HIGH RESOLUTION Ne-AUGER SPECTRUM PRODUCED IN 4.2 MeV H^+-Ne COLLISIONS

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Auger electrons resulting from 4.2 MeV proton impact on Ne were measured by 1.2 eV spectroscopic resolution. The proton-induced Auger spectrum was found to be identical to the spectra previously observed by electron and photon bombardment.

Highly resolved Ne-Auger spectra have been measured by electron [1–4], photon [3, 4], and proton [5] impact. These spectra show in addition to diagram lines a number of satellite lines resulting primarily from simultaneous ionization of the inner and outer shell of the target atom. Carlson et al. [6] have shown that multiple ionization by electrons is nearly independent of the impact energy. Furthermore, Krause et al. [3] have found that electrons and photons produce satellite lines of nearly equal intensities. Both measurements [3, 6] indicate that the outer shell excitation is mainly caused by electron shake-off. (According to the concept of the sudden approximation, electron shake-off is independent of the excitation mode of the inner shell.) For proton impact a high resolution Ne-Auger spectrum has been reported on by Edwards and Rudd [5] showing that slow protons of 300 keV produce much more intense satellite lines than electrons or photons. Similar results have been obtained by Schneider et al. [7] for Ne-Auger spectra measured by 0.10 to 2.0 MeV proton impact at low resolution. The mechanism producing the comparably strong outer shell excitation by proton impact is best described as a consecutive Coulomb ionization of the K-shell and the L-shell by the colliding proton. This process has recently been formulated by Hansteen and Mosebekk [7]. Also K-shell ionization followed by L-shell electron capture is a mechanism important for multiple ionization by protons at low impact energies [8].

In contrast to electron shake-off the consecutive Coulomb excitation is strongly dependent on the velocity of the incident particle. It has been shown in the low resolution work [7] that the multiple ionization decreases as the proton energy increases up to 2 MeV. These results suggest that protons of several MeV produce the same Auger spectrum as electrons or photons. Therefore we measured Ne-Auger electrons at a high resolution by 4.2 MeV proton impact to study the spectral satellite structures in comparison with the results previously obtained by Krause et al. [3].

The apparatus has been described in detail elsewhere [10]. We used a new parallel-plate spectrometer with 2.6% resolution. To improve the spectroscopic resolution the Auger electrons were slowed down in a de-celeration system before entering the spectrometer. During the data acquisition the de-celeration voltage was adjusted such that the electrons passed the analyzer at a constant energy of 30 eV. Thus, the resolution is constant within the scanning range of 720 to 810 eV. By analyzing monoenergetic 800 eV electrons from an electron source a FWHM of 1.2 eV was observed in the de-celeration mode. The same width was found for nearly all individual lines in the present Ne-Auger spectrum. It should be noted that the natural line width [1] of 0.15 eV and the maximum Doppler broadening calculated to be about 0.3 eV can be neglected in comparison with the instrumental resolution.

As the de-celeration of the Auger electrons may influence the analyzer transmission by means of focusing effects, the transmission dependence on the primary electron energy was determined in an auxiliary experiment. This was done by measuring 720 to 810 eV electrons continuously ejected at 40° in 300 keV H^+-Ar collisions both with and without de-celeration. As in the latter case the transmission T-dependence on the electron energy E is well known ($T \propto E$), the results obtained without de-celeration were used to determine the transmission in the de-celeration mode. As a result

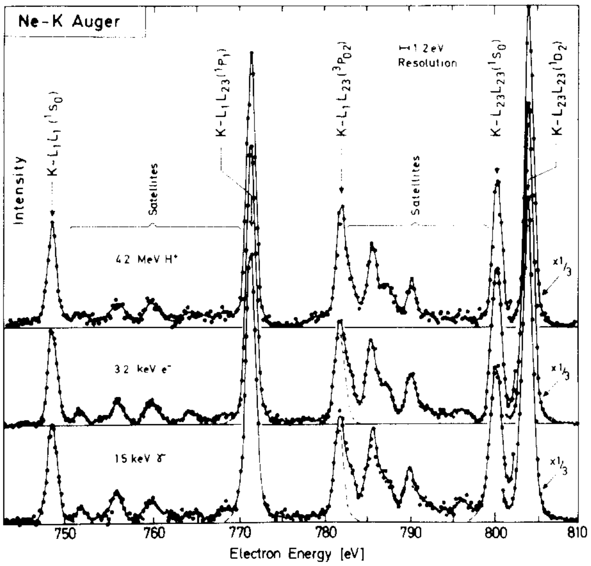

Fig. 1. Neon Auger spectrum measured at 150° by 4.2 MeV proton impact. A small constant background was subtracted. The spectra with electron and photon impact are from Krause et al. [3].

Table 1

Relative intensities of diagram lines and satellite lines in Ne-Auger spectra. The diagram lines are normalized to the $K\text{-}L_1L_1(^1S_0)$ line. The relative satellite intensity is obtained by integrating all satellite lines in the range of 720 to 810 eV and relating the sum to the total spectrum.

Line	4.2 MeV Proton	0.3 MeV Proton*	3.2 keV Electron**	1.5 keV Photon**
$K\text{-}L_1L_1(^1S_0)$	1.00	1.00	1.00	1.00
$K\text{-}L_1L_{23}(^1P_1)$	2.64 ± 0.25	2.5	2.87	2.92
$K\text{-}L_1L_{23}(^3P_{02})$	1.13 ± 0.15	0.6	1.06	1.06
$K\text{-}L_{23}L_{23}(^1S_0)$	1.45 ± 0.15	1.5	1.5	1.5
$K\text{-}L_{23}L_{23}(^1D_2)$	9.3 ± 0.8	7.0	10.0	10.13
Satellites / Total	0.23 ± 0.02	0.52	0.211	0.205

* Edwards and Rudd [5, 11]. The relative satellite intensity of 0.52 given here is due to the sum of all satellites, whereas adding only KL-satellites yields a corresponding value of 0.46.

** Krause et al. [3].

the transmission in the de-celeration mode was found to be nearly constant showing that focusing effects are small.

In fig. 1 the Ne-Auger spectrum obtained by 4.2 MeV proton impact is compared with the corresponding spectra resulting from electron and photon bombardment [3]. The spectra in fig. 1 show a significant agreement in the satellite structure indicating that fast protons produce the same Ne-Auger spectrum as photons and electrons.

This observation is quantitatively confirmed by the agreement of the relative satellite intensities given in table 1 for 4.2 MeV protons, 3.2 keV electrons, and 1.5 keV photons. As shown previously [5], the relatively large satellite intensity for 0.3 MeV protons is an indication for the strong multiple ionization effects by slow protons.

In table 1 also intensities of diagram lines are compared for different projectiles. As expected the diagram lines are found to be equal in intensity as different projectiles are used.

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