.26	50.52	.26
50.69	.26	52.30	.29	52.91	.29	54.15	.31	54.42	.32
54.70	.32	55.06	.32	55.24	.33	56.19	.34	56.92	.35
57.36	.36	57.56	.36	57.68	.36	58.96	.38	59.62	.39
60.30	.40	60.85	.40	61.07	.41	61.57	.41	61.90	.42
62.30	.42	62.35	.42	62.77	.43	62.92	.43	63.16	.44
63.30	.44	63.65	.44	63.72	.44	64.11	.45	64.60	.46
65.21	.46	65.71	.47	65.85	.47	66.30	.48	67.14	.49
67.35	.49	68.35	.50	69.65	.52	70.00	.52	70.54	.53
70.75	.53	71.00	.53	71.94	.54	72.31	.55	72.63	.55
72.80	.55	72.95	.55	73.55	.56	74.21	.57	74.44	.57
74.83	.57	75.03	.58	75.29	.58	75.46	.58	75.73	.58
76.01	.59	76.48	.59	76.63	.59	76.94	.60	77.70	.60
77.74	.60	78.56	.61	78.70	.61	79.08	.62	79.48	.62
79.76	.63	80.00	.63	80.21	.63	80.55	.63	80.94	.64
81.13	.64	81.56	.64	81.94	.65	82.43	.65	82.67	.66
83.25	.66	83.42	.66	83.67	.67	84.00	.67	84.26	.67
84.50	.68	84.72	.68	84.86	.68	85.16	.68	85.50	.69
85.69	.69	85.97	.69	86.23	.69	86.40	.70	86.77	.70
86.98	.70	87.30	.71	87.61	.71	88.10	.71	88.11	.71
88.14	.71	88.42	.72	88.64	.72	88.90	.72	89.14	.72
89.70	.73	90.14	.74	90.45	.74	90.71	.74	91.00	.74
91.48	.75	91.69	.75	91.81	.75	92.05	.76	92.55	.76
92.81	.76	93.61	.77	94.07	.78	94.25	.78	94.39	.78
94.81	.78	94.90	.79	95.07	.79	95.51	.79	95.81	.80
96.05	.80	96.49	.80	96.83	.81	97.12	.81	97.51	.81
97.87	.82	98.12	.82	98.23	.82	98.50	.82	98.80	.83
99.44	.83	99.71	.84	99.99	.84	100.54	.87	100.96	.89
101.57	.93	102.15	.96	103.01	1.01	103.15	1.02	103.17	1.02
103.78	1.04	103.94	1.06	104.23	1.08	104.76	1.10	105.23	1.13
106.25	1.19	106.57	1.21	106.93	1.23	108.05	1.29	108.46	1.31
109.50	1.37	109.96	1.39	110.56	1.43	110.62	1.43	110.76	1.44
111.10	1.45	111.25	1.47	113.80	1.61	114.09	1.62	114.24	1.63
115.39	1.71	115.82	1.72	116.75	1.77	117.20	1.80	120.40	1.97
121.15	2.02	121.79	2.05	122.70	2.10	123.70	2.15	127.65	2.38
129.57	2.50	130.80	2.47	131.02	2.51	131.21	2.52	136.21	2.79
136.25	2.79	136.34	2.80	136.43	2.80	136.43	2.80	145.21	3.25
145.70	3.29	148.08	3.50	150.13	3.61	152.15	3.70	152.84	3.78
154.20	3.85	157.73	4.07	158.33	4.11	159.54	4.20	164.13	4.42
167.50	4.61	168.17	4.64	168.55	4.67	168.92	4.69	171.76	4.81
172.12	4.83	172.52	4.93	173.10	4.94	174.53	5.04	175.24	5.08
175.47	5.10	177.22	5.22	178.02	5.27	179.74	5.36	180.40	5.37
180.71	5.39	181.14	5.40	182.16	5.45	182.37	5.46	183.91	5.52
184.10	5.57	184.32	5.55	184.75	5.56	185.21	5.58	186.60	5.64
186.97	5.65	188.20	5.71	188.70	5.74	190.00	5.80	191.29	5.87
192.36	5.93	192.60	5.95	193.50	5.99	195.14	6.09	196.00	6.13

TABLE A-5 (continued)

