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TECHNICAL REPORT 19

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RECENT STUDIES OF VIBRATIONAL EXCITATION
OF N₂ BY ELECTRON IMPACT

G. J. SCHULZ

ARPA Order Number: 125-62 (Amd. 7)

Contract Number: NONR 2584(00)

Project Code: 2720

Principal Investigators: A. V. Phelps
G. J. Schulz

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Physics Department
Westinghouse Research Laboratories
Pittsburgh 35, Pennsylvania

This research is a part of Project DEFENDER, sponsored by the
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G. J. Schulz,

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RECENT STUDIES OF VIBRATIONAL EXCITATION
OF N₂ BY ELECTRON IMPACT*

G. J. Schulz
Westinghouse Research Laboratories
Pittsburgh 35, Pennsylvania

↓
The vibrational excitation of nitrogen molecules by electron impact ~~has been recently studied using a double electrostatic analyzer.~~ (1)
In that experiment, to be referred to as Part I, the forward scattered electrons were analyzed for energy losses and it was found that vibrational levels were excited up to the eighth level when the incident electron energy was between 1.7 and 3.5 eV. The experiment of Part I had two deficiencies, namely (a) the elastically scattered electrons could not be distinguished from the primary beam since there is essentially no energy loss connected with the elastically scattered electrons and (b) the cross section to the first vibrational level, $v = 1$, could not be measured because the residual background current from the primary beam was too high. Both these deficiencies are associated with the fact that electrons were analyzed in the forward direction. The present experiment overcomes both these deficiencies by analyzing electrons at ^{an} ~~another~~ angle, ^{of 72 degrees.} which is ~~arbitrarily chosen as 72 degrees.~~ Also it seemed desirable to

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ascertain that the basic conclusions arrived from the experiment of Part I, namely that a compound state of nitrogen, N_2^- , is consistent with the observed vibrational excitation, can be substantiated with experiments at another angle.

I. Experiment

A schematic diagram of the apparatus is shown in Fig. 1. It is identical to that described in Part I except for the angle of collection, the addition of a multiplier at the output, and the focusing electrodes just before and after the collision chamber. The operation of the instrument is described in the caption. A separate differential pumping system is used for pumping on the electron multiplier. More details of the new instrument will be given in a subsequent publication.

II. Results

Figure 2 shows the energy dependence of the cross section for excitation of $v = 1$ through $v = 8$. The relative magnitude of the cross sections is significant; the absolute cross section scale is arbitrary. Several features of these curves are noteworthy. The cross section for $v = 1$ does not reach zero sharply around 1.7 eV, as would be expected by comparison with the other cross sections. The long tail of the cross section below 1.7 eV is attributed to "direct" excitation of the first vibrational level. This is consistent with a recent analysis by Phelps, Engelhardt, and Risk of transport coefficients obtained from swarm experiments.

It should be noted that there is a definite shift of the electron energies at which the peaks occur. The electron energy at which the peak occurs increases as one goes to higher vibrational states.

The elastic cross section also exhibits structure in the energy range 1.7 to 3.5 eV, with four pronounced peaks evident.

III. Discussion

from right
~~As in Part I,~~ the vibrational excitation in N_2 is interpreted as a process involving a compound state of the nitrogen molecule. Baranger and Gerjuoy⁽²⁾ have pointed out that compound states may play an important role in atomic excitation by electron impact. Herzenberg and Mandl⁽³⁾ have extended these considerations to N_2 molecules. They consider two limiting cases, namely a lifetime long or short compared to vibrational times. When the lifetime is long one would expect a number of well defined peaks in the cross section to the individual vibrational levels, all peaks occurring at the same energy. Since there is a definite shift in the position of the peaks as one goes to higher vibrational states (see Fig. 2), this simple model is not sufficient.

One should remark that, if the lifetime of the compound state were long compared to 10^{-14} sec, i.e. of the order of 10^{-13} sec, then the peaks would be so narrow on the energy scale that, even with the good energy resolution employed in the present experiment, one would not be able to observe them. From these considerations one would conclude that the lifetime of the compound state is comparable to the vibration time, i.e., of the order of 10^{-14} sec. *to the -14th power* This conclusion is consistent with the theory of Herzenberg and Mandl.

