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February 1983

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PHOTOELECTRON ANGULAR DISTRIBUTIONS OF THE N₂O OUTER
VALENCE ORBITALS IN THE 19-31 eV PHOTON ENERGY RANGE

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ABSTRACT

Photoelectron asymmetry parameters, partial cross sections, and branching ratios for the X, A, B, and C states of N_2O^+ were measured using synchrotron radiation in the photon energy range 19-31 eV. Vibrationally-averaged data are reported for all four states, as well as vibrationally-resolved data for the A and C states. The data are compared with a multiple scattering calculation, (e,2e) dipole measurements, and similar data on CO_2 . The N_2O and CO_2 results show remarkable state-by-state similarity in their asymmetry parameters.

I. Introduction

Photoelectron spectroscopy of the individual molecular orbitals of molecules, using tunable-energy radiation, is in principle capable of yielding a great deal of information about molecular electronic structure. This is a consequence of the fact that the photoionization process is sensitive to details of the initial and final electronic states—or, more generally, to the molecular potential.

It is useful first to write the expression for the differential cross section for (dipole) photoemission from a randomly-oriented sample of molecules irradiated by linearly-polarized light:¹

$$\frac{d\sigma(\epsilon, \theta)}{d\Omega} = \frac{\sigma(\epsilon)}{4\pi} [1 + \beta(\epsilon)P_2(\cos\theta)] , \quad (1)$$

where $P_2(\cos\theta) = (3\cos^2\theta - 1)/2$ is the second Legendre polynomial, θ is the angle between the polarization direction and the photoelectron propagation direction, and ϵ is the photoelectron kinetic energy. If spin is neglected,² measurement of both $\sigma(\epsilon)$ and $\beta(\epsilon)$ as functions of ϵ will yield all the measurable information about a given photoionization channel (e.g., ionization from a given molecular orbital). Variation of ϵ is effected by adjusting the photon energy $h\nu$ from a tunable source, such as synchrotron radiation. The two energies are related by

$$h\nu = \epsilon + B \quad (2)$$

for photoionization from an orbital of binding energy B . Thus photoelectron spectroscopy can provide more information than that obtained from more conventional methods, such as absorption spectroscopy, because each photoionization channel with a particular binding energy can be monitored independently. In addition, $\sigma(\epsilon)$ and $\beta(\epsilon)$ are sensitive to the molecular potential in different ways.

As yet, the development of variable-energy photoelectron spectroscopy is in a very early stage. On the experimental side, the increasing availability and use of synchrotron radiation is facilitating the acquisition of a rapidly growing body of data. For example, recently reported data on triatomic molecules such as H_2O ,³ OCS ,⁴ CS_2 ,⁴ and CO_2 ⁵ have measured the sensitivity of both $\sigma(\epsilon)$ and $\beta(\epsilon)$ to shape resonances, autoionization, and predissociation, as well as confirming the sensitivity of these parameters to the molecular potential.

The theoretical situation is still evolving. Modelling the photoionization process is a challenge to theory if the goal is to provide a reasonably accurate description of $\sigma(\epsilon)$ and $\beta(\epsilon)$, while preserving both computational tractability and a faithful description of physically interesting features in the molecular potentials. Among the models used to date, the multiple scattering method (MSM), although it assumes a muffin-tin potential for the molecular potential and very much simplifies the true dynamics of the photoionization process, has nevertheless been successful in describing $\beta(\epsilon)$ and $\sigma(\epsilon)$ for some molecular systems.⁶ Yet to come are a sufficient number of

comparisons between theory and experiment to allow broad conclusions to be drawn concerning the efficacy of various theoretical approaches. Still further away is the stage in which qualitative interpretation of the parameters is feasible, without recourse to careful comparison with theory, to obtain qualitatively useful information.

This paper is organized in three more sections: II. Experimental, III. Results and Discussion, and IV. Conclusions. The body of the paper appears in Section III, in which photoionization of each valence orbital is discussed in turn.