λ	σ_T	λ	σ_T	λ	σ_T	λ	σ_T	λ	σ_T
197.41	6.27	198.53	6.30	200.00	6.40	201.10	6.45	202.64	6.59
203.78	6.67	204.89	6.75	206.26	6.85	206.38	6.85	207.46	6.93
208.33	6.99	209.63	7.08	209.78	7.09	209.93	7.10	211.32	7.13
212.15	7.27	214.75	7.39	215.16	7.41	216.90	7.51	218.21	7.59
219.09	7.64	220.08	7.71	221.26	7.78	221.51	7.80	223.26	7.92
223.72	7.95	224.81	8.03	225.12	8.05	227.01	8.19	227.47	8.22
228.79	8.32	230.65	8.44	231.55	8.51	232.60	8.58	233.84	8.65
234.36	8.69	235.55	8.76	237.36	8.86	239.97	8.99	240.73	9.03
242.03	9.14	243.94	9.25	246.24	9.26	246.71	9.29	247.13	9.30
249.20	9.37	251.10	9.44	251.96	9.47	252.17	9.48	253.80	9.54
254.37	9.65	255.69	9.66	257.48	9.69	258.40	9.73	259.50	9.78
261.06	9.85	262.99	9.93	264.27	9.99	264.90	10.01	270.50	10.21
271.99	10.24	272.70	10.26	274.24	10.28	275.35	10.30	275.76	10.30
276.15	10.31	276.77	10.32	277.00	10.33	277.27	10.33	278.40	10.35
281.41	10.45	284.15	10.53	285.25	10.57	288.36	10.61	289.17	10.65
290.72	10.94	291.03	10.95	292.00	11.00	292.87	11.05	295.57	11.18
296.17	11.21	299.50	11.37	303.78	11.61	315.02	12.36	315.05	12.36
316.20	12.45	319.83	12.78	335.05	14.67	335.39	14.71	345.13	15.69
345.74	15.96	347.42	16.14	349.85	16.39	353.66	16.77	356.07	16.96
360.76	17.36	364.80	17.69	366.07	17.95	401.70	20.11	405.00	20.32
406.00	20.38	407.00	20.44	408.00	20.49	409.00	20.55	410.00	20.60
411.00	20.65	412.00	20.69	413.00	20.74	414.00	20.78	415.00	20.83
416.00	20.89	417.00	20.93	417.24	20.94	417.71	20.96	418.00	20.98
419.00	21.04	420.00	21.10	421.00	21.17	422.00	21.24	423.00	21.32
424.00	21.40	425.00	21.48	426.00	21.56	427.00	21.63	428.00	21.69
429.00	21.75	430.00	21.80	430.50	21.82	431.00	21.84	432.00	21.87
433.00	21.89	434.00	21.90	435.00	21.90	436.00	21.90	436.10	21.90
437.00	21.90	438.00	21.90	439.00	21.90	440.00	21.90	441.00	21.90
442.00	21.91	443.00	21.92	444.00	21.92	445.00	21.94	446.00	21.95
447.00	21.96	448.00	21.97	449.00	21.99	450.00	22.00	451.00	22.01
452.00	22.02	453.00	22.03	454.00	22.04	455.00	22.04	456.00	22.04
457.00	22.04	458.00	22.03	459.00	22.02	460.00	22.00	461.00	21.98
462.00	21.95	463.00	21.91	464.00	21.86	465.00	21.84	465.22	21.84
466.00	21.81	467.00	21.78	468.00	21.75	469.00	21.72	469.80	21.70
470.00	21.70	471.00	21.69	472.00	21.68	473.00	21.67	474.00	21.67
475.00	21.68	476.00	21.68	477.00	21.69	478.00	21.69	479.00	21.70
480.00	21.70	481.00	21.70	482.00	21.70	482.10	21.70	483.00	21.69
484.00	21.69	485.00	21.66	486.00	21.65	487.00	21.65	488.00	21.63
489.00	21.69	489.50	21.65	490.00	21.70	491.00	21.72	492.00	21.74
493.00	21.77	494.00	21.80	495.00	21.83	496.00	21.87	497.00	21.90
498.00	21.94	499.00	21.97	499.27	21.99	500.00	22.00	501.00	22.03
502.00	22.05	503.00	22.09	504.00	22.12	507.40	22.40	515.60	23.59
521.10	25.19	525.30	25.59	537.03	25.30	542.30	25.19	550.00	25.10
554.51	24.74	558.60	24.32	562.80	24.02	568.50	23.77	572.30	23.57
580.40	23.19	584.36	23.21	599.60	23.11	605.00	23.08	609.00	23.09
609.85	23.10	610.00	23.10	611.00	23.11	612.00	23.12	613.00	23.14
614.00	23.15	615.00	23.16	616.00	23.17	616.60	23.16	617.00	23.18
618.00	23.19	619.00	23.20	620.00	23.20	621.00	23.20	622.00	23.20
623.00	23.20	624.00	23.20	625.00	23.20	625.28	23.20	626.00	23.20
627.00	23.19	628.00	23.19	629.00	23.20	629.73	23.20	630.00	23.20
631.00	23.21	632.00	23.21	633.00	23.23	634.00	23.24	635.00	23.25

TABLE A-5 (continued)

