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IDENTIFICATION AND THE ANGULAR DISTRIBUTION OF THE KL-LL$_{2,3}$ L$_{2,3}$ SATELLITES IN THE Ne K AUGER SPECTRA FROM THE 5.5 MeV/u Ne^{3+}-Ne COLLISION PROCESS

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There are relatively few studies in which the rather complex satellite structure of Auger spectra from gas targets after heavy-ion-atom collisions has been analysed. Matthews and his coworkers (Matthews et al.1973, Matthews et al.1974) determined the energy /and the relative intensity in many cases/ for 67 lines in the K Auger spectrum of Ne from the O^{5+} 33 MeV – Ne collision process. Mann et al (1981), in a study of the electron capture from neutral target atoms by the recoiling highly ionized target atoms, compared the experimental and theoretical Auger electron energies of Ne and N from the decay of the Li-like and Be-like states produced by 1.4 MeV/u Ar^{12+} and Xe^{24+} ion impact. At the same time a detailed study of these Auger spectra is a copious source of information not only about the states of highly ionized atoms produced in energetic heavy-ion-atom collisions, but also about the collision process itself if the projectile species and charge are varied.

Using the triple pass electrostatic electron spectrometer ESA-21 (Varga et al. 1981, Kövér et al. 1983) with an improved resolution /FWHM = 1 eV/ the highly ionized Ne states produced in Ne^{3+} (5.5 MeV/u) – Ne collision were studied. The current of the heavy-ion beam from the cyclotron U-300 in Dubna, JINR was about 100 nA at the gas target. For a description of the experimental arrangement, see Kádár et al.(1985). In the present study the spectrometer was used in the fixed pass energy mode with a recently built-in preretardation lens to decelerate the electrons before entering the main energy analyzer working with a fixed pass energy. This mode has the advantage that the shape of the measured electron lines is independent of the measured kinetic energy, the decomposition of the spectra easier.

The energy scale of the spectrometer was calibrated in two steps. First, the slope of the energy scale /which is identical in all the angular channels/ in the 782 – 805 eV energy range was determined from the spectrum measured in the collision studied Ne KLL Auger spectrum measured independently by electron excitation using the kinetic energy values of these transitions measured by Krause et al.(1971). Second, the additive constant of the scale was determined from the kinetic energy of the diagram lines in the accepting that the kinetic energy of the KL_2L_3 diagram transition was equal to 804.3 eV. The errors given in Table 1 for the energy values measured in the present study do not contain the calibration error, which amounts to cca 0.1 eV. The measured kinetic energy values of the transitions originating from the $1s^1 2s^2 2p^5$ initial configuration agree, within the experimental error, with those measured by Krause et al. (1971).

In the present study not only the energies and intensities of the Auger satellite transitions were determined in the region of the first satellite group but also the angular distribution was measured for these satellites and the anisotropy parameters were determined.

The Auger transitions were identified in the 782 - 805 eV energy range with the help of the energy values measured by Körber and Mehlhorn (1966), Matthews et al.(1974) and by Krause et al. (1971), as well as of the theoretical values calculated by Matthews et al.(1975), Kauffman (1975) and Schmidt (1973). All these values are given in Table 1 and the spectrum taken in the present study is shown in Fig. 1 where the identification is also indicated for the individual spectrum lines. The branching ratios for the different multiplets involved in the doubly ionized initial configurations were taken from the calculations of Schmidt (1973) for transitions originating from the $1s^1 2s^1 2p^6$ initial configuration, while for transitions from the $1s^1 2s^2 2p^5$ initial configuration we used the values measured by Krause et al (1971).