II. Experimental

The photoelectron spectra were obtained using a double-angle time-of-flight spectrometer. A detailed discussion of this instrument has been published.⁷ Two detectors, one placed at 0° and another at 54.7° with respect to the polarization axis of the radiation, detect photoelectrons with microchannel plates. A time spectrum of the photoelectrons is collected, and their intensities as functions of kinetic energy are analyzed to yield $\sigma(\epsilon)$ and $\beta(\epsilon)$. All spectra presented here were collected for 1000 seconds. The $\beta(\epsilon)$ parameters are obtained from the intensity ratio of photoelectrons measured at 0° to those measured at 54.7° . The ratios were corrected for the relative efficiency of the two detectors by a calibration procedure which has been explained in detail.⁸ Relative partial cross sections were obtained from the intensity of photoelectrons measured

at 54.7° , the "magic angle". At this angle the intensity is independent of the asymmetry parameter. After correcting partial cross sections for the transmission of the 54.7° detector, they were normalized for photon flux and sample density, then scaled to the (e,2e) total cross sections given by Hitchcock et al.⁹

The Stanford Synchrotron Radiation Laboratory provides a tunable ultraviolet radiation source at the 8° beam line. Our measurements used photon energies in the range 18–31 eV. The bandpass of the monochromator was 2.7 Å for these experiments. Additional broadening from our spectrometer of ~3% of the kinetic energy of the photoelectrons increases the overall experimental resolution.

III. Results and Discussion

The ground state electronic configuration of N_2O can be written $(1\sigma)^2(2\sigma)^2(3\sigma)^2(4\sigma)^2(5\sigma)^2(6\sigma)^2(1\pi)^4(7\sigma)^2(2\pi)^4 1\Sigma^+$. We present the partial cross sections, branching ratios, and asymmetry parameters for ejection of photoelectrons from the 2π , 7σ , 1π , and 6σ orbitals of N_2O , leading respectively to the X, A, B, and C states of N_2O^+ .

A complete designation of these channels is given by

where $\overline{2\pi}$ denotes a hole in the $(2\pi)^4$ configuration, etc. A comment on notation is needed. Because the photoionization process involves both initial and final states, we believe that clarity is best served, at the cost of a little redundancy, by fully specifying "the $X^2\overline{\Pi 2\pi}$ channel", etc., throughout.

The mean binding energies of these electronic states are 12.9(X), 16.4(A), 18.3(B), and 20.1(C) eV. A typical spectrum, taken at 24.6 eV photon energy and converted to an energy scale, is shown in Fig. 1. The density of data channels varies with the kinetic energy of the detected photoelectrons as $\epsilon^{-3/2}$. Vibrationally-resolved data for the $A^2\Sigma^+\overline{7\sigma}$ and $C^2\Sigma^+\overline{6\sigma}$ channels are shown in Figs. 2 and 3, respectively. It has been proposed by Domcke¹⁰ that the asymmetry parameter as a function of vibrational state may be used to probe vibronic coupling effects in photoelectron spectra. A simplex algorithm¹¹ determined the initial estimates for a nonlinear least squares fitting routine, which deconvolute selected spectra. The peak shapes were assumed to be gaussian. The accuracy of the fitted areas is 10-20 %. The variation of the derived partial cross sections and asymmetry parameters for the vibrational channels is more accurate than an absolute comparison of their values. The assignments of the vibrational modes in N_2O^+ are given by Dehmer et al.¹²

Our results are discussed in the following format. First, the branching ratios of the ionic states referenced to the total cross section are shown in Fig. 4, along with the total cross section. Table I contains a tabulation of the partial cross sections and $\beta(\epsilon)$

for the first four states of N_2O^+ . Section A will discuss the $X^2\Pi_{2\pi}$ channel, Section B the $A^2\Sigma^+_{7\sigma}$ channel, Section C the $B^2\Pi_{1\pi}$ channel, and Section D the $C^2\Sigma^+_{6\sigma}$ channel.

The other figures fall into two groups. Figs. 7 and 10 show vibrational partial cross sections and asymmetry parameters for the A and C states. They are described in the appropriate subsections. The remaining four figures (5, 6, 8 and 9) display the main results of this work. They all have the same format. The MSM calculations of Whitley and Grimm, which will be discussed in detail in a later publication,¹³ are represented by the solid curves for both $\sigma(\epsilon)$ and $\beta(\epsilon)$. The (e,2e) results of $\sigma(\epsilon)$ from Brion and Tan¹⁴ are represented by open circles, and the filled circles represent the present N_2O measurements. The open triangles in the lower panel of Fig. 5 are our recent $\beta(\epsilon)$ results for CO_2 , which will be described in detail in a later publication.

