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AUGER ELECTRON SPECTRA IN 5.5 MeV/amu Ne^{q+} AND Ar^{q+} ION IMPACT ON Ne

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1. Introduction

In the last ten years a number of measurements has been carried out on Auger electrons produced in heavy ion-atom collisions (see, e.g., Stolterfoht 1978, Berényi 1981). In most of these studies (especially in the high impact energy region) the Ne K-Auger electrons were studied using different heavy ion projectiles in a broad velocity range with various charge states. The overwhelming majority of the high energy measurements were performed in the 1-2 MeV/amu region (Burch et al. 1972, Burch et al. 1974, Matthews et al. 1974a, 1974b, Stolterfoht et al. 1974, Woods et al. 1975a, 1975b, 1976, Matthews et al. 1976, Stolterfoht et al. 1977, Mann et al. 1981, 1982a). Measurements on Auger electron spectra induced by heavy ions with impact energy higher than 1-2 MeV/amu were carried out only recently (Mann et al. 1982b, Beyer et al. 1982, Schneider et al. 1982, Prost et al. 1982, Folkmann et al. 1983; see also Schneider et al. 1979, Prost 1980), to investigate the satellite structure, Auger production yields, etc., as a function of the impact energy and charge state for different species of the projectile, which are important to obtain further information on the collision process and on the structure of the atom in highly ionized state (see, e.g., Berényi 1983a).

In order to complement the available information on the few MeV/amu region, a research program was initiated by us in the last years for the study of electrons from high energy heavy ion-atom collisions (Berényi 1982). A special electron spectrometer has been constructed and tested in Debrecen and it has been in use at the beam of the heavy ion cyclotron U-300 in Dubna, JINR since 1982. Within the frame of this program we studied Ne K-Auger spectra induced by projectiles of equal velocity with different charge states (see a preliminary publication of Berényi et al. 1983b).

2. Experimental arrangement and data evaluation

A schematic drawing of the experimental layout including a sketch of the electrostatic electron energy analyser ESA-21 built in ATOMKI, Debrecen, is shown in figure 1. During the measurements Ne^{3+} and Ar^{6+} ions of 5.6 MeV/amu nominal energy have been used, without and with stripping. In the latter case the beam passed through a carbon foil of about 80 $\mu g/cm^2$ thickness and the Ne^{10+} and Ar^{17+} ions have been selected out by the switching magnet. The actual energy of the Ne^{3+} and Ar^{6+} ions has been measured to be 5.50 ± 0.05 MeV/amu by recording the electron loss peak at 0 degree. This value applies to all the four projectiles, since the energy loss in the stripper foil is less than 0.02 MeV/amu.

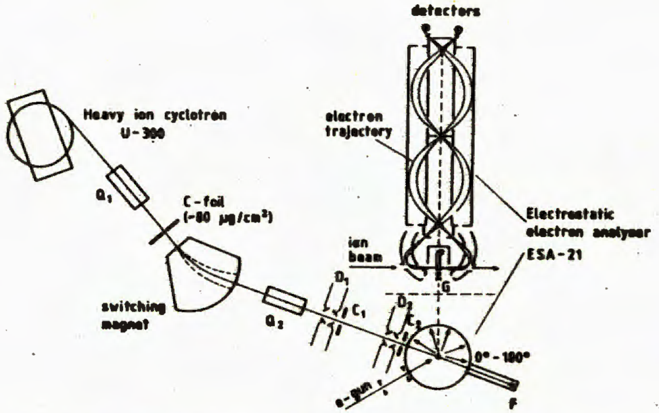

Fig. 1. Schematic drawing of the experimental arrangement including the electrostatic analyser ESA-21. Here Q_1 and Q_2 are quadrupole lenses, D_1 and D_2 beam diagnostic devices, C_1 and C_2 collimators, F Faraday-cup and G a gas-beam-target.

The heavy ion beam passes through a collimator system providing an about 2.5 mm diameter beam at the target. The strong collimation ensures that the ion beam traverses the spectrometer without touching any of its solid parts, thus allowing to study the electron spectra from gaseous targets in the forward and backward direction relative to the beam, too. The intensity of the incident beam at the target was as follows (the total number of projectile ions at the individual points of the spectra is given in brackets):

Ne^{3+} - $2*10^{11}s^{-1}(5*10^{12})$, Ne^{10+} - $2.5*10^{10}s^{-1}(2.3*10^{12})$,

Ar^{6+} - $2*10^{10}s^{-1}(4.2*10^{12})$, Ar^{17+} - $1*10^{10}s^{-1}(0.5*10^{12})$.