λ	σ_T	λ	σ_T	λ	σ_T	λ	σ_T	λ	σ_T
636.00	23.26	637.00	23.27	638.00	23.28	639.00	23.29	640.00	23.30
641.00	23.31	642.00	23.31	643.00	23.31	644.00	23.31	644.10	23.31
645.00	23.31	646.00	23.31	647.00	23.30	648.00	23.30	649.00	23.30
650.00	23.30	651.00	23.69	652.00	24.10	653.00	24.52	654.00	24.94
655.00	25.36	656.00	25.77	657.00	26.14	657.30	26.25	658.00	26.49
659.00	26.77	660.00	27.00	661.00	27.17	661.40	27.21	662.00	27.27
663.00	27.33	664.00	27.34	665.00	27.33	666.00	27.29	667.00	27.24
668.00	27.19	669.00	30.72	670.00	30.69	671.00	33.86	671.50	33.86
672.00	33.87	673.00	33.89	674.00	27.14	675.00	35.14	676.00	35.15
677.00	35.17	678.00	27.19	679.00	27.16	680.00	23.91	680.94	23.82
681.00	23.82	681.70	30.07	682.00	38.03	683.00	37.88	684.00	37.71
685.00	26.39	685.70	26.25	686.00	26.20	687.00	26.01	688.00	25.83
689.00	25.66	690.00	22.31	691.00	22.19	692.00	22.07	693.00	43.49
694.00	43.44	694.30	43.43	695.00	43.41	696.00	43.42	697.00	43.46
698.00	25.22	699.00	25.34	700.00	25.50	701.00	25.70	702.00	25.94
703.00	26.22	703.40	26.34	704.00	26.57	705.00	26.85	706.00	27.20
707.00	27.56	708.00	27.94	709.00	28.32	710.00	28.70	711.00	29.08
712.00	29.45	712.70	29.69	713.00	29.80	714.00	30.12	715.00	36.78
716.00	37.07	717.00	37.03	718.00	31.11	718.30	31.06	719.00	31.09
720.00	31.10	721.00	31.03	722.00	57.17	723.00	56.92	724.00	56.57
725.00	56.10	726.00	55.52	727.00	54.80	728.00	27.66	729.00	26.66
730.00	25.50	731.00	24.19	732.00	22.78	733.00	21.33	734.00	27.07
735.00	7.17	736.00	33.99	737.00	26.82	738.00	33.02	739.00	28.71
740.00	29.26	741.00	29.26	742.00	29.26	743.00	20.97	744.00	29.45
745.00	29.45	746.00	29.45	747.00	29.43	748.00	28.63	749.00	28.31
750.00	28.84	751.00	24.70	752.00	24.70	753.00	17.73	754.00	17.73
755.00	31.99	756.00	31.96	757.00	31.93	758.00	32.16	758.70	32.16
759.00	26.09	759.40	26.09	760.00	26.09	760.40	30.27	761.00	30.27
762.00	30.27	762.00	30.27	763.00	30.27	764.00	18.64	764.60	18.64
765.00	35.47	766.00	35.47	767.00	35.47	768.00	9.72	769.00	9.72
770.00	9.72	770.40	9.72	771.00	9.72	772.00	26.88	773.00	26.88
774.00	26.88	775.00	26.88	776.00	36.25	776.00	47.10	777.00	47.10
778.00	47.10	779.00	47.10	780.00	24.67	780.30	24.67	781.00	24.67
782.00	49.79	783.00	49.79	784.00	54.83	785.00	64.83	786.00	54.83
786.40	16.26	787.00	16.26	787.71	16.26	788.00	16.26	789.00	16.26
790.00	29.21	790.21	29.21	791.00	29.21	792.00	59.36	793.00	59.85
794.00	59.65	795.00	26.77	796.00	26.97	797.00	26.97	798.00	2.25
799.00	7.29	800.00	5.92	801.00	5.03	802.00	45.06	803.00	45.05
804.00	.00	805.00	29.59	806.00	.00	807.00	31.80	808.00	45.59
809.00	48.59	810.00	25.36	811.00	.00	812.00	.00	813.00	.00
814.00	35.91	815.00	35.91	816.00	35.91	817.00	.00	818.00	.00
819.00	.00	820.00	49.33	821.00	49.33	822.00	.00	823.00	16.00
824.00	16.00	825.00	9.33	826.00	9.33	827.00	15.73	828.00	15.73
829.00	15.73	830.00	.00	831.00	.00	832.00	.00	833.00	.00
834.00	.00	834.20	.00	835.00	.00	836.00	32.00	837.00	32.00
838.00	32.00	839.00	8.31	840.00	8.31	841.00	8.31	842.00	21.53
843.00	21.53	844.00	21.53	845.00	21.53	846.00	10.97	847.00	10.97
848.00	10.97	849.00	8.21	850.00	8.11	851.00	13.82	852.00	13.82
853.00	13.82	854.00	13.82	855.00	36.42	856.00	36.42	857.00	36.42
858.00	33.01	859.00	29.64	860.00	29.64	861.00	29.64	862.00	9.36
863.00	9.86	864.00	9.36	865.00	16.01	866.00	16.01	867.00	54.03

TABLE A-5 (continued)

λ	σ_T	λ	σ_T	λ	σ_T	λ	σ_T	λ	σ_T
866.00	41.97	869.00	41.97	870.00	41.97	871.00	41.97	872.00	36.90
873.00	37.96	874.00	37.96	875.00	37.96	876.00	37.96	877.00	47.87
878.00	47.87	879.00	47.87	880.00	47.87	881.00	47.87	882.00	63.18
883.00	63.18	884.00	63.18	885.00	63.18	886.00	.00	887.00	49.66
888.00	176.16	889.00	176.16	890.00	9.37	891.00	9.37	892.00	45.71
893.00	45.71	894.00	45.71	895.00	10.26	896.00	10.26	897.00	10.26
898.00	61.92	899.00	106.06	900.00	106.06	901.00	18.11	902.00	18.11
903.00	22.77	904.00	19.25	904.10	203.78	905.00	203.78	906.00	18.04
907.00	18.04	908.00	18.04	909.00	11.62	910.00	11.62	911.00	11.62
912.00	14.50	913.00	14.50	914.00	40.92	915.00	40.92	916.00	40.92
917.00	40.92	918.00	10.04	919.00	10.04	920.00	10.04	921.00	95.77
922.00	95.77	923.00	55.55	923.10	31.92	924.00	31.92	925.00	31.92
926.00	31.92	926.20	19.03	927.00	19.03	928.00	19.03	929.00	19.03
930.00	64.51	930.70	64.51	931.00	64.51	932.00	64.51	933.00	3.13
933.40	3.13	934.00	3.13	935.00	3.13	936.00	3.13	937.00	2.94
937.90	3.15	938.00	3.15	939.00	3.15	940.00	120.77	941.00	120.77
942.00	120.77	943.00	120.77	944.00	39.78	944.50	39.78	945.00	39.78
946.00	39.78	947.00	39.78	948.00	.00	949.00	.00	949.74	.00
950.00	7.16	951.00	7.16	952.00	7.16	953.00	7.16	954.00	7.16
955.00	7.16	956.00	7.16	957.00	15.89	958.00	15.89	959.00	15.89
960.00	260.78	961.00	260.78	962.00	56.87	963.00	56.87	964.00	56.87
965.00	56.87	966.00	56.87	967.00	63.37	968.00	63.37	969.00	63.37
970.00	63.37	971.00	63.37	972.00	63.37	972.30	68.11	973.00	68.11
974.00	68.11	975.00	68.11	976.00	68.11	977.00	68.11	977.05	68.11
978.00	68.11	979.00	68.11	980.00	44.22	981.00	44.22	982.00	44.22
983.00	44.22	984.00	44.22	985.00	44.22	986.00	44.22		

