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## Observation of the $R(0.5) \ ^2\Pi_{1/2}$ transition of $^{15}\text{N} \ ^{18}\text{O}$ in helium nanodroplets

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### Abstract

Using our diode-laser- helium cluster machine setup we were able to detect the R(0.5)  $^2\Pi_{1/2}$  transition in  $^{15}\text{N}^{18}\text{O}$  at  $1796.38\text{ cm}^{-1}$ . The line is red-shifted by  $1.55\text{ cm}^{-1}$  with respect to the gas-phase. The transition has a FWHM of  $0.050\text{ cm}^{-1}$ , which agrees very well with the result for  $^{14}\text{N}^{16}\text{O}$ , indicating rotational relaxation.

## 1 Introduction

Spectroscopy of molecules in helium nanodroplets is seen as a promising technique to study ultracold chemical reactions. Following the pioneering studies on spectroscopy of dopants in helium droplets [1], [2] there is an increasing interest in the study of radicals at ultralow temperatures [3], [4]. We have recently reported the measurement of the Q(0.5) and R(0.5) transition of the  $^{14}\text{N}^{16}\text{O}$   $^2\Pi_{1/2}$  state. For the Q(0.5) we were able to fully resolve the  $\Lambda$ -doubling and hyperfine splitting; for the R(0.5) we found a lifetime-broadening, which did not permit a further resolution [5]. Within this note we present the measurement of the R(0.5) transition of the isotope  $^{15}\text{N}^{18}\text{O}$ .

## 2 Experimental

The experiments have been carried out using our helium-cluster machine in combination with our diode-laser, as is shown in figure 1. The setup is similar to that used by Hartmann et al. and explained in detail elsewhere [6]. Here we give only a brief description. Helium is expanded at 40 bar and 20 K through a nozzle of 5  $\mu\text{m}$  in diameter into vacuum, which leads to the formation of large droplets of a mean size of  $N = 3000$  atoms. These are doped with NO while passing through a chamber, which is filled with NO gas at a pressure of  $\approx 2.5 \cdot 10^{-5}$  mbar. The pick-up pressure is chosen so that the maximum of the poisson distribution is peaked at a single molecule, which is subsequently embedded in the liquid He-droplet. The doped droplets then interact with laser light, which is collinearly coupled into the vacuum chamber. After 1240 mm distance, they enter the ionization region of a quadrupole mass spectrometer. Infrared radiation is generated by means of a lead salt laser diode (Laser Components). Frequency calibration is achieved by simultaneously measuring the absorption lines of about 10 mbar NO at room temperature in a cell, whose frequencies are well known [7]. The laser beam also passes through a confocal etalon in order to linearize the spectrum. The accuracy in absolute frequencies is  $0.01 \text{ cm}^{-1}$ . Absorption of IR photons is detected by means of beam depletion. We assume that after IR excitation the NO molecule remains in a vibrationally metastable state. Energy transfer to the He can occur by pick-up of a second molecule. This will cause coagulation into a van der Waals complex, which has many low lying combination modes. These can couple efficiently to the He modes and, thus, release the vibrational excess energy. An energy transfer to the He droplet leads to the evaporation of 300 to 400 He atoms due to the vibrational excess energy. The depletion signal is measured using a high-pass filter, which integrates over all masses 10 and higher. This revealed the best signal to noise ratio.

## 3 Measurements and Discussion

We have scanned the frequency range between **1796.27** and  $1796.70 \text{ cm}^{-1}$  and found one transition at the position  $1796.38 \text{ cm}^{-1}$ . This has been assigned as the

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8 R(0.5)  $^2\Pi_{1/2}$  transition (see figure 2). Several scans were added and averaged in  
9 order to increase the signal to noise ratio. A Lorentz-fit yielded a FWHM of 0.05  
10  $\text{cm}^{-1}$  which corresponds to a lifetime of  $1.06 \times 10^{-10}$  s. If we compare this to the  
11 lifetime of the same transition in  $^{14}\text{N}^{16}\text{O}$  which has been observed earlier in our  
12 group [5] we find a similar width and frequency shift compared to the gas-phase.  
13 All results are summarized in table ???. We conclude in accordance with our  
14 previous publication [5] that the lineshape is dominated by lifetime-broadening,  
15 which is supported by the Lorentz fit. This observation confirms our previous  
16 assumption that the main path of energy relaxation is the rotational relaxation  
17 from  $J = 1.5$  to the  $J = 0.5$  level in the vibrational excited state. Additional  
18 transitions were not accessible within the frequency range of our laser.

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	gas-phase	He-cluster	frequency shift	FWHM
$^{15}\text{N}^{18}\text{O}$	1797.93260(17) [8] *	1796.38(1)	1.55(1)	0.050(2)
$^{14}\text{N}^{16}\text{O}$	1881.040895(21) [7]	1879.386(4) [5]	1.655(4)	0.04648(18)

Table 1: IR spectroscopy of NO in helium nanodroplets for  $^{14}\text{N}^{16}\text{O}$  and  $^{15}\text{N}^{18}\text{O}$

\* Center frequency of the two hyperfine components

all values are given in  $\text{cm}^{-1}$

Figure captions:

Fig. 1: The diode-laser spectrometer in combination with the helium cluster machine

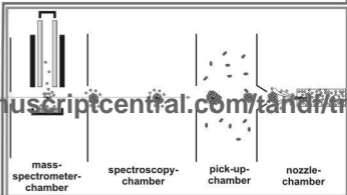
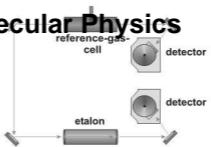
Fig. 2: The R(0.5)  $^2\Pi_{1/2}$  transition of  $^{15}\text{N}^{18}\text{O}$

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