In these measurements the target was an atomic Ne beam. The average pressure in the effective region was estimated to be 3 - 5 mbar. At this pressure only single collision events are expected to occur. The pressure measured in the scattering chamber was $5*10^{-5}$ mbar.

The Auger spectra were taken by the electrostatic electron spectrometer ESA-21 (briefly described in Varga et al. 1980, 1981, Kádár et al. 1981, Kövér et al. 1983; a more detailed article is in preparation). The energy analyser is a combination of a spherical mirror and of a double - pass, second order focusing cylindrical mirror. With the help of its 13 channeltrons located on the ring focus of the cylindrical mirror, it allows one to measure simultaneously the energy and angular distribution of electrons at 13 angles from 0 to 180 degrees. The solid angle of one angular channel is about $4*\pi*10^{-3}$, the energy resolution was 0.37% (i.e., 3.0 eV FWHM for the 804 eV

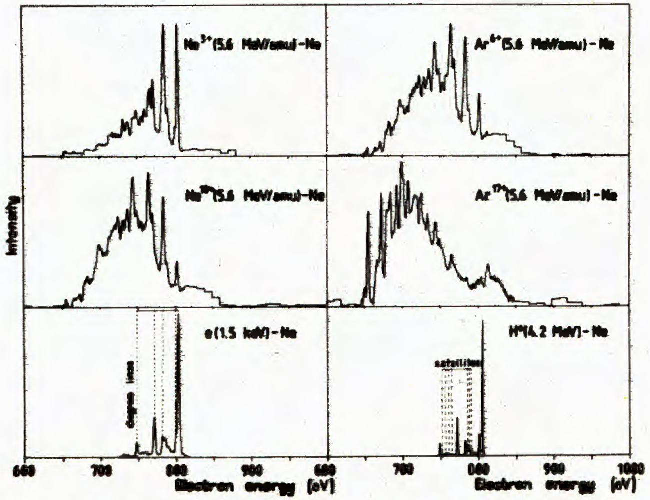

Fig. 2. The Ne K Auger spectra taken at different heavy ion as well as electron impact. The proton impact spectrum was measured by Stolterfoht et al 1973.

diagram line). The measured spectra have been corrected for the background contribution and instrumental efficiency as follows.

The background has been subtracted in each angular channel by fitting a straight line to both wings of the spectra taken about 100 eV (containing about 10 measured points) before and after the KLL - KLM Auger region. The spectra measured at individual angles, after subtraction of the background, were summed to obtain a better statistics (figure 2).

The measurements were done without deceleration so in order to correct for the efficiency of the analyzer as a whole, the intensity data were simply divided by the corresponding electron energy values, neglecting the dependence of the detector efficiency on the electron energy in this range. To correct for the possible changes of the target pressure and beam geometry, the intensity of the $KL_{2,3}L_{2,3}$ diagram lines produced by unstripped ion beams were used.

3. Results and discussion

Figure 2 shows the Ne K-Auger electron spectra obtained in the present study for Ne^{3+}, Ne^{10+}, Ar^{6+} and Ar^{17+} ion impact of the same velocity (14.8 a.u.). These spectra are rather complex, full of overlapping satellites, but yet individual lines can be differentiated. For comparison, figure 2 includes also the Ne K-Auger electron spectrum measured at 1.5 KeV electron impact (measured by the same equipment as the above spectra) and that at 4.2 MeV proton impact from Stolterfoht et al. (1973). The last two spectra consist mainly of diagram lines and of the so-called shake off satellites of relatively small intensity.

