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A STUDY OF MOLECULAR EFFECTS IN BEAM-FOIL SPECTROSCOPY

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Résumé. Nous avons étudié la radiation optique émise par des projectiles monoatomiques suivant l'excitation beam-foil des faisceaux de H^+, H_2^+, H_3^+, O^+ et O_2^+.

Abstract. We have investigated the optical radiation from the monatomic projectiles following beam-foil excitation using beams of H^+, H_2^+, H_3^+, O^+ and O_2^+.

We have investigated the optical radiation from the monatomic projectiles following beam-foil excitation using beams of H^+, H_2^+, H_3^+, O^+ and O_2^+. When beams of monatomic species are used, there is essentially zero probability for having two projectiles in the foil at the same time, whereas at least two projectile nuclei are close together for incident molecular particles. Thus, information about the interaction between atomic particles and solids may be obtained by comparing the outcome using different beams of the same element.

The accelerated atomic and molecular ions were sent through carbon foils of thickness 12 μg/cm^2, the optical radiation detected perpendicular to the beam direction, and the projectiles were finally energy analyzed in an electrostatic analyzer [1]. The accelerator high tension was adjusted so that the projectiles had the same energy after the foil. In the measurements with different hydrogen beams, the exit proton energy was 100 keV, and the measurements with oxygen were carried out at exit energies of 100 keV and 155 keV. The beam current was measured with no foil in the beam path, and the photon yields were in all cases referred to the same flux of incoming projectile nuclei (i.e. H_2^+ counts two, etc.).

The hydrogen results are shown in the figure together with some data obtained at 25 keV per proton in Copenhagen. We see for all levels observed an increase in the intensity of electronic transitions of approximately 25% when going from a proton beam to an H_2^+ beam and a further increase of approximately 25% when H_3^+ is

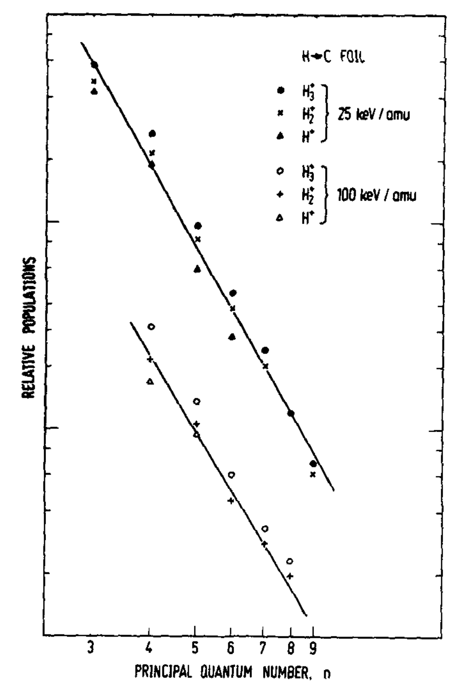

Fig. 1 - Relative populations of ns + nd levels in hydrogen as functions of the principal quantum number n, using various molecular incoming beams.

accelerated. This effect is independent of the level of excitation and thus actually a statement about the charge state of the emergent atom, in agreement with earlier charge state distribution measurements done with H^+ and H_2^+ beams [2]. Very few molecular ions survive passage through the foil, so essentially all final particles are single atoms regardless of which beam is used. However, those H_2^+ ions which enter the foil collinearly may travel together through the foil in such a way that the second proton is carried along in the negative wake potential of the first proton [3] at a distance of a few angstroms. Behind the foil the H_2^{++} system will suffer a Coulomb explosion so that only single atoms are detected, but the double charge will be more efficient in tearing an electron away from the foil than will a single proton, and therefore will enhance the neutral charge fraction. The wake attraction only extends over a 30° angle behind the first proton [4], so an H_2^+ ion entering the foil broadside will break up and emerge as independent atoms. The triangular H_3^+ will have a larger probability of having two of its protons hit the foil collinearly and therefore shows an even larger neutral charge fraction than H_2^+. As observed in ion-atom collisions [5] the relative level population falls off as n^p with p slightly less than -3 (-4.0 for 25 keV/amu, -3.6 for 100 keV/amu) and approaching -3 at large velocities.

The table presents some typical data for oxygen. The overall uncertainty related to the numbers of the last two columns is approximately 5%. The relative change of intensity for different lines of the same charge state is almost the same, and, especially for OIV, the same effect is found as for hydrogen. Two complicating circumstances obscure the picture for this projectile. One is the much lower velocity, the other the fact that the oxygen ions are multiply charged when they leave the foil [6] and therefore need to pick up several electrons to end up in the charge states measured.

excited level	ratio of signal produced by O_2^+ and O^+ beams at	
	100 keV	155 keV
OII 3d'	1.04	0.89
OII 4f'	1.00	0.91
OII 4f	0.99	0.93
OIII3d	0.94	1.10
OIII3d	0.83	1.21
OIII3p	0.93	1.07
OIV 3p	1.06	1.58

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