The CO_2 results have been corrected for the difference between the binding energies for the X states of CO_2^+ and N_2O^+ , in order to compare $\beta(\epsilon)$ at equal kinetic energies. The motivation for making a comparison between CO_2 and N_2O is that these two molecules are isoelectronic and have similarities in spectral features. The remarkable similarity between the $\beta(\epsilon)$ parameters for the X ionic states of N_2O^+ and CO_2^+ is intriguing — especially so because the molecules are isoelectronic and the two X states both have $^2\Pi$ symmetry. The other three states of N_2O^+ show $\beta(\epsilon)$ values quite similar to those of the A, B, and C states of CO_2^+ . However, we

are reluctant to draw conclusions from this observation because states of different symmetry must be paired to produce the best match of $\beta(\epsilon)$ values.

A. The $X^2\Pi\overline{2}\pi$ Channel

McLean and Yoshimine¹⁵ have described the 2π molecular orbital as a combination of $N_1(2p)$ and $O(2p)$ atomic orbitals. Fig. 5 presents the cross section and asymmetry parameter for photoelectrons emitted via ionization of this orbital. The partial cross section indicates a probable maximum at ~ 19.2 eV and a minimum at 21 eV, superimposed on a monotonically decreasing overall $\sigma(\epsilon)$. Dibeler et al.¹⁶ obtained a photoionization curve for N_2O which shows an autoionizing peak at 19.2 eV that could be due to the population of superexcited, preionized states followed by internal conversion. Eland¹⁷ observed an $(ns\sigma)$ type resonance at ~ 18.6 eV that appeared strongly in the first four ionic channels.

The MSM calculation agrees only qualitatively with the data in describing the general shape of the decrease in cross section. Our cross section measurements are in good overall agreement with the $(e,2e)$ results.¹⁴

The $\beta(\epsilon)$ results for the $X^2\Pi\overline{2}\pi$ channel, also shown in Fig. 5, start at a low value of -0.2 at 19 eV and increase to an asymptotic value of ~ -0.8 at 30 eV. Because $\sigma(\epsilon)$ does not show any resonance behavior in the high-energy portion of our measurements, Coulomb phase shifts are presumed to be responsible for the rapid variation in

$\beta(\epsilon)$.¹⁸ The $\chi^2_{\Pi_g} \overline{1\pi_g}$ channel in CO_2 is particularly interesting to consider at this point, because it seems to have an almost identical $\beta(\epsilon)$ behavior to that of the $\chi^2_{\Pi_2} \overline{2\pi}$ channel in N_2O (Fig. 5, lower panel). The $1\pi_g$ molecular orbital in CO_2 is composed of out-of-phase overlap of the p_π atomic orbitals on each of the oxygen atoms. Like the N_2O 2π orbital, it is nonbonding with a two-fold degeneracy¹⁹. The similarity in $\beta(\epsilon)$ is probably a consequence of the similarity in the ionic potentials. The MSM calculation of $\beta(\epsilon)$ for N_2O agrees qualitatively with the present measurements.

B. The $A^2_{\Sigma^+} \overline{7\sigma}$ Channel

Calculations suggest that the 7σ molecular orbital of N_2O is composed mainly of $\text{N}_1(2s)$, $\text{N}_2(2p)$, and $\text{O}(2p)$ character, and is weakly bonding.¹⁵ The partial cross section for the corresponding $A^2_{\Sigma^+} \overline{7\sigma}$ channel is shown in Fig. 6. The $\sigma(\epsilon)$ data again show a maximum at around 19.2 eV, and a monotonic decrease to 31 eV photon energy. The maximum in the partial cross section could again be due to an autoionizing resonance, as for the $\chi^2_{\Pi_2} \overline{2\pi}$ channel. There is little agreement with the MSM calculation. The (e,2e) results of Brion and Tan are in excellent agreement with the present measurements, except at ~19.2 eV.

