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ELECTRON EXCITATION OF THE $^1\Pi$ AND $2^1\Sigma^+$ STATES OF N_2O

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Abstract. - In this work a system for experimental data analysis is presented. An experiment for measuring relative differential cross sections for the electron - atom scattering oscillator strength (GOS) has been applied to the electron excitation of the $2^1\Sigma^+$ state of N_2O. Measurements were made at electron impact energies of 15, 20, 30, 50 and 80 eV using the electron spectrometer briefly described here. For the transition from the ground state to the $2^1\Sigma^+$ we determined the optical oscillator strength (OOS) to be 0.13 ± 0.02, from the absolute value of DCS at 80 eV electron impact energy and the absolute DCS value at 30 eV.

1. INTRODUCTION

Nitrous oxide has been a molecule of broad interest in science and application. Nevertheless, the quantitative description of excitation processes by electron impact is scare in the literature. Electron impact excitation and assigment of the low - lying electronic states of nitrous oxide (states lying within 10 eV of the ground state), reported by Hall *et al.* [1]. Marinković *et al.* [2], have determined absolute values for differential cross - sections (DCS) for the excitation of the $^1\Pi$ (energy loss of 8.5 eV) and $2^1\Sigma^+$ (energy loss of 9.6 eV) states at single impact energy (80 eV). They had

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also determined relative DCS for these transitions at 15, 20, 30 and 50 eV impact energies. Very recently, Michelin *et al.* [3] have calculated DCS for the $^1\Pi$ and $^3\Pi$ states at 10, 12.5, 15, 20, 30, 50 and 80 eV impact energies.

In this letter, we present for the first time a method for normalizing differential cross sections emplying forward scattering function for generalized oscillator strengths (GOS) developed by Avdonina *et al.* [4]. Absolute DCS at 80 eV have been converted to GOS values in order to determine optical oscillator strength (OOS) for the transition from the ground state to the $2^1\Sigma^+$ state. Normalizing relative GOS values at other impact energies on the thus derived forward scattering function at zero scattering angle, we have obtained absolute values of DCS for this transition.

2. THEORY

Momentum dispersion method (MDM) of Haffad *et al.* [5] uses the more accurately determined larger angular measurements to extrapolate the experimental data through the difficult to access small-angle, including zero, regime to obtain reliable DCSs. The GOS, denoted as $f(K,E)$ and DCS, $\mathrm{d}\sigma/\mathrm{d}\Omega$, values for atomic and molecular excitation by an electron are related by

$$f(K,E) = \frac{\omega}{2}\frac{k_\mathrm{i}}{k_\mathrm{f}} K^2 \left(\frac{\mathrm{d}\sigma}{\mathrm{d}\Omega}\right), \tag{1}$$

where k_i and k_f are the electron momenta before and after the collision, K is the momentum transfer, ω and E are the excitation and impact energies, respectively (atomic units are used throughout). The dimensionless variables

$$x = \frac{K^2}{2\omega}, \quad t = \frac{\omega}{E}, \quad y = \cos\theta \tag{2}$$

transform the expression for K^2 to

$$xt = 2 - t - 2\sqrt{1-ty} \tag{3}$$

with the conditions $0 \le t \le 1$, $x \ge 0$ whereas y is unrestricted. Recently, Avdonina *et al.* [4] have used equations (2) and (3) to obtain the forward scattering function

$$\phi(x) = f^0 \left[1 - \frac{x}{x_\mathrm{max}}\right] \mathrm{e}^{(x/x_\mathrm{max})^2} \tag{4}$$

where $x_\mathrm{max} = 0.25$ and f^0 is the OOS. Eq. (4) provides a unique path, without transversing the unphysical region ($y > 1$), through the $\theta = 0°$ GOS points at various E-values to reach the OOS at $K^2 = 0$ with $E_\mathrm{min} = 2.5\,\omega$ such that $t = 4x/(1+x)^2$.

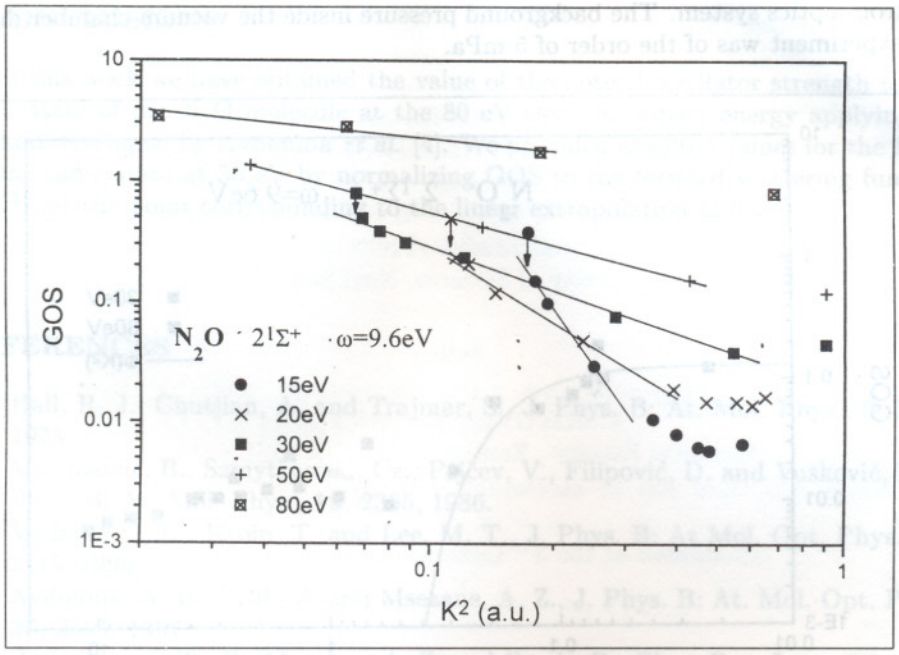

Fig. 1. - Generalized oscillator strength for the $2^1\Sigma^+$ state of N_2O in relative units versus squared momentum transfer, K^2.