TABLE A-6

MOLECULAR NITROGEN PHOTOIONIZATION CROSS SECTIONS σ_I (Mb)

λ	σ_I	λ	σ_I	λ	σ_I	λ	σ_I	λ	σ_I
14.25	.03	14.40	.03	15.01	.03	15.26	.03	16.01	.04
16.77	.04	17.05	.04	17.11	.04	18.62	.05	18.97	.05
21.60	.06	21.80	.06	22.10	.06	26.47	.09	28.79	.09
29.52	.10	30.02	.10	30.43	.10	33.74	.11	40.95	.14
43.76	.16	44.04	.16	44.16	.16	45.66	.20	46.40	.21
46.67	.21	47.37	.23	49.22	.24	50.36	.26	50.52	.26
50.69	.26	52.30	.29	52.91	.29	54.15	.31	54.42	.32
54.70	.32	55.00	.32	55.34	.33	56.08	.34	56.52	.35
57.36	.35	57.56	.36	57.83	.36	58.96	.38	59.62	.39
60.70	.40	60.85	.40	61.07	.41	61.63	.41	61.90	.42
62.30	.42	62.35	.42	62.77	.43	62.92	.43	63.16	.44
63.30	.44	63.65	.44	63.72	.44	64.11	.45	64.60	.46
65.21	.46	65.71	.47	65.85	.47	66.30	.48	67.14	.49
67.35	.49	68.05	.50	69.65	.52	70.00	.52	70.54	.53
70.75	.53	71.00	.53	71.94	.54	72.31	.55	72.63	.55
72.80	.55	72.95	.55	73.55	.56	74.21	.57	74.44	.57
74.85	.57	75.03	.58	75.29	.58	75.46	.58	75.73	.58
76.01	.59	76.48	.59	76.63	.59	76.94	.60	77.30	.60
77.74	.60	78.56	.61	78.70	.61	79.08	.62	79.48	.62
79.76	.63	80.00	.63	80.21	.63	80.55	.63	80.94	.64
81.16	.64	81.58	.64	81.94	.65	82.43	.65	82.67	.66
83.25	.66	83.42	.66	83.67	.67	84.02	.67	84.26	.67
84.50	.68	84.72	.68	84.86	.68	85.16	.68	85.50	.69
85.65	.69	85.87	.69	86.23	.69	86.40	.70	86.77	.70
86.95	.70	87.30	.71	87.61	.71	88.10	.71	88.11	.71
88.14	.71	88.42	.72	88.64	.72	88.90	.72	89.14	.72
89.70	.73	90.14	.74	90.45	.74	90.71	.74	91.00	.74
91.48	.75	91.69	.75	91.81	.75	92.09	.76	92.55	.76
92.81	.76	93.61	.77	94.07	.78	94.25	.78	94.39	.78
94.81	.78	94.90	.79	95.37	.79	95.51	.79	95.81	.80
96.05	.80	96.49	.80	96.63	.81	97.12	.81	97.51	.81
97.87	.82	98.12	.82	98.25	.82	98.50	.82	98.88	.83
99.44	.83	99.71	.84	99.99	.84	100.54	.87	100.96	.89
101.57	.93	102.15	.96	103.01	1.01	103.15	1.02	103.17	1.02
103.56	1.04	103.94	1.06	104.23	1.08	104.76	1.10	105.23	1.13
106.25	1.19	106.57	1.21	106.93	1.23	108.05	1.29	108.46	1.31
109.50	1.37	109.96	1.39	110.56	1.43	110.62	1.43	110.76	1.44
111.13	1.45	111.25	1.47	113.80	1.61	114.09	1.62	114.24	1.63
115.39	1.70	115.82	1.72	116.75	1.77	117.20	1.90	120.40	1.97
121.15	2.02	121.79	2.05	122.70	2.10	123.50	2.15	127.65	2.38
129.97	2.50	130.30	2.47	131.02	2.51	131.21	2.52	136.21	2.79
136.26	2.77	136.34	2.80	136.45	2.80	136.48	2.80	144.21	3.25
145.00	3.29	148.03	3.50	150.10	3.61	152.15	3.72	152.84	3.78
154.20	3.86	157.73	4.07	158.38	4.11	159.94	4.20	164.13	4.42
167.50	4.61	168.17	4.64	168.55	4.67	168.72	4.69	171.06	4.81
172.12	4.89	172.92	4.93	173.10	4.94	174.33	5.04	175.24	5.03
175.47	5.10	177.22	5.22	178.02	5.27	179.74	5.30	180.40	5.37
180.71	5.38	181.14	5.40	182.16	5.45	182.39	5.46	183.91	5.52
184.10	5.53	184.52	5.55	184.76	5.56	185.21	5.58	186.60	5.64
188.87	5.65	189.23	5.71	189.70	5.74	190.00	5.80	191.29	5.87
192.35	5.97	192.80	5.95	193.50	5.99	195.14	6.09	196.63	6.18