The $\beta(\epsilon)$ parameter for the $A^2_{\Sigma^+} \overline{7\sigma}$ channel starts at a low value, near zero, and increases to an asymptotic value of ~1.2. The MSM calculation is in poor agreement with the measured asymmetry

parameter. The CO_2 $A^2\overline{\Pi}\pi_u$ channel $\beta(\epsilon)$ parameter (not shown) matches the N_2O data remarkably well. However, the two channels are very different. The $1\pi_u$ orbital of CO_2 is composed of two perpendicular pairs of $2p\pi$ orbitals on each atom which are overlapping in-phase to form C — O bonding. Thus, if the symmetry assignments of the two A states are correct — and they appear to be correct — the similarity of the two $\beta(\epsilon)$ parameters remains unexplained.

Fig. 2 shows a typical vibrationally-resolved spectrum collected at $h\nu = 20$ eV plotted linearly in time. Both the log and linear plots were fitted with the simplex and nonlinear least-squares routines. The log plot confirms that there are five vibrational peaks in the spectrum: in particular, the (0,0,2) line is evident. We could not determine $\sigma(\epsilon)$ and $\beta(\epsilon)$ values for the (0,0,2) peak, because of its weak intensity. The four vibrational peaks analyzed correspond to the (0,0,0), (1,0,0), (0,0,1), and the (1,0,1) vibrational modes, with binding energies of 16.40, 16.57, 16.71, and 16.85 eV, respectively.²⁰ The quantum numbers represent, from left to right, the symmetric, bending, and asymmetric stretch modes.

The derived $\sigma(\epsilon)$ and $\beta(\epsilon)$ values for the vibrationally resolved $A^2\Sigma^+\overline{7}\sigma$ channel at selected photon energies are presented in Table II. The $\sigma(\epsilon)$ and $\beta(\epsilon)$ values of the (0,0,0), (1,0,0), (0,0,1), and (1,0,1) channels are shown in Fig. 7. The $\beta(\epsilon)$ parameter for the (0,0,1) channel is not plotted for clarity, because it has poor statistical error over most of the 19 to 21 eV photon energy range. The $\sigma(\epsilon)$ and $\beta(\epsilon)$ values for individual members of this vibrational

manifold show varied behavior, indicating that more information is available at higher resolution. The vibrationally-unresolved cross section, illustrated in Fig. 6, shows only weak structure in the $h\nu = 19-21$ eV region, whereas the resolved cross sections show more variation. The unresolved $\beta(\epsilon)$ values tend to smooth out structure because the radial dependencies of the various channels are averaged.²¹ These results illustrate the well-known principle that vibrationally-resolved asymmetry parameters contain information about the dependence of $\beta(\epsilon)$ on the internuclear separations in molecules.²²

C. The $B^2\Pi\overline{\Pi}$ Channel

According to McLean and Yoshimine,¹⁵ the 1π molecular orbital is mostly the result of N-O π bonding with little N-N bonding character. Our $\sigma(\epsilon)$ and $\beta(\epsilon)$ results are presented in Fig. 8. The partial cross-section data show a low point at 20 eV and a high value at 21.2 eV. The low point may arise through a competing mechanism dissociating this channel. Lorquet and Cadet²³ have calculated potential energy surfaces of N_2O and a correlation diagram of the N_2O ion to show the possible dissociation channels. Their calculations predict an asymptotic dissociation at 20.29 eV above the ground state of N_2O . The process is

More careful measurements near 20 eV are warranted. The MSM calculation predicts $\sigma(\epsilon)$ values that are about 50% lower than the present results and that show a different energy dependence. Again, there is good agreement between our data and the (e,2e) results.

The $\beta(\epsilon)$ values show variations at ~22 eV and below which could arise from the same causes as the variations in $\sigma(\epsilon)$. The asymmetry parameter $\beta(\epsilon)$ starts at a low value, near zero, and increases to unity. There is only fair agreement with the MSM calculation of Whitley, et al.¹³ The $C^2\Sigma_g^+ \overline{4\sigma_g}$ results for $\beta(\epsilon)$ in CO₂ (not shown) are in fair to good agreement with $\beta(\epsilon)$ for the $B^2\Pi\pi$ channel in N₂O. However, we are again reluctant to draw any conclusions from this similarity because the states have different symmetries.