References

1. G. J. Schulz, Phys. Rev. 125, 229, 1962.
2. E. Baranger and E. Gerjuoy, Phys. Rev. 106, 1182, 1957; and
Proc. Roy. Soc. (London) A72, 326, 1958.
3. A. Herzenberg and F. Mandl, Proc. Roy. Soc. A270, 48, 1962.

Figure Captions

Figure 1 Schematic diagram of double electrostatic analyzer. Electrons from the filament traverse the first electrostatic analyzer at about 1.5 eV energy. They are accelerated into the collision chamber where they are crossed by a molecular beam. Those electrons scattered at 72 degrees are energy analyzed in the second electrostatic analyzer. After passing through the second electrostatic analyzer, electrons impinge on an electron multiplier and the output is measured on a vibrating reed electrometer operated at +2000 volts above ground.

Figure 2 Energy dependence of vibrational excitation of N_2 by electron impact. If the electron energy at which the peaks occur is plotted against vibrational quantum number, a family of linear lines is obtained. The line corresponding to the first peak is essentially parallel to the lines for the second, third or fourth peaks.

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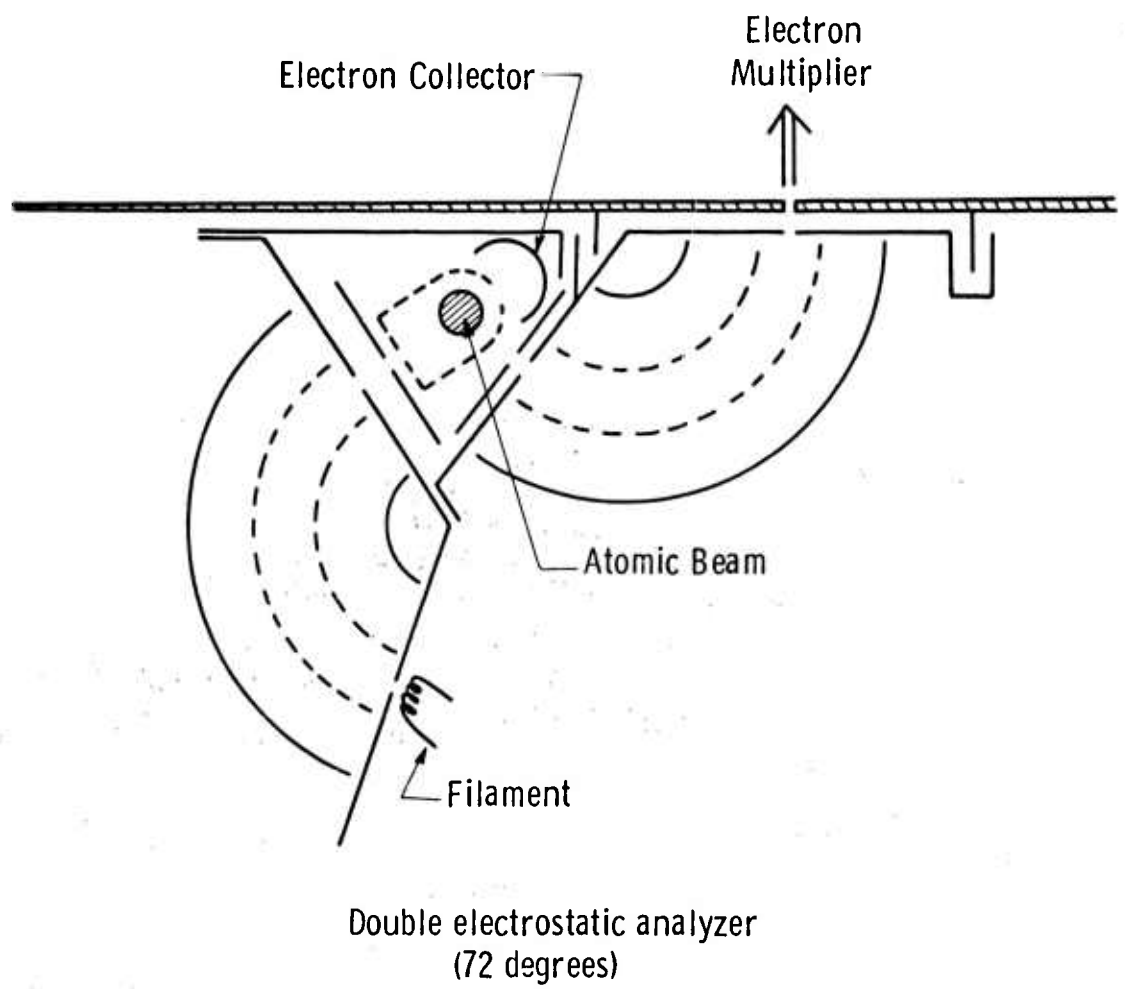