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TABLE A-6 (continued)

λ	σ_I	λ	σ_I	λ	σ_I	λ	σ_I	λ	σ_I
197.41	6.23	198.53	6.30	200.00	6.40	201.10	6.48	202.64	6.59
203.78	6.67	204.89	6.75	206.26	6.85	206.38	6.85	207.46	6.93
208.33	6.99	209.63	7.08	209.73	7.09	209.93	7.10	211.32	7.18
212.15	7.23	214.75	7.39	215.16	7.41	216.70	7.51	218.21	7.59
219.09	7.64	220.08	7.71	221.26	7.78	221.51	7.80	223.26	7.92
223.72	7.95	224.61	8.03	225.12	8.05	227.01	8.19	227.47	8.22
228.79	8.32	230.65	8.44	231.55	8.51	232.60	8.58	233.84	8.65
234.36	8.69	235.55	8.76	237.36	8.86	239.87	8.99	240.73	9.03
243.03	9.14	245.94	9.25	246.24	9.26	246.71	9.29	247.18	9.30
249.23	9.37	251.10	9.44	251.96	9.47	252.17	9.48	253.90	9.54
256.37	9.63	256.69	9.66	257.48	9.69	258.40	9.73	259.50	9.78
261.08	9.85	262.99	9.93	264.27	9.97	264.80	10.01	270.50	10.21
271.99	10.24	272.70	10.26	274.24	10.28	275.35	10.30	275.76	10.30
276.15	10.31	276.77	10.32	277.00	10.33	277.27	10.33	278.40	10.35
281.61	10.45	284.15	10.58	285.85	10.67	288.36	10.81	289.17	10.85
290.72	10.94	291.63	10.99	292.00	11.00	292.93	11.05	295.57	11.13
296.17	11.21	299.50	11.37	303.78	11.61	315.02	12.36	315.05	12.36
316.20	12.45	319.83	12.78	335.05	14.67	335.39	14.71	345.13	15.89
345.74	15.96	347.42	16.14	349.85	16.39	353.36	16.77	356.07	16.96
360.76	17.36	364.30	17.69	368.07	17.95	401.70	20.11	405.00	20.32
406.00	20.38	407.00	20.44	408.00	20.49	409.00	20.55	410.00	20.60
411.00	20.65	412.00	20.69	413.00	20.74	414.00	20.78	415.00	20.83
416.00	20.88	417.00	20.93	417.24	20.94	417.71	20.96	418.00	20.98
419.00	21.04	420.00	21.10	421.00	21.17	422.00	21.24	423.00	21.32
424.00	21.40	425.00	21.48	426.00	21.56	427.00	21.63	428.00	21.69
429.00	21.75	430.00	21.80	430.50	21.82	431.00	21.84	432.00	21.87
433.00	21.88	434.00	21.90	435.00	21.90	436.00	21.90	436.10	21.90
437.00	21.90	438.00	21.90	439.00	21.90	440.00	21.90	441.00	21.90
442.00	21.91	443.00	21.92	444.00	21.92	445.00	21.94	446.00	21.95
447.00	21.96	448.00	21.97	449.00	21.99	450.00	22.00	451.00	22.01
452.00	22.02	453.00	22.03	454.00	22.04	455.00	22.04	456.00	22.04
457.00	22.04	458.00	22.03	459.00	22.02	460.00	22.00	461.00	21.98
462.00	21.95	463.00	21.91	464.00	21.88	465.00	21.84	465.22	21.84
466.00	21.81	467.00	21.76	468.00	21.75	469.00	21.72	469.80	21.70
470.00	21.70	471.00	21.69	472.00	21.68	473.00	21.67	474.00	21.67
475.00	21.68	476.00	21.68	477.00	21.69	478.00	21.69	479.00	21.70
480.00	21.70	481.00	21.70	482.00	21.70	482.10	21.70	483.00	21.69
484.00	21.69	485.00	21.68	486.00	21.68	487.00	21.66	488.00	21.63
489.00	21.67	489.50	21.65	490.00	21.70	491.00	21.72	492.00	21.74
493.00	21.77	494.00	21.80	495.00	21.83	496.00	21.87	497.00	21.90
498.00	21.94	499.00	21.97	499.27	21.98	500.00	22.00	501.00	22.03
502.00	22.05	503.00	22.08	504.00	22.12	507.90	22.40	511.60	22.59
521.10	25.13	525.30	25.59	537.03	25.30	542.80	25.13	550.00	25.10
554.51	24.70	558.60	24.52	562.80	24.02	566.30	23.77	572.30	23.57
580.40	23.19	584.32	23.21	599.60	23.11	608.00	18.65	609.00	18.64
609.85	18.64	610.00	18.64	611.00	18.64	612.00	18.64	613.00	18.64
614.00	18.65	615.00	18.65	616.00	18.66	616.50	18.66	617.00	18.67
618.00	18.67	619.00	18.68	620.00	18.69	621.00	18.69	622.00	18.70
623.00	18.70	624.00	18.71	625.00	18.72	625.29	18.72	626.00	18.73
627.00	18.74	628.00	18.75	629.00	18.77	629.73	18.78	630.00	18.79
631.00	18.81	632.00	18.84	633.00	18.87	634.00	18.90	635.00	18.93