3. EXPERIMENT

The electron spectrometer used in this experiment is designed for crossed beam measurements. The electron beam is formed in the system of cylindrical electrostatic lenses and hemispherical energy selector. It is focussed by means of a zoom-lens to intersect the molecular beam (formed by a 2.5 cm long and 0.05 cm wide tube) at 90°. Detection of the scattered electrons is done by the rotating analyzer which covers the angular range form −30° to 150°, in the plane perpendicular to the molecular beam. A constant position between an analyzer and the molecular beam source has been provided by fixing the gas-tube to the analyzer's support and rotating them together. The analyzer is of the same construction as the electron monochromator except that it has a channel electron multiplier as a single-electron detector at the end. All materials used in the apparatus were carefully checked to be non-magnetic and the external magnetic fields were minimized by a double μ-metal shield inside the vacuum chamber. Electrodes are made of OFHC copper and gold plated, while the hemispheres and diaphragms are made of molybdenum.

The best obtained energy resolution was 38 meV and the angular uncertainty was estimated to be 0.5°.

Two diffusion pumps provide differential pumping of the vacuum chamber and

electron - optics system. The background pressure inside the vacuum chamber during the experiment was of the order of 5 mPa.

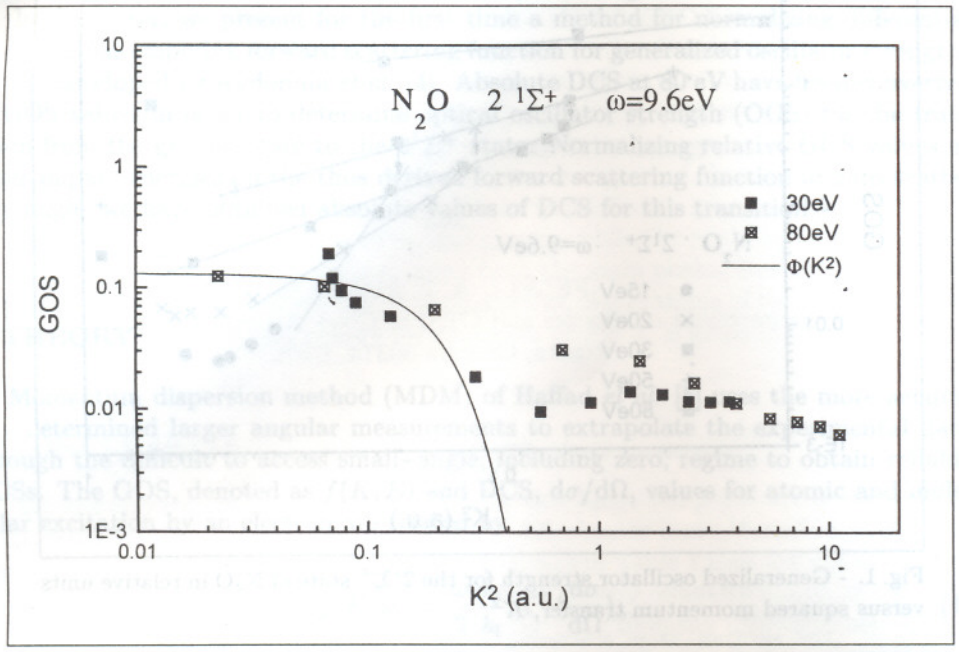

Fig. 2. - Generalized oscillator strength in absolute units, for 80 eV and 30 eV electron impact energy.

4. RESULTS

Firstly, we check the accurary of the small angle (near $\theta = 0°$) measured data. For this we exploit the linear variation of the GOS with K^2 in an appropriate representation [4], which covers many scattering angles when E is close to ω. Fig. 1 shows a plot of the unnormalized measured relative data on a log - log graph for the $2^1\Sigma^+$ state of N_2O at $E = 15$, 20, 30, 50 and 80 eV. Consistent with the MDM, the data points near $\theta = 0°$ are connected by straight lines, ignoring the extraneous points, particularly those at $\theta = 0°$.

Secondly, the absolute data at 80 eV are converted to GOS. The forward scattering function, $\Phi(K^2)$, for GOS [4] is then normalized at the corresponding K^2 value to the GOS value at $\theta = 0°$. This is shown in Fig. 2. Extrapolating this curve at $K^2 = 0$ values, we obtain the OOS for the transition from the ground state to the $2^1\Sigma^+$ state. It is determined to be 0.13 ± 0.02. Then, the data points at 30 eV impact energy are normalized at $\Phi(K^2)$ curve at the point corresponding to the linear extrapolation at $\theta = 0°$. The measured value at $\theta = 0°$ is excluded as an erroneous value.

5. CONCLUSIONS

In this work we have obtained the value of the optical oscillator strength for the $2^1\Sigma^+$ state of the N_2O molecule at the 80 eV electron impact energy applying the method developed by Avdonina *et al.* [4]. We provided absolute values for the DCSs for the same state at 30 eV by normalizing GOS to the forward scattering function $\Phi(K^2)$, at the point corresponding to the linear extrapolation at $\theta = 0°$.

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