ARKIV FÖR FYSIK Band 26 nr 10

Communicated 27 November 1963 by MANNE SIEGBAHN

The K Auger group intensities in Cl^{37}

By P. ERMAN, J. ROSSI, E. C. O. BONACALZA and J. MISKEL

ABSTRACT

The K Auger group intensities have been measured in the decay of Ar^{37} to Cl^{37}. The measured $KLL{:}KLX{:}KXY$ intensities are 1: $0.156 \pm 0.010 : 0.009 \pm 0.001$. These data are compared with corresponding results for higher Z-values obtained by other authors and with the theory of Geffrion and Nadeau.

Introduction

The knowledge of relative K Auger group intensities, $KLL{:}KLX{:}KXY$, where X and Y denote shells higher than L is important for several purposes e.g. determination of Q-values in electron capture decays (cf. ref. [1]) and estimates of atomic level widths [2]. For example in allowed E.C. transitions the Q-value can be written as

$$Q = \frac{E_{LI} - E_K \sqrt{\frac{P_L}{P_K} \cdot \frac{g_K^2}{g_{LI}^2 + f_{LII}^2}}}{1 - \sqrt{\frac{P_L}{P_K} \cdot \frac{g_K^2}{g_{LI}^2 + f_{LII}^2}}}$$

where E_K and E_{LI} are the binding energies of the K and L_I shells of the daughter atom and g_K, g_{LI}, f_{LII} are the "large components" of the respective Dirac radial wave functions in each shell derived by Brysk and Rose [3], and P_L/P_K is the relative capture ratio from L and K shells. The ratio P_L/P_K may be determined, if the $KLL{:}KLX$ ratio is known, according to the relation:

$$\frac{P_L}{P_K} = \omega_K \left\{ \frac{I_L}{I_K} \cdot \frac{1}{\bar{\omega}_L} - \frac{I_{K\alpha}}{I_K} \right\} - a_K \left\{ 2 + \frac{KLX}{KLL} \right\}$$

where I_K, I_{K_α} and I_L denote the K, K_α