TABLE A-6 (continued)

λ	σ_I	λ	σ_I	λ	σ_I	λ	σ_I	λ	σ_I
636.00	18.97	637.00	19.00	638.00	19.04	639.00	19.08	640.00	19.11
641.00	19.15	642.00	19.19	643.00	19.22	644.00	19.26	644.10	19.26
645.00	19.29	646.00	19.33	647.00	19.37	648.00	19.41	649.00	19.45
650.00	19.52	651.00	19.99	652.00	20.47	653.00	20.96	654.00	21.43
655.00	21.89	656.00	22.31	657.00	22.70	657.30	22.81	658.00	23.05
659.00	23.33	660.00	23.55	661.00	23.69	661.40	23.73	662.00	23.76
663.00	23.78	664.00	23.74	665.00	23.65	666.00	23.53	667.00	23.38
668.00	23.21	669.00	26.06	670.00	25.37	671.00	28.32	671.50	28.21
672.00	28.09	673.00	27.85	674.00	22.08	675.00	28.27	676.00	28.25
677.00	28.40	678.00	22.05	679.00	22.11	680.00	19.53	680.94	19.50
681.00	19.59	681.70	31.22	682.00	31.21	683.00	31.13	684.00	31.03
685.00	21.73	685.70	21.62	686.00	21.53	687.00	21.42	688.00	21.26
689.00	21.10	690.00	18.32	691.00	18.19	692.00	18.06	693.00	35.52
694.00	35.39	694.30	35.36	695.00	35.23	696.00	35.18	697.00	35.11
698.00	20.31	699.00	20.33	700.00	20.38	701.00	20.47	702.00	20.58
703.00	20.71	703.40	20.77	704.00	20.87	705.00	21.04	706.00	21.23
707.00	21.42	708.00	21.62	709.00	21.83	710.00	21.98	711.00	22.23
712.00	22.43	712.70	22.56	713.00	22.61	714.00	22.77	715.00	27.71
716.00	27.81	717.00	27.88	718.00	23.16	718.50	23.16	719.00	23.16
720.00	23.12	721.00	23.03	722.00	42.35	723.00	42.12	724.00	41.63
725.00	41.47	726.00	41.05	727.00	40.54	728.00	20.48	729.00	19.77
730.00	18.56	731.00	18.03	732.00	17.04	733.00	16.01	734.00	20.41
735.00	5.75	736.00	29.17	737.00	23.99	738.00	30.12	739.00	29.25
740.00	26.43	741.00	25.73	742.00	24.59	743.00	17.06	744.00	22.76
745.00	21.51	746.00	20.29	747.00	19.16	748.00	18.50	749.00	16.78
750.00	16.69	751.00	14.23	752.00	14.55	753.00	10.98	754.00	11.87
755.00	19.56	756.00	19.72	757.00	19.80	758.00	20.16	758.70	20.28
759.00	16.49	759.40	16.55	760.00	16.63	760.40	19.36	761.00	19.46
762.00	19.62	762.00	19.62	763.00	19.73	764.00	12.27	764.60	12.33
765.00	23.52	766.00	23.67	767.00	23.81	768.00	6.56	769.00	6.59
770.00	6.61	770.40	6.62	771.00	6.63	772.00	18.35	773.00	18.36
774.00	18.34	775.00	18.30	776.00	24.58	776.00	31.95	777.00	31.78
778.00	29.47	779.00	29.19	780.00	15.17	780.30	15.14	781.00	15.08
782.00	24.83	783.00	24.77	784.00	39.31	785.00	39.28	786.00	39.27
786.46	9.85	787.00	9.35	787.71	9.35	788.70	9.85	789.00	9.85
790.00	17.79	790.21	17.70	791.00	18.12	792.00	33.29	793.00	26.59
794.00	17.04	795.00	7.68	796.00	.00				

TABLE A-9

HELIUM PHOTOIONIZATION CROSS SECTIONS σ_I (Mb)