The spectra were evaluated to obtain the following data compiled in table 1.

a) The centroid energies $\bar{E}$ of the measured KLL Auger spectra.

b) The relative KLL Auger production cross sections

$$\sigma^{rel}_{KLL}=100[I_{KLL}(X^{q+})/I_{KLL}(Ne^{10+})], \qquad (1)$$

where I_{KLL} is the corresponding Auger yield.

c) The ratio of the KLM to KLL Auger production cross sections.

d) The relative production cross section of the prominent peaks in the spectra: σ_0 is the fraction of the Auger cross sections $\sigma^A_{KL}0$ belonging to the sum of the 800 eV and 804 eV $KL_{2,3}L_{2,3}$ lines, σ_6 is similarly that for $\sigma^A_{KL}6$ belonging to the sum of the 652 eV and 656 eV satellites (c.f. eq. (4)).

Table 1. Data derived directly from the experimental spectra

Projectile and energy in MeV	$\bar{E}$ (eV)	σ^{rel}_{KLL}	$\sigma_{KLM}/\sigma_{KLL}$ %	σ_0/σ_{KLL} %	σ_6/σ_{KLL} %
Ne 3+ 110	758.6±0.3	71.6±3.8	8.1±1.2	10.3±0.5	<0.1
Ne 10+ 110	742.8±0.2	100	9.8±0.8	1.3±0.1	0.3±0.1
Ar 6+ 220	743.7±0.3	153.5±10.7	9.6±0.7	1.9±0.1	0.2±0.1
Ar 17+ 220	719.8±0.4	269.2±21.3	9.3±0.9	<0.2	3.0±0.2

3.1 Average quantities characterizing the collision process and the Auger spectra

Because of the complexity of the Auger spectra produced in high energy heavy-ion impact it seems to be expedient to introduce average quantities (Stolterfoht 1976) such as $\bar{E}$ - the centroid energy of the KLL Auger spectrum (see table 1), $\bar{n}_L$ - the average number of L vacancies produced simultaneously with the K vacancy and Z_{eff} - the effective charge of the projectile realized in the process of ionization in order to study the variation of these quantities as a function of the collision parameters.

The mean number of the L vacancies $\bar{n}_L$ was calculated from our spectra using q_n for the probability of producing n vacancies in the L-shell with the simultaneous ejection of one K-electron. Assuming the probability p_L for the ejection of one L-shell electron to be independent of the number of electrons ejected from the L-shell along with one K-electron (Hansteen and Mosebekk, 1972),

$$q_n=\binom{8}{n} p_L^n (1-p_L)^{8-n} \qquad (2)$$

and

$$\bar{n}_L = 8p_L. \qquad (3)$$

Since the electrons detected in the $KL_{2,3}L_{2,3}$ diagram lines (at 800 and 804 eV) originate evidently from the 0-hole

L-state and similarly, the peaks at 652 and 656 eV correspond to the 6 L-holes Li-like state (only these peaks are resolved clearly enough to evaluate them individually), they can be assigned to the probabilites q_0 and q_6, respectively:

$$\frac{\sigma_n}{\sigma_{KLL}} = \frac{\alpha_n \sigma^A_{KLn}}{\sigma_{KLL}} = \frac{q_n(1-\bar{\omega}_n)\alpha_n}{\sum_{i=0}^{6} q_i(1-\bar{\omega}_i)} = \frac{I_n}{I_{KLL}} \tag{4}$$

for n=0 and 6.

The branching ratios α_n of the particular line intensities to the total intensity, which belong to the given n-hole configuration and the fluorescence yields $\bar{\omega}_n$ were taken from Chen and Crasemann 1975 and Matthews et al. 1976.

As in the cases of Ne^{10+} and Ar^{6+} projectiles, where both lines are visible in the spectra, the experimental q_0 and q_6 values lead to independent values for p_L, which differ from each other, we accepted the p_L values obtained from a weighted least squares fit of the binomial distribution (eq. (2)) to these q_n^{exp} values. Knowing the distribution q_n the mean Auger yield $\bar{a}_{KLL}$ may be calculated in the following way:

$$\bar{a}_{KLL} = \sum_{n=0}^{6} q_n \, (1-\omega_n). \tag{5}$$

Using this value one can determine the relative K ionization cross section from the relative Auger production cross section data:

$$\sigma_K^{rel}\,(X^{q+}) = \frac{\bar{a}_{KLL}\,(Ne^{10+})}{\bar{a}_{KLL}\,(X^{q+})}\,\sigma_{KLL}^{rel}\,(X^{q+}). \tag{6}$$

The mean K fluorescence yield $\bar{\omega}_K$ can be determined also from the known q_n distribution as follows

$$\bar{\omega}_K = \sum_{n=0}^{7} q_n \, \bar{\omega}_n. \tag{7}$$

The calculated values of $\bar{\omega}_K$ for the different collision systems are shown in table 2.