D. The $C^2\Sigma_g^+ \overline{6\sigma}$ Channel

The 6σ molecular orbital is a combination of N-O and N-N antibonding s-like orbitals.¹⁵ The partial cross sections and asymmetry parameters for this channel are shown in Fig. 9. The cross section varies slowly over the entire photon energy range, and there is no evidence of resonances. The agreement between the behavior of the calculated MSM partial cross sections and the present results is poor, but once again there is excellent agreement with the (e,2e) measurements.

The asymmetry parameter for the $C^2\Sigma_g^+ \overline{6\sigma}$ channel shows a steep increase from -0.5 at 21 eV to 1.0 at 31 eV, with most of the rise

occurring between 24 and 27 eV. The variation of $\beta(\epsilon)$ for this channel is very different than that of the first three channels. As was the case for $\sigma(\epsilon)$, there is poor agreement between the MSM calculation of $\beta(\epsilon)$ and our results. However, the $\beta(\epsilon)$ data for the $B^2\Sigma_u^+3\sigma_u$ channel in CO_2 (not shown) follow these data quite closely. The $3\sigma_u$ molecular orbital of CO_2 , according to Mulligan,²⁴ is also nearly nonbonding, with "sp" oxygen character. Hybridized 2s and 2p orbitals on the oxygen atoms overlap a $2p\sigma$ orbital on the carbon atom.

Fig. 3 shows the partially-resolved vibrational peaks observed in the time-of-flight spectra for the $C^2\Sigma^+6\sigma$ channel. There are three peaks, corresponding to the (0,0,0), (1,0,0), and (0,0,1) channels, with binding energies of 20.15, 20.30, and 20.43 eV, respectively.²⁰ The $\sigma(\epsilon)$ and $\beta(\epsilon)$ values for these peaks are shown in Fig. 10. Partial cross sections and asymmetry parameters are tabulated in Table III. The $\beta(\epsilon)$ results do not show any resonance behavior, but they vary over a large range, and $\beta(\epsilon)$ for the (1,0,0) vibrational mode is near -1 for the entire region measured.

IV. Conclusions

The main conclusions of this work are as follows:

(1.) The partial photoelectron cross sections and asymmetry parameters for the first four ionic states of N_2O were measured.

They were found to be substantially different for the X, A, B, and C ionic states, demonstrating the sensitivity of $\sigma(\epsilon)$ and $\beta(\epsilon)$ to details of the molecular potential.

(2.) Resolved measurements of $\sigma(\epsilon)$ and $\beta(\epsilon)$ for individual vibrational levels in the A and C states showed large variations with vibrational quantum numbers, demonstrating high sensitivity to internuclear spacing.

(3.) The published (e,2e) partial cross sections of Brion and Tan are in good or excellent agreement with the present results.

(4.) There is a close empirical, pairwise correspondence between the $\beta(\epsilon)$ values for the molecular orbitals of CO_2 and N_2O . The correspondence is between the CO_2 $X^2\Pi_g \overline{1}\pi_g$ and N_2O $X^2\Pi \overline{2}\pi$, CO_2 $A^2\Pi_u \overline{1}\pi_u$ and N_2O $A^2\Sigma^+ \overline{7}\sigma$, CO_2 $C^2\Sigma_g^+ \overline{4}\sigma_g$ and N_2O $B^2\Pi \overline{1}\pi$, and CO_2 $B^2\Sigma_u^+ \overline{3}\sigma_u$ and N_2O $C^2\Sigma^+ \overline{6}\sigma$ ionic states. The significance of this observation is unclear. In the first and last pairs, states of the same symmetry are matched, but the other two pairs involve states of opposite symmetry.

(5.) Better calculations are needed to describe the measured asymmetry parameters and partial cross sections.

Acknowledgements

We would like to thank T.A. Carlson for a discussion of his upcoming paper on the photoionization of N_2O . We also thank T.A. Whitley and F.A. Grimm for their MSM calculations prior to publication.

This work was supported by the Director, Office of Energy Research, Office of Basic Energy Sciences, Chemical Sciences Division of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098. It was performed at the Stanford Synchrotron Radiation Laboratory, which is supported by the NSF through the Division of Materials Research.