λ	σ_I	λ	σ_I	λ	σ_I	λ	σ_I	λ	σ_I
14.25	.05	14.40	.05	15.01	.05	15.26	.05	16.01	.05
16.77	.05	17.05	.06	17.11	.06	18.62	.06	18.97	.06
21.60	.07	21.80	.07	22.10	.07	28.47	.08	28.79	.09
29.52	.09	30.02	.09	30.43	.09	33.74	.10	40.95	.12
43.76	.12	44.02	.13	44.16	.13	45.66	.13	46.40	.13
46.67	.13	47.37	.13	49.22	.14	50.36	.14	50.52	.14
50.65	.14	52.30	.15	52.91	.15	54.15	.15	54.42	.15
54.70	.15	55.06	.15	55.34	.15	56.08	.16	56.92	.16
57.36	.16	57.56	.16	57.88	.16	58.96	.16	59.62	.17
60.30	.17	60.85	.17	61.07	.17	61.63	.17	61.90	.17
62.30	.17	62.35	.17	62.77	.17	62.92	.17	63.16	.17
63.30	.17	63.65	.18	63.72	.18	64.11	.18	64.60	.18
65.21	.18	65.71	.18	65.85	.18	66.30	.18	67.14	.18
67.35	.19	68.35	.19	69.65	.19	70.00	.19	70.54	.19
70.75	.19	71.00	.19	71.94	.20	72.31	.20	72.63	.20
72.80	.20	72.95	.20	73.55	.20	74.21	.20	74.44	.20
74.85	.20	75.03	.21	75.29	.21	75.46	.21	75.73	.21
76.01	.21	76.46	.21	76.83	.21	76.94	.21	77.30	.21
77.74	.21	78.53	.21	78.70	.21	79.08	.22	79.46	.22
79.76	.22	80.00	.22	80.21	.22	80.35	.22	80.94	.22
81.16	.22	81.58	.22	81.94	.22	82.43	.22	82.67	.23
83.25	.23	83.42	.23	83.67	.23	84.00	.23	84.26	.23
84.50	.23	84.72	.23	84.86	.23	85.16	.23	85.50	.23
85.69	.23	85.97	.23	86.23	.23	86.40	.23	86.77	.24
86.96	.24	87.30	.24	87.61	.24	88.10	.24	88.11	.24
88.14	.24	88.42	.24	88.64	.24	88.90	.24	89.14	.24
89.70	.24	90.14	.24	90.45	.25	90.71	.25	91.00	.25
91.46	.25	91.69	.25	91.81	.25	92.09	.25	92.55	.25
92.81	.25	93.61	.25	94.07	.25	94.25	.26	94.39	.26
94.81	.26	94.90	.26	95.37	.26	95.51	.26	95.81	.26
96.05	.26	96.49	.26	96.83	.26	97.12	.26	97.51	.26
97.87	.26	98.12	.27	98.23	.27	98.59	.27	98.88	.27
99.44	.27	99.71	.27	99.99	.27	100.54	.28	100.96	.28
101.57	.29	102.15	.29	103.01	.30	103.15	.30	103.17	.30
103.56	.31	103.94	.31	104.23	.31	104.76	.32	105.25	.32
106.25	.33	106.37	.33	106.93	.34	108.05	.35	108.46	.35
109.50	.36	109.90	.37	110.56	.37	110.62	.37	110.76	.37
111.16	.39	111.25	.39	113.80	.40	114.09	.41	114.24	.41
115.39	.42	115.82	.42	116.75	.43	117.20	.44	120.40	.47
121.15	.48	121.79	.48	122.70	.49	123.50	.50	127.65	.54
129.97	.56	130.30	.56	131.02	.57	131.21	.57	136.21	.62
136.26	.62	136.34	.62	136.45	.62	136.48	.62	144.21	.70
145.00	.71	148.08	.75	150.10	.76	152.15	.78	152.84	.79
154.20	.81	157.78	.83	158.03	.84	159.94	.85	164.15	.89
167.50	.90	168.17	.91	168.55	.91	168.92	.91	171.06	.93
172.12	.93	172.92	.94	173.10	.94	174.53	.95	175.74	.96
175.47	.96	177.22	.97	178.02	.98	179.74	.99	180.40	1.00
180.71	1.00	181.14	1.00	182.16	1.01	182.39	1.01	183.91	1.03
184.10	1.03	184.52	1.03	184.76	1.04	185.21	1.04	186.60	1.06
188.97	1.06	189.23	1.07	190.70	1.08	190.99	1.09	191.29	1.11
192.38	1.12	192.80	1.13	193.50	1.14	195.14	1.16	196.65	1.19

TABLE A-9 (continued)

λ	σ_I	λ	σ_I	λ	σ_I	λ	σ_I	λ	σ_I
197.41	1.20	198.53	1.22	200.00	1.24	201.10	1.26	202.64	1.29
202.78	1.31	204.89	1.34	206.26	1.36	206.38	1.37	207.46	1.39
208.33	1.41	209.63	1.44	209.78	1.44	209.93	1.45	211.32	1.48
212.15	1.50	214.75	1.55	215.16	1.55	216.90	1.59	218.21	1.61
219.09	1.62	220.06	1.63	221.26	1.64	221.51	1.65	223.26	1.66
223.72	1.67	224.31	1.68	225.12	1.68	227.01	1.70	227.47	1.70
228.79	1.72	230.65	1.75	231.55	1.76	232.60	1.78	233.84	1.80
234.73	1.81	235.55	1.83	237.36	1.86	239.37	1.90	240.73	1.92
243.03	1.96	245.94	2.00	246.24	2.01	246.91	2.02	247.18	2.02
249.23	2.05	251.10	2.08	251.96	2.09	252.17	2.10	253.80	2.12
256.37	2.16	256.69	2.17	257.48	2.18	258.40	2.20	259.50	2.22
261.08	2.25	262.95	2.26	264.27	2.30	264.90	2.31	270.50	2.42
271.99	2.44	272.70	2.46	274.24	2.49	275.35	2.51	275.76	2.51
276.15	2.52	276.77	2.53	277.00	2.54	277.27	2.54	278.40	2.56
281.41	2.62	284.15	2.67	285.65	2.71	288.36	2.75	289.17	2.77
290.72	2.80	291.63	2.81	292.00	2.82	292.83	2.84	295.57	2.89
296.17	2.90	297.50	2.96	303.78	3.04	315.02	3.26	315.05	3.26
316.20	3.28	319.53	3.35	335.05	3.67	335.39	3.68	345.13	3.88
345.74	3.89	347.42	3.92	349.85	3.97	353.86	4.03	356.07	4.07
360.76	4.15	364.80	4.22	368.07	4.28	401.70	5.69	405.00	5.87
406.00	5.92	407.00	5.97	408.00	6.02	409.00	6.07	410.00	6.11
411.00	6.16	412.00	6.21	413.00	6.25	414.00	6.29	415.00	6.33
416.00	6.37	417.00	6.41	417.24	6.42	417.71	6.44	418.00	6.45
419.00	6.49	420.00	6.52	421.00	6.55	422.00	6.59	423.00	6.62
424.00	6.65	425.00	6.68	426.00	6.71	427.00	6.74	428.00	6.76
429.00	6.79	430.00	6.81	430.50	6.83	431.00	6.84	432.00	6.86
433.00	6.88	434.00	6.90	435.00	6.92	436.00	6.94	436.10	6.94
437.00	6.96	438.00	6.96	439.00	6.99	440.00	7.01	441.00	7.02
442.00	7.04	443.00	7.05	444.00	7.06	445.00	7.07	446.00	7.09
447.00	7.10	448.00	7.11	449.00	7.12	450.00	7.13	451.00	7.13
452.00	7.14	453.00	7.15	454.00	7.16	455.00	7.16	456.00	7.17
457.00	7.18	458.00	7.18	459.00	7.19	460.00	7.19	461.00	7.20
462.00	7.20	463.00	7.20	464.00	7.21	465.00	7.21	465.22	7.21
466.00	7.22	467.00	7.22	468.00	7.22	469.00	7.22	469.80	7.23
470.00	7.23	471.00	7.23	472.00	7.23	473.00	7.24	474.00	7.24
475.00	7.24	476.00	7.24	477.00	7.25	478.00	7.25	479.00	7.25
480.00	7.25	481.00	7.26	482.00	7.26	482.10	7.26	483.00	7.26
484.00	7.27	485.00	7.27	486.00	7.28	487.00	7.28	488.00	7.29
489.00	7.29	489.50	7.29	490.00	7.30	491.00	7.30	492.00	7.31
493.00	7.31	494.00	7.32	495.00	7.33	496.00	7.34	497.00	7.35
498.00	7.35	499.00	7.36	499.27	7.37	500.00	7.37	501.00	7.39
502.00	7.40	503.00	7.41	504.00	7.42				