Figure 1. Schematic diagram of double electrostatic analyzer.

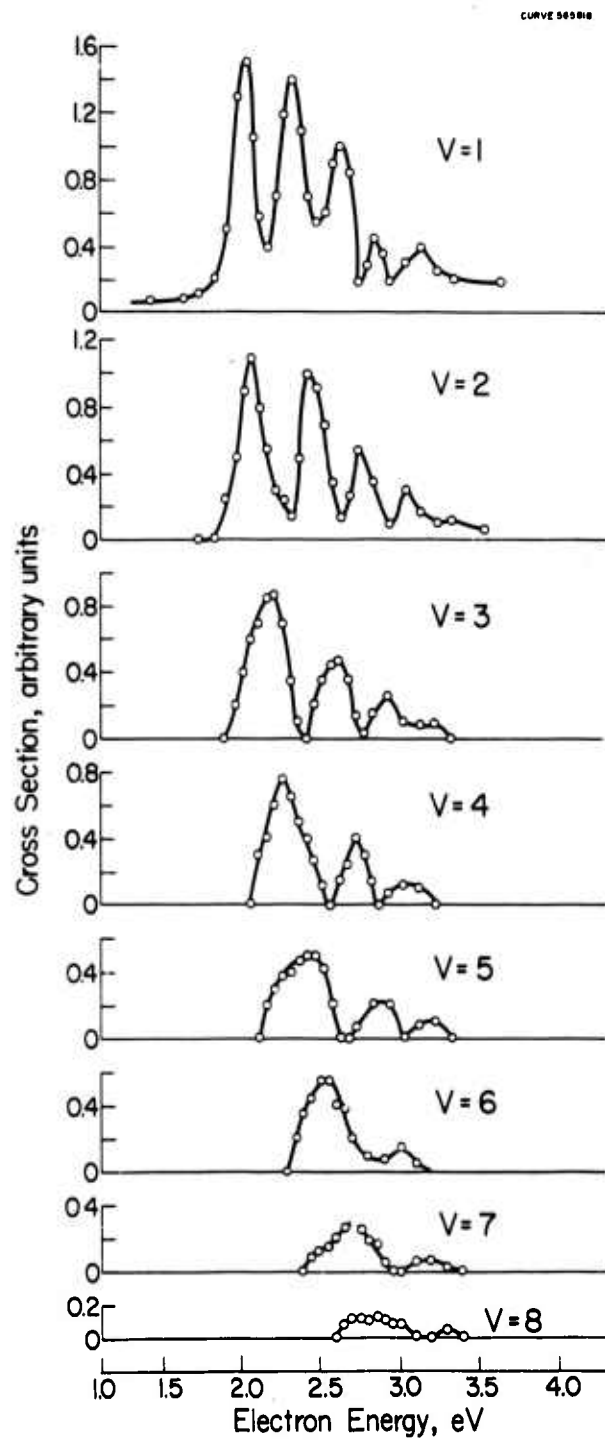


Figure 2. Energy dependence of vibrational excitation of N_2 by electron impact.

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