BEAM FOIL- AND BEAM GAS- EXCITATION OF MONO- AND DI-ATOMIC PROJECTILES

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Résumé. Des projectiles moléculaires d'énergie 1 MeV sont très ionisés et très excités par intéraction avec des cibles gazeuses ou solides. Après la collision, les fragments moléculaires, chargés positivement explosent par répulsion Coulombienne et imposent leur cinématique au rayonnement de desexcitation par effet Doppler. Nous reportons ici la première observation d'explosion Coulombienne affectant la desexcitation par emission d'électron Auger.

Abstract. Molecular projectiles of ca. 1 MeV energy are highly excited and highly ionized by the interaction with gaseous or solid targets. After the collision the positively-charged molecular fragments explode by their Coulomb repulsion and impose their kinematics on the deexcitation radiation via a Doppler effect. This paper reports the first observation of Coulomb explosion effecting the deexcitation by Auger electron emission.

INTRODUCTION

The experimental observation of Coulomb explosion of molecules after collisions in the energy range around 1 MeV with matter has been reported recently: 1. From molecular targets after heavy-ion impact detecting the Auger electron emission [1,2], 2. from molecular beams measuring the kinematics of the exploding molecular fragments with high energy-and angular-resolution [3] and 3. from molecular beams recording the electromagnetic deexcitation radiation [4]. This paper reports 4. from Coulomb explosion observed in Auger electron spectra of beam foil- and beam gas- excited molecular projectiles.

EXPERIMENT

Auger electron energy spectra from mono-atomic (N^+) and diatomic (N_2^+) nitrogen projectiles (57 keV/amu and 71 keV/amu) were measured after beam foil- and after beam gas- excitation. A cylindrical mirror analyzer in connection with a channel electron multiplier served as electron energy spectrometer [5]. The projectiles interacted with a carbon foil (5 to 10 $\mu g/cm^2$) or gas targets (He, N_2, Ar at target pressure 10 mTorr). The charge distribution of the projectiles was measured after their interaction with the gas target as a function of target pressure in order to assure single collisions conditions and single charge state prior to the target interaction.

Auger electron spectra were recorded from both N^+ and N_2^+ at the same projectile velocity v (Fig. 1). In addition, spectra were taken from Auger electrons emitted at a distance x downstream from the target; this yields information on metastable states with a lifetime t in the order of $t = v/x$ (Fig. 2).

RESULTS

Figure 1 presents a typical prompt (i.e. $x = 0$) KLL-Auger electron energy spectrum of mono- and diatomic nitrogen ions excited under single collision conditions by N_2-gas target.

Since too many different Auger transitions overlap it is difficult to determine quantitatively the line width ΔE especially from the N_2-data in Fig. 1. Therefore, the delayed spectra (i.e. $x \neq 0$) as in Fig. 2, have been used to extract the line width ΔE since here, only few rather well-separated lines are observed [5]. However, in both cases (Fig. 1 and Fig. 2) we observe clearly the much broader line width from molecular projectiles (N_2) than from mono-atomic projectiles (N). The experimental line width ΔE is composed of (i) natural line width, (ii) instrumental and geometrical line broadening, (iii) recoil line broadening and, in the case of molecular Auger electron emitters, (iv) Coulomb explosion broadening. Analytical details have been compiled e.g. in [2]. It is assumed that the total width ΔE_{calc} can be calculated by quadratically summing over the individual contributions. Also, we obtain the experimental contribution of the Coulomb explosion as displayed in Table I by quadratically subtracting $\Delta E(N_2)$ and $\Delta E(N)$, without the detailed knowledge of the contribution (i), (ii) and (iii).

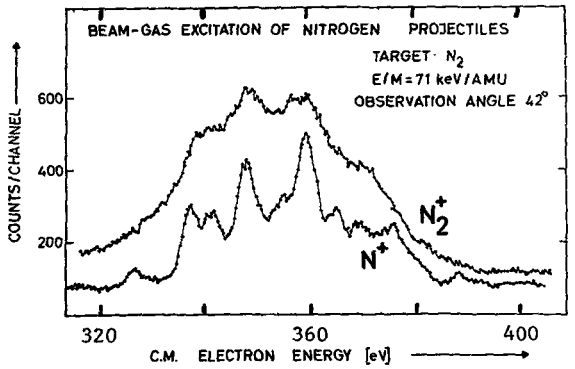

Fig. 1. Auger electron spectra observed under 42° from N_2^+ and from N^+ at 71 keV/AMU excited by N_2-gas target.

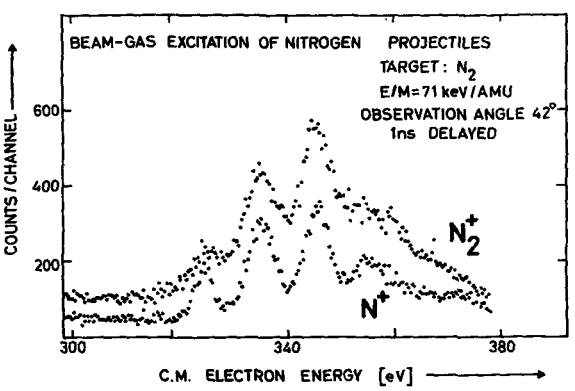

Fig. 2. Auger electron spectra observed under 42° from N_2^+ and N^+ at 71 keV/AMU ca. 1 nsec after excitation by N_2-gas target.

TABLE I

Auger electron line width contribution by Coulomb explosion

Target	Gas	Solid
ΔE_{exp} (eV)	4.6 ± 0.5	3.9 ± 0.4
ΔE_{calc} (eV)	4.8	(3.6)

The calculated contribution to the line width by the Coulomb explosion is given in Ref. [2]. We find a very satisfactory agreement between ΔE_{calc} and ΔE_{exp} for beam gas excitation (Table I). The ΔE_{exp} values in solids and gases should be the same in straightforward considerations. Surprisingly, however, the ΔE_{exp} in solids tends to be more than 15% smaller than the value in gases. We explain this by the wake potential [3] which tends to align the linear molecule N_2 into the direction of the beam, thus yielding a kinematic broadening by the Coulomb explosion which originates only from the projection of the molecular fragment velocity vectors into the direction of the electron detector. Assuming a complete alignment of the molecules we obtain the value given in brackets in Table II.

CONCLUSIONS

Beam foil- and beam gas- Auger electron spectroscopy of swift molecular ion beams yields rather detailed information of the Coulomb explosion in gases and in solids. Also, the electronic configurations of the excited states involved (here mostly from Be- and B- like systems) and their intensities can be studied to understand the excitation mechanisms in different collision systems.

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