B-1

APPENDIX B

THE DIFFUSIVE TRANSPORT MODEL

The model used for the diffusive transport of atomic oxygen ions is essentially that of Schunk and Walker (1973). There are two relevant equations, the first of which is the equation of continuity

$$\frac{\partial n_j}{\partial t} + \nabla \cdot (n_j \underline{v}_j) = P_j - L_j \qquad \text{(B-1)}$$

where n_j is the number density of species j, $\underline{v}_j$ is the drift velocity, P_j is the production rate, and L_j is the loss rate. The second relevant equation is the equation of motion. If thermal diffusion, viscosity, and non-linear acceleration terms are neglected, the particle drift velocities may be obtained by solving the equations

$$\nabla p_j - n_j m_j \underline{G} - n_j e_j \underline{E} = n_j m_j \sum_k r_{jk} (\underline{v}_k - \underline{v}_j) \qquad \text{(B-2)}$$

where $P_j = n_j k T_j$ is the partial pressure for species j, T_j is its temperature, m_j its mass, e_j its charge, $\underline{G}$ is the acceleration due to gravity, $\underline{E}$ is the electric field, k is Boltzmann's constant, and r_{jk} is the momentum transfer collision frequency of species j with species k. Equation (B-2) is valid for both electrons and ions. Using the subscripts i and j to denote ions, n and m to denote neutrals, e to denote electrons, and the convention that a sum over subscript k is over all particles, equation (B-2) takes the following explicit form for electrons:

$$\nabla p_e - n_e m_e \underline{G} - n_e e_e \underline{E} = n_e m_e \sum_k{}' r_{ek} (\underline{v}_k - \underline{v}_e) \qquad \text{(B-3)}$$

This equation determines the electric field:

$$e\,\underline{E} = \frac{1}{n_e}\left[-\nabla p_e + n_e m_e \underline{G} + n_e m_e \sum_k r_{ek}(\underline{v_e} - \underline{v_k})\right] \qquad \text{(B-4)}$$

where $e \equiv -|e_e|$. The electric field can be eliminated from (B-2) with the help of (B-4). If the neutral atmosphere is assumed stationary, terms of order m_e/m_j are neglected, and ion-ion and ion-electron collision frequencies are neglected (compared to ion-neutral collision frequencies), the equation for a single ion (O^+ in this instance) reduces to

$$\underline{v}_i = -\frac{kT_i}{m_i r_{in}^*}\left[\frac{1}{n_i}\nabla n_i + \frac{1}{T_i}\nabla T_i - \frac{m_i}{kT_i}\underline{G} + \frac{T_e}{n_e T_i}\nabla n_e + \frac{1}{T_i}\nabla T_e\right] \qquad \text{(B-5)}$$

where $r_{in}^* = \sum_n r_{in}$ is the effective ion-neutral collision frequency. For the vertical component, the equation for the drift velocity becomes

$$v_z = -\frac{1}{n} D\left\{\frac{dn}{dz} + n\left[\frac{1}{T}\frac{d(T_e+T)}{dz} + \frac{mg}{kT}\right] + \frac{n}{n_e}\frac{T_e}{T}\frac{dn_e}{dz}\right\} \qquad \text{(B-6)}$$

where $D = \frac{kT}{mr^*}$, and the subscripts have been dropped from quantities that refer to the ion. It can be shown that, in the presence of a magnetic field, the diffusion coefficient D is reduced by the factor $\sin^2 I$, where I is the dip angle. If (B-6) is substituted in (B-1), and the time derivative is set to zero, the resulting diffusion equation is one of second order in the ion density n.