Table 2. The $p_L, \bar{\omega}_K, \sigma_K^{rel}$ and $Z_{eff,K}$ values from the present study at v_p=14.8 a.u.

Projectile name&charge	p_L	$\bar{\omega}_K$ *0.01	σ_K^{rel}	$Z_{eff,K}^{exp}$	$Z_{eff,K}^{BEA}$	$Z_{eff,K}^{PWBA}$
Ne 3+	0.20±0.02	2.1	70.0	8.4±0.2	8.6	8.2
Ne 10+	0.38±0.07	4.2	100	10.	10.	10.
Ar 6+	0.35±0.05	3.6	152.5	12.3±0.3	15.6	13.7
Ar 17+	0.52±0.02	9.6	290.5	17.0±0.5	17.0	17.1

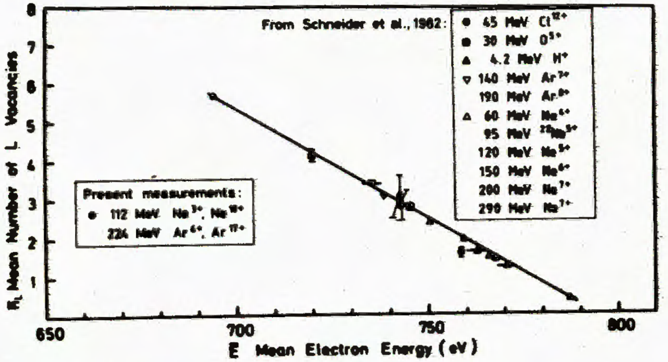

Fig. 3. The mean number of L vacancies $\bar{n}_L$ produced simultaneously with the K vacancy, versus the Ne KLL Auger centroid energy $\bar{E}$. Other data are taken from Schneider et al (1982).

In figure 3 the present data for $\bar{E}$ and $\bar{n}_L$ (see tables 1 and 2 and eq. (3)) are shown in a $\bar{n}_L$ - $\bar{E}$ plot, made on the basis of the similar one in the paper of Schneider et at.(1982). It should be mentioned that our data for the projectiles Ne^{3+} and Ar^{17+} apply to the lowest and highest charge states in the concerned plot, at all. The linear dependence between $\bar{n}_L$ and $\bar{E}$ is confirmed also by the present data. The estimated errors of our data are given in tables 1 and 2 and those for Schneider et al.(1982) are about $\Delta\bar{n}_L$=±0.2, ±0.5 and ±1.0 for H^+, O^{5+} and Cl^{12+}, respectively (Stolterfoht 1983).

For the projectiles Ne^{10+} and Ar^{6+} we could not obtain a good agreement between the two values of p_L derived on the basis of these separated lines. Suppose again the same conditions as in deriving the binomial distribution (2) except that p_P (the probability of the ejection of one electron from the $L_{2,3}$ subshell) is r times higher than the corresponding probability p_S for the L_1 subshell. The probability of producing alltogether n holes in the L-shell is originally given by Hansteen and Mosebekk (1972)

$$q_n = \sum_{\substack{i=0,k=0\\(i+k=n)}}^{i=2,k=6} \binom{2}{i} p_S^i (1-p_S)^{2-i} \binom{6}{k} p_P^k (1-p_P)^{6-k}. \quad (8)$$

The average $\bar{p}_L$ can be derived as

$$\bar{p}_L = \frac{1}{8}\left(\frac{2}{r} + 6\right)p_P. \quad (9)$$

We analyzed our data according to this detailed distribution, too. We found that in the cases of Ne^{10+} and Ar^{6+} the two p_L values in the fit were compatible. To test further the validity of the above assumptions, however, further and more accurate data are needed.