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Figure Captions

- Figure 1. TOF photoelectron spectrum showing the $X^2\Pi2\pi$, $A^2\Sigma^+7\sigma$, $B^2\Pi1\pi$, and $C^2\Sigma^+6\sigma$ ionic states of N_2O^+ .
- Figure 2. TOF photoelectron spectrum showing the $A^2\Sigma^+7\sigma$ vibrational states of N_2O^+ . The curves in the linear spectrum are deconvoluted peaks from nonlinear least-squares fits. The curve in the log plot represents the sum of deconvoluted peaks calculated with the same fitting method.
- Figure 3. TOF photoelectron spectrum showing the $C^2\Sigma^+6\sigma$ vibrational states of N_2O . The curves are the deconvoluted peaks as in Fig. 2.
- Figure 4. Branching ratios to the ionic states in N_2O^+ , and total photoionization cross section of N_2O . The symbols represent states as follows: $X(\Delta)$, $A(O)$, $B(\blacksquare)$, and $C(\square)$. All are referenced to our total cross-section measurements, denoted by $\bullet$. The $\blacktriangle$ are (e,2e) total cross-section measurements of Brion and Tan.¹⁴
- Figure 5. The $\sigma(\epsilon)$ and $\beta(\epsilon)$ results for the $X^2\Pi2\pi$ ionic state. The present results are plotted as filled circles. The curves are the MSM calculations of Whitley and Grimm.¹³ Open circles in the $\sigma(\epsilon)$ plot are the (e,2e) results of Brion and Tan.¹⁴ Open triangles in the $\beta(\epsilon)$ panel are our measurements on the $X^2\Pi_g1\pi_g$ state of CO_2 . The

CO₂ results were adjusted by 0.9 eV to compare equal kinetic energies.

Figure 6. The $\sigma(\epsilon)$ and $\beta(\epsilon)$ results for the $A^2\Sigma^+7\sigma$ ionic state. The notation is similar to Fig. 5.

Figure 7. Vibrational resolved $\sigma(\epsilon)$ and $\beta(\epsilon)$ of the $A^2\Sigma^+7\sigma$ ionic state.

Figure 8. The $\sigma(\epsilon)$ and $\beta(\epsilon)$ values for the $B^2\Pi\pi$ ionic state. The notation is similar to Fig. 5.

Figure 9. The $\sigma(\epsilon)$ and $\beta(\epsilon)$ values for the $C^2\Sigma^+6\sigma$ ionic state. The notation is similar to Fig. 5.

Figure 10. Vibrational resolved $\sigma(\epsilon)$ and $\beta(\epsilon)$ of the $C^2\Sigma^+6\sigma$ ionic state.

Table I. Cross sections and asymmetry parameters of the X, A, B, and C Channels to N_2O^+ .

$h\nu(\text{eV})$	$\chi^2_{\Pi 2\pi}$		$A^2_{\Sigma^+7\sigma}$		$B^2_{\Pi 1\pi}$		$C^2_{\Sigma^+6\sigma}$	
	$\sigma(\text{Mb})^a$	$\beta(\epsilon)$	$\sigma(\text{Mb})$	$\beta(\epsilon)$	$\sigma(\text{Mb})$	$\beta(\epsilon)$	$\sigma(\epsilon)$	$\beta(\epsilon)$
19.0	15.29(34) ^b	0.24(2)	12.09(28)	0.07(1)				
19.2	17.00(40)	-0.15(3)	15.57(37)	0.00(3)	8.89(22)	0.20(4)		
20.0	15.64(35)	-0.12(2)	10.90(25)	0.20(3)	7.89(18)	0.22(3)		
20.5	14.30(32)	-0.06(3)	9.12(21)	0.39(4)	10.17(23)	0.18(3)		
21.2	12.27(27)	-0.03(3)	8.76(21)	0.43(1)	11.48(27)	0.11(3)	6.70(16)	-0.36(2)
		0.0(1) ^c		0.35(10) ^c		-0.2(2) ^c		-0.4(2) ^c
21.8	13.03(30)	0.15(3)	6.30(15)	0.67(5)	10.26(25)	0.48(4)	5.94(14)	-0.26(2)
23.0	14.18(31)	0.32(3)	6.34(15)	0.81(2)	10.28(24)	0.45(4)	6.24(12)	-0.17(2)
24.0	13.12(29)	0.41(4)	5.55(13)	0.90(3)	9.93(23)	0.58(4)	5.70(14)	-0.13(3)
25.0	13.74(30)	0.50(4)	4.59(12)	1.00(3)	10.01(24)	0.73(5)	5.39(13)	0.13(3)
26.0	12.52(28)	0.61(4)	4.27(11)	1.06(3)	9.31(22)	0.85(5)	4.61(12)	0.45(5)
27.0	12.70(31)	0.68(5)	4.38(13)	1.07(6)	8.49(22)	1.08(7)	4.58(13)	0.80(7)
28.0	12.29(22)	0.86(5)	4.23(10)	1.15(7)	8.46(19)	1.00(6)	3.67(9)	0.87(6)
29.0	11.27(29)	0.76(5)	4.88(15)	1.03(4)	8.56(22)	1.06(7)	3.13(10)	0.90(7)
29.5	8.80(22)	0.88(6)	3.83(11)	1.17(8)	7.61(19)	1.01(6)	3.04(12)	0.95(7)
31.0	9.87(31)	0.78(6)	4.37(18)	1.16(5)	7.92(25)	1.09(9)	3.26(15)	0.96(10)