The spectrum has been decomposed by using numerical line shapes. These line shapes were obtained from the 804.3 eV diagram line in the different angular channels. The peak observed at 785.7 eV seems to be an unresolved doublet, since its width is larger than that of the others. It can, however, be well fitted by two peaks of the same width as the remaining lines. The intensity considerations /i.e., all transitions originating from the same initial multiplet should give the same population for this multiplet/ have led to the identification shown in Fig. 1, namely, that the peak at 785.5 eV represents the 125pp(^{3}P-^{2}D) transition, while that at 786.0 eV the 116pp(^{3}S-^{2}D) transition /for the notation see Matthews et al.1974/. Accordingly, the peak observed at 792.2 eV corresponds to the 116pp(^{1}S-^{2}D) transition in contrast to the results of Krause et al.(1971), who found this peak to be due to the 116pp(^{3}S-^{2}D) transition. Considerations concerning the energy separations of the transitions originating from the $1s^1 2s^2 2p^5$ initial states /i.e., the energy separation of the two transitions leading to the same final state should agree with the energy separation of their initial states/ suggest that the 116pp(^{3}S-^{2}D) transition should be assigned to the 785.5 eV line, and the 125pp(^{3}P-^{2}D) transition to the 786 eV line with all the other assignements remaining unchanged. Since the separation of the two transitions in energy in the unresolved doublet observed at 785.7 eV is smaller than the FWHM of the peaks,

Table 1

The energies of the Auger transitions found in the 782 - 805 eV energy region of the Ne K Auger spectrum obtained in the Ne^{3+}- Ne collision

Transition	Present work /exp/	Krause et al. /1971/ /exp/	Körber and Mehlhorn /1966/ /exp/	Matthews et al. /1974/ /exp/	Matthews et al. /1975/ /theor/	Kauffman /1975/ /theor/	Schmidt /1973/ /theor/	Körber and Mehlhorn /1966/ /theor/
126sp(^{2}S-^{3}P)	782.14(4)	782.1(1)	782.0(1)	782.1(3)	782.9	782.98	-	781.97
125pp(^{3}P-^{2}P)	783.19(2)	783.1(1)	783.2(3)	783.1(3)	783.6	783.59	-	783.1(1)
125pp(^{3}P-^{2}D)	785.49(3)	785.9(1)	785.8(2)	785.5(3)+	787.3	787.28	-	785.6(1.0)
116pp(^{3}S-^{2}D)	785.97(3)	-	-	-	787.7	787.73	781.5(1.2)	-
125pp(^{1}P-^{2}P)	787.55(3)	787.6(2)	787.6(3)	787.5(3)++	787.9	787.90	-	787.8(1.0)
125pp(^{1}P-^{2}D)	790.29(1)	790.4(1)	790.4(2)	790.3(3)+++	791.6	791.59	-	790.4(1.0)
116pp(^{1}S-^{2}D)	792.21(2)	792.3(3)x	792.4(4)x	-	795.2	788.88	788.5(2.0)	791.8(1.0)x
126pp(^{2}S-^{1}S)	800.54(1)	800.6(1)	800.5(1)	800.6(3)	800.9	800.93	-	800.4
126pp(^{2}S-^{1}D)	804.3 xx	804.3 xx	804.15	804.2(3)	806.0	806.01	-	-

x Identified as 116pp(^{3}S-^{2}D)

xx Reference line /error in the energy scale cca 0.1 eV/

\+ Unresolved doublet - contains 115pp(^{2}P-^{3}D) and 125pp(^{3}P-^{2}D)

++ Unresolved doublet - contains 116pp(^{3}S-^{2}D) and 125pp(^{1}P-^{2}P)

+++ Unresolved doublet - contains 116pp(^{1}S-^{2}S) and 125pp(^{1}P-^{2}D) we cannot exclude the possibility that the intensities and thus the anisotropy parameters of these two transitions are not given correctly by the decomposition procedure. Therefore for these two transitions intensity values and those of the anisotropy parameters are uncertain. The errors given in Table 2 contain only the experimental uncertainties and those originating from the evaluation procedure, but the supposed systematic errors are not included.