In the analysis of our measured data we made the basic assumptions as follows:

a) From the relative total K ionization cross sections one can determine the experimental values of $Z^{exp}_{eff,K}$ on the basis of the first order (direct Coulomb) ionization theories by means of the Z^2 scaling rule. Although this assumption may fail in a higher order Born approximation for the highly charged projectiles, especially at lower impact velocities, such calculations are not available for direct examination in the present cases.

b) A further question is the neglect of the contribution to the vacancy production due to electron capture, the dependence of which on the collisional parameters, in general, greatly differs from that of the Coulomb ionization. The total K-ionization cross sections σ^{ion}_K predicted in the plane wave Born (Khandelwal et al., 1969) and in the binary encounter approximations (Garcia et al., 1973) as well as the screened Brinkmann-Kramers cross section (McDowell and Coleman 1970, Nikolaev 1966), $\sigma^{EC}_{OBK}(1s^2 \to \sum n\ell)$, are related to each other as $\sigma^{EC}_{OBK} \sim 0.75\sigma^{ion}_{PWBA,BEA}$ for the Ne^{10+} (5.5 MeV/amu)-Ne collisions, but it is well known (e.g., McDowell and Coleman 1970) that the Brinkman-Kramers approximation considerably overestimates the cross section of the electron capture process.

There exist also experimental indications (Richard, 1980) based on multiply charged F^{q+} ions impinging on Ne within the impact energy range of 1-1.8 MeV/amu, that in these most similar collisions, but at sufficiently lower energies compared to our case (5.5 MeV/amu), one has to expect non-negligible contribution from electron capture into the vacant K-shell of the projectile. An extrapolation of the earlier data to our cases should however be avoided. Instead, independent measurements and/or reliable calculations would be very needed to decide this matter.

On the basis of the assumptions above, experimental $Z^{exp}_{eff,K}$ values were determined for our projectiles from the relative cross sections related to that for the bare Ne^{10+} as

$$Z^{exp}_{eff,K} = 10\,[\sigma^{rel}_K(X^{q+}) / \sigma^{rel}_K(Ne^{10+})]^{1/2}, \quad (10)$$

supposing the validity of the Z^2 scaling for the heavy ion induced ionization cross sections of interest as well as a low probability of electron capture by these projectiles. These $Z^{exp}_{eff,K}$ values are contained in table 2, together with the corresponding results based on the calculations in the binary encounter (BEA, Vriens 1969) and plane wave Born (PWBA, Madison and Merzbacher 1975) approximations.

The calculation of $Z^{BEA}_{eff,K}$ in BEA was carried out according to Toburen et al. (1981), i.e.,

$$Z^{BEA}_{eff,K} = Z_p - \sum_i N_{(nl)i}\, S_{(nl)i}(R_{ad}), \quad (11)$$

where Z_p is the nuclear charge, $N_{(nl)i}$ is the number of electrons in the shell (nl)i, and the screening functions $S_{(nl)i}(R)$ are calculated by the integration of the electron density using the corresponding hydrogenic wave functions up to the adiabatic interaction radius R_{ad}. The value of R_{ad} was determined from the Massey criterion, where the average energy transferred to a K-shell electron was calculated in the BEA (Vriens 1969, Ziem 1974).

Since the calculated value of R_{ad} (0.196 a.u.) at our projectile velocity is considerably larger that the K-shell radius of the Ne atom (0.125 a.u.), the validity of this approximation is questionable (Schneider et al.1982). This seems to be confirmed also by the value of $Z^{BEA}_{eff,K}$ calculated for the Ar^{6+} projectile ion (15.6), which deviates significantly from $Z^{exp}_{eff,K}$ for this projectile.

In order to calculate the $Z_{eff,K}$ values for the K-shell ionizations by ionic projectiles one can directly use the PWBA (Madison and Merzbacher 1975) to the ionization cross section to the average of the squared momentum transfer (q) dependent projectile charge $Z_1(q)$ as

$$Z^{PWBA}_{eff,K}{}^2 = \frac{\int dW \int dQ\, Q^{-2}\, Z_1^2\,(q)\,|F_{WK}(Q)|^2}{\int dW \int dQ\, Q^{-2}\, |F_{WK}\,(Q)\,|^2}\,, \qquad (12)$$

where the notations of Madison and Merzbacher (1975) are used, and for comparison, $Z_1(q)$ involves here only the static screening (e.g., McGuire et al.1981)

$$Z_1(q) = Z_p - \sum_i N_{(nl)i}\, F_{(nl)i}(q). \qquad (13)$$

This approach to $Z_{eff,K}$ gives rise to a better agreement with the present experimental data as seen in table 2. The screening functions $S_{(nl)i}(R_{ad})$ of Toburen et al.(1981) in eq. (10) may be regarded as an approximation to the (elastic) formfactors $F_{(nl)i}(q)$ in eq. (13).

As concerns the behaviour of the multiple KL^n ionization, it seems to be quite clear qualitatively, that p_L increases with an increase in the ionic charge of the projectile and decreases with increasing projectile velocity. Such a dependence on v_p/q (q is the ionic charge) is expressed recently, e.g., in the plot of figure 3 in the paper of Mann et al.(1982b) or in figure 7 (from X-ray spectra) of Folkmann et al.(1983).

Figure 4 compares experimental data with the results of the calculation of $p_L(0)$ based on a simple encounter probability model (Sulik et al , to be published) expected to be relevant in the $v_p \gg v_e$ region of the impact velocity v_p (v_e is the orbital electron velocity) for bare heavy projectiles. This model establishes a simple universal scaling rule for p_L as a function of Z_p/v_p:

$$p_L \approx p_L(0) = 1 - \frac{x^2}{2} K_2(x), \qquad (14)$$

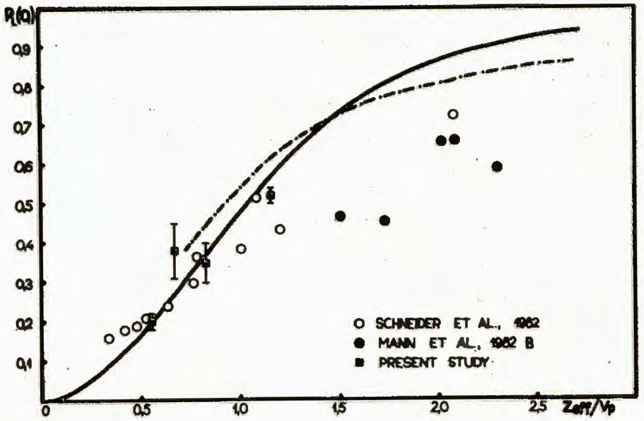

Fig. 4. Experimental p_L values versus $Z_{eff,K}/v_p$ from Auger measurements. Dashed line: the curve of Folkmann et al (1983), fitted to data derived from X-ray measurements on fully and highly ionized projectile impact on Ne (ionic charges regarded as approximate Z_{eff}). Solid line: results of a model calculation for bare projectiles (Sulik et al, to be published).

where $x=2Z_p/v_p$ and $K_2(x)$ is a modified Bessel function. It behaves asymptotically as $p_L \approx (Z_p/v_p)^2$ for low projectile charge Z_p and tends to unity for high Z_p values. For projectiles carrying electrons, Z_p should be replaced by some characteristic Z_{eff} value.

According to this scaling, our data, together with the corresponding ones of Schneider et al.(1982) and Mann et al. (1982b), are plotted as a function of $Z^{PWBA}_{eff,K}/v_p$.

Since one may expect $Z_{eff,K}$ to approximate the Z_{eff,KL^n} (c.f. Hansteen and Mosebekk 1972) we used $Z^{PWBA}_{eff,K}$ for all the ionic projectiles except for those of the present study where $Z^{exp}_{eff,K}$ were used in figure 4. This seems to give rise to a satisfactory agreement with the data up to about $Z_{eff,K}/v_p=1.5$. The disagreement in the higher region of $Z_{eff,K}/v_p$ may probably occur because of the failure of the assumptions made above. It is worth mentioning that there exists a rather large systematic difference in the values of p_L taken from Auger and X-ray measurements (Mann et al.1982b, Folkmann et al. 1983) just in this region. That is the reason for giving the curve fitted to the p_L values from X-ray measurements

(Kauffman et al. 1975, Folkmann et al. 1983) in figure 4 as well.

Finally, the satellite to total ratio can be deduced from our spectra. Our data, together with those of Matthews et al. (1974a), are given in table 3. These data are plotted as a function of Z_{eff}^{PWBA}/v_p in figure 5, compared with the model calculation above.

Table 3. Satellite to total ratios for Ne K-Auger electron spectra at impact of various projectiles on Ne

Projectile	E_p (MeV)	$\frac{Z_{eff,K}}{v_p}$	S/T
H +	6.0	0.064	0.18±0.02
H +	4.2	0.077	0.23±0.02
H +	0.25	0.311	0.35±0.04
He +	1.0	0.63	0.75
O 5+	33.	0.76	0.97
Ne 3+	110.	0.56	0.83±0.05
Ne 10+	110.	0.68	0.98±0.02
Ar 6+	220.	0.83	0.97±0.05
Ar 17+	220.	1.15	1.0 ±0.05

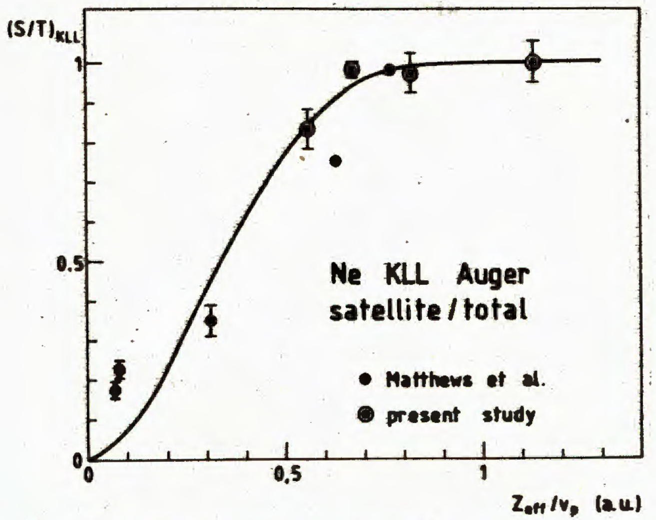

Fig. 5. Satellite to total ratios of Ne K Auger electron spectra for different projectiles. The data are taken from table 3. The solid line shows a model calculation (Sulik et al, to be published).

3.2 Results on individual lines and groups in the spectra

As one can see in figure 2, the 804 eV diagram line appears in three spectra (Ne^{3+}, Ar^{6+} and Ne^{10+}) but it is not present at all in the case of Ar^{17+}. The Li-like lines can be seen practically only in the Ar^{17+} induced spectrum.

As regards the case of Ne^{10+}, a somewhat higher intensity of the Li-like lines is expected on the basis of equation (2) and of the calculated p_L value than the intensity of the diagram line. In contrast to this, however, we can see (fig. 2b) that the Li-like lines are hardly observable here. It should be mentioned in connection with the angular distribution of the Li-like lines that it was observed to be isotropic. The ratio of the groups centered at about 655 eV to that at 670 eV was found to be constant within the limits of the experimental errors at all the thirteen angles from 0 to 180 degrees.

It is also an interesting issue of the hypersatellites. It was stated by Woods et al. (1975b) that the intensity of the peak centered at 915 eV (KLM hypersatellites) decreases with increasing impact energy and the probability for hypersatellite production should be peaked about the symmetric Z collisions with bare nuclear projectiles when a Ne gas target was bombarded by 1-2 MeV/amu N, O and F ions. Our findings seem to be in contradiction with this statement at least in the studied higher impact energy range. If we compare the Ne^{10+} and Ar^{17+} induced spectra (fig . 2b and e), the intensity of the spectrum region around 915 eV is negligible for Ne^{10+} while in the case of Ar^{17+} it is surely higher. Here the velocity of the two projectiles is the same, and the collision for the bare Ne^{10+} is symmetric while for the nearly bare Ar^{17+} it is strongly asymmetric. A possible explanation of this fact may be the capture of target K electrons into the L_1 subshell of the Ar^{17+} projectile.

The center of the KLM group is located at about 825-830 eV in the spectra. Since the Ne atom has electrons in the M-shell only in excited states, to have KLM Auger electrons it should be excited to its M-shell during the collision, or can capture electrons into its M-shell. The target pressure was however kept low enough so that the probability of secondary collisions could be neglected. As can be seen in table 1 the relative intensity of the group in question compared to the body of the spectrum (all the spectrum below this group) is practically the same (8-10 %) within experimental errors in each case of the incident ions in this study. The reason for this experimental fact is so far unknown.

4. Concluding remarks

The data obtained in the present study confirm that there exists a linear relationship between the mean kinetic energy of the KLL Auger electrons $\bar{E}$ and the mean number of L-shell vacancies $\bar{n}_L$ produced simultaneously with a K hole in the target Ne atom at different heavy ion impact.

Having projectile ions of the same velocity including the bare Ne^{10+}, it was possible to determine the experimental values of $Z^{exp}_{eff,K}$ for the projectiles. Our experimental data obtained at a velocity of 14.8 a.u. show a better agreement with the results of the PWBA based calculation than with those derived from the BEA and Massey criterion (Toburen et al. 1981).

From our data experimental values have been deduced for the probability p_L of ejecting one electron from the L-shell simultaneously with one K electron.

When comparing these p_L values as well as those from Schneider et al. (1982) and Mann et al. (1982b) with the universal scaling curve from the simple model calculation for $p_L(0)$ (eq. (14)) which depends only on Z_p/v_p for bare projectiles we assumed for the projectiles carrying electrons that their effective charge in the multiple ionization Z_{eff,KL^n} can be roughly approximated usually by $Z_{eff,K}$ which characterizes the K-shell ionization. The assumption of using $Z_{eff,K}$ for the scaling of the experimental data coincides with the prediction of the model calculation only in the not too high $Z_{eff,K}/v_p$ region. This agreement, however, breaks down in the higher region and the $Z_{eff,K}/v_p$ scaling of the data itself fails. Considering the divergence of the X-ray and of the not too numerous Auger data on p_L in this region we cannot judge the validity of our assumptions on the scaling at present.

The satellite-to-total ratio as a function of $Z_{eff,K}/v_p$ seems to follow a similar course for heavy ions as that for the lightest ions according to the scaling.

Finally, the relative intensity of the Ne KLM Auger group to the KLL group (the whole spectrum at lower energies than the KLM group) was found to be nearly constant within the experimental error. It is a finding the explanation of which is yet unknown.

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Спектры оже-электронов в столкновениях атомов Ne
с ионами и Ne^{q+} и Ar^{q+} с энергией 5,5 МэВ/нуклон

В данной работе изучались К-оже-спектры неона, облучаемого тяжелыми ионами Ne^{3+}, Ne^{10+}, Ar^{6+} и Ar^{17+} с энергией 5,5 МэВ/нукл. Из полученных экспериментальных данных извлекались некоторые усредненные величины, характеризующие KL^n ионизационные процессы, а именно: средняя энергия KLL оже-спектра, среднее число вакансий на L-оболочке, произведенных одновременно с К-вакансией, эффективный в данном процессе заряд налетающего иона, отношение интенсивности сателлитов к полному спектру. Определены относительные сечения ионизации К-оболочки и отношения интенсивностей KLM- и KLL-переходов. Вычисленные из экспериментальных данных значения $Z_{эфф}$ сравниваются с расчетами по PWBA и BEA моделями. Проведены расчеты по простой модели для объяснения зависимости вероятности выбивания электрона из L-оболочки (p_L) от $Z_{эфф}/V_p$. Делаются некоторые утверждения относительно отдельных линий и групп в спектре.

Работа выполнена в Лаборатории ядерных реакций ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1984

Berényi D. et al. E7-84-142
Auger Electron Spectra in 5.5 MeV/amu
Ne^{q+} and Ar^{q+} Ion Impact on Ne

A study of Ne K-Auger spectra induced by 5.5 MeV/amu Ne^{3+}, Ne^{10+}, Ar^{6+} and Ar^{17+} heavy ions on Ne is presented. Some average quantities (the centroid energy of KLL Auger spectra, the average number of L vacancies produced simultaneously with the K vacancy, the effective charge of the projectile in the actual process, the satellite to total intensity ratio) characterizing the KL^n ionization process have been extracted from these spectra. Relative K-shell ionization cross sections and KLM to KLL cross section ratios have also been evaluated. The deduced experimental Z_{eff} values have been compared to the results of PWBA and BEA calculations. A simple model calculation is made in an attempt to interpret the variation of the probability for the ejection of an L-shell electron (p_L) as a function of Z_{eff}/v_p. Some statements regarding individual lines and groups in the Auger spectra are made.

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

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