(a) Absolute cross sections were obtained by scaling to (e,2e) data (Ref. 9).

(b) Errors in the last place are given parenthetically.

(c) Ref. 25.

Table II. Cross sections and asymmetry parameters of the $A^2\Sigma^+7\sigma$ vibrational channels of N_2O^+ .

$h\nu(\text{eV})$	$(0,0,0)$			$(1,0,0)$			$(0,0,1)$			$(1,0,1)$		
	$\sigma(\text{Mb})^a$	$\beta(\epsilon)$	$\sigma(\text{Mb})$	$\beta(\epsilon)$	$\sigma(\text{Mb})$	$\beta(\epsilon)$	$\sigma(\text{Mb})$	$\beta(\epsilon)$	$\sigma(\text{Mb})$	$\beta(\epsilon)$	$\sigma(\text{Mb})$	$\beta(\epsilon)$
19.0	7.42(16)	0.16(3)	3.39(16)	0.04(5)	0.72(7)	0.76(9)	0.55(13)	-.45(7)				
19.2	9.33(34)	0.11(3)	4.91(35)	-0.34(5)	0.94(19)	0.70(25)	0.39(5)	.02(12)				
20.0	6.12(47)	0.36(2)	3.46(47)	-0.30(10)	1.09(40)	0.23(45)	0.21(2)	.28(16)				
20.5	5.37(38)	0.76(11)	3.61(40)	-0.21(8)	0.52(10)	0.90(36)	0.42(11)	.18(36)				
21.2	5.86(12)	0.57(3)	1.78(8)	0.61(9)	0.76(4)	0.49(15)	0.35(4)	.02(26)				
		0.35^b		$0.45(5)^b$		$0.20(20)^b$						

(a) The total cross section was obtained by scaling to (e,2e) data (Ref. 9).
(b) Ref. 25.

Table III. Cross sections and asymmetry parameters of the $C2\Sigma^+6\sigma$ vibrational channels of N_2O^+ .

$h\nu(\text{eV})$	$(0,0,0)$		$(1,0,0)$		$(0,0,1)$	
	$\sigma(\text{Mb})^a$	$\beta(\epsilon)$	$\sigma(\text{Mb})$	$\beta(\epsilon)$	$\sigma(\text{Mb})$	$\beta(\epsilon)$
23.0	4.05(10)	.36(3)	1.32(7)	-.75(4)	0.88(7)	-.51(6)
24.0	3.53(38)	.15(11)	1.17(24)	-.72(6)	1.38(17)	-.46(9)
25.0	3.45(38)	.57(12)	1.65(70)	-.70(13)	1.35(23)	-.18(12)
26.0	3.14(23)	.80(5)			1.47(18)	-.17(11)

(a) The total cross section was obtained by scaling to (e,2e) data (Ref. 9).

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Figure 1

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Figure 2

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Figure 3

Figure 4

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Figure 5

Figure 6

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Figure 7

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Figure 8

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Figure 9

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Figure 10

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