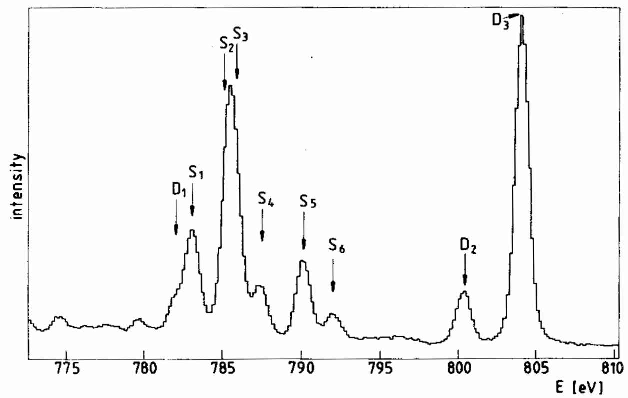

Fig. 1. Identification of the Auger lines found in the 782 - 805 eV energy range /5.5 MeV/u Ne^{3+}- Ne collision, 165 degrees observation angle/. For the notation see Matthews et al (1974). Diagram lines: D_1=126pp(^2S-^3P), D_2=126pp(^2S-^1S), D_3=126pp(^2S-^1D). Satellite lines: S_1=125pp(^3P-^2P), S_2=125pp(^3P-^2D), S_3=116pp(^3S-^2D), S_4=125pp(^1P-^2P), S_5=125pp(^1P-^2D), S_6=116pp(^1S-^2D).

With the knowledge of the intensities of the individual satellite transitions in each angular channel, it was possible to determine their angular distribution. We corrected the intensities for differences in the efficiencies of the different angular channels by normalizing the intensity data to the intensity of the 804.3 eV diagram line, which was supposed to be isotropic.

A definite nonisotropic angular distribution was found for all the satellite transitions in the Ne^{3+}- Ne collision except for the 116pp(^1S-^2D) one. For the diagram lines of 782.1 and 800.5 eV an isotropic angular distribution was found, thus confirming the results obtained for other transitions. In the present study similar measurements were carried out for the Ar^{6+}- Ne and Ne^{10+}- Ne collisions, too.

In these cases, however, the error of the measured intensity values did not allow us to make a definite conclusion concerning the angular distributions.

The fitted A_2 anisotropy parameter values are shown in Table 2, the angular distribution and the fitted curves are given in Fig. 2.

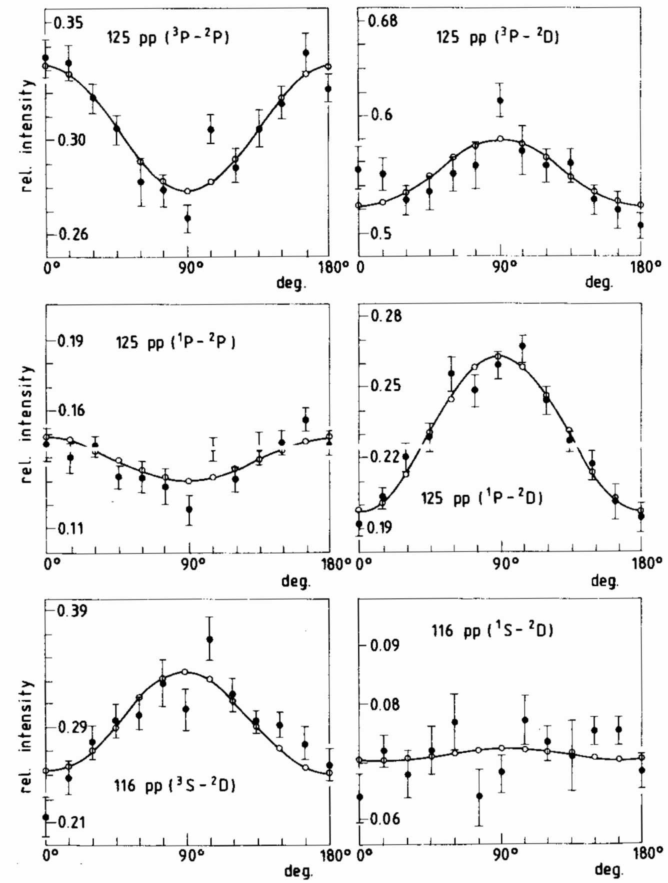

Fig. 2. Angular distribution of the measured satellite lines from the 5.5 MeV/u Ne^{3+}- Ne collision. Full circles: experimental data, empty circles: fitted points.

The data presented in the table and in the figure are the average values estimated from two independently measured spectra. The individual values estimated from the two spectra agree within their errors.

Table 2
The 5.5 MeV/u Ne^{3+}- Ne collision
Anisotropy parameters

Transition	A_2
126sp (^2S-^3P)	-0.03(6)
125pp (^3P-^2P)	0.11(3)
125pp (^3P-^2D)	-0.07(4)
116pp (^3S-^2D)	-0.15(7)
125pp (^1P-^2P)	0.08(6)
125pp (^1P-^2D)	-0.18(3)
116pp (^1S-^2D)	0.00(6)
126pp (^2S-^1S)	0.01(4)
126pp (^2S-^1D)	0.00 x

x Supposed to be isotropic

Unfortunately, there is no corresponding theoretical calculation available for comparison.

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REFERENCES

Kádár I., Ricz S., Shchegolev V. A., Sulik B., Varga D., Végh J., Berényi D., Hock G. 1985 J. Phys. B: At. Mol. Phys. 18 275 - 87.

Kauffman R. 1975 Ph.D. Dissertation, Kansas State University, Manhattan, unpublished.

Körber H. and Mehlhorn W. 1966 Z. Phys. 191 217 - 30.

Kövér Á., Varga D., Szabó Gy., Berényi D., Kádár I., Ricz S., Végh J. and Hock G. 1983 J. Phys. B: At. Mol. Phys. 16 1017 - 27.

Krause M. D., Carlson T. A. and Moddeman W. E. 1971 J. de Phys. 32 C4 139 - 44.

Mann R., Folkmann F. and Beyer H. F. 1981 J. Phys. B: At. Mol. Phys. 14 1161 - 81.

Matthews D. L., Johnson B. M., Mackey J. J. and Moore C. F. 1973 Phys. Rev. Lett. 31 1331 - 34.

Matthews D. L., Johnson B. M., Mackey J. J., Smith L. E., Hodge W. and Moore C. F. 1974 Phys. Rev. A 10 1177 - 87.

Matthews D. L., Johnson B. M. and Moore C. F. 1975 Atomic and Nuclear Data Tables 15 41 - 47.

Schmidt W. 1973 Proc. Int. Conf. on Inner Shell Ionization Phenomena and Future Applications, January 1973, Oak Ridge, Tenn., pp 548 - 58.

Varga D., Végh J., Kövér Á., Ricz S. and Domonyi A. 1981 Atomki Közl. 23 40 - 41.

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Риц Ш. и др. E7-85-655

Идентификация и угловое распределение $KL\text{-}LL_{2,3}LL_{2,3}$ сателлитных линий в спектре К оже-электронов, возникающих в ион-атомных столкновениях $Ne\text{-}Ne^{3+}$ (5,5 МэВ/а.е.м.)

Исследовался спектр возбуждения атомов неона в процессе ион-атомных столкновений на ионах Ne^{3+} (5,5 МэВ/а.е.м.). Наблюдались оже-переходы с помощью электростатического спектрометра электронов. Измерялось угловое распределение электронов, возникающих в сателлитных переходах $KL\text{-}LL_{2,3}LL_{2,3}$. Обнаружено, что линии $125pp(^3P\text{-}^2P)$, $125pp(^1P\text{-}^2P)$ и $125pp(^1P\text{-}^2D)$, а также сумма линий $125pp(^3P\text{-}^2D)$ и $116pp(^3S\text{-}^2D)$ имеют неизотропное угловое распределение. В то же время угловое распределение линии $116pp(^1S\text{-}^2D)$ является изотропным. Данное явление обнаружено впервые и для его объяснения требуется разработка теоретической модели.

Работа выполнена в Лаборатории ядерных реакций ОИЯИ.

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Identification and the Angular Distribution of the $KL\text{-}LL_{2,3}L_{2,3}$ Satellites in the Ne K Auger Spectra from the 5.5 MeV/u Ne^{3+}-Ne Collision Process

The angular distributions of the $KL\text{-}LL_{2,3}L_{2,3}$ satellite transitions were measured in the 5.5 MeV/m Ne-Ne collision. A definite nonisotropic angular distribution was found for the satellite transitions $125pp(^3P\text{-}^2P)$, $125pp(^1P\text{-}^2P)$, and $125pp(^1P\text{-}^2D)$, as well as for the sum of the $125pp(^3P\text{-}^2D)$ and $116(^3S\text{-}^2D)$ transitions, while an isotropic angular distribution characterizes the $116pp(^1S\text{-}^2D)$ transition.

The investigation has been performed at the Laboratory of Nuclear Reactions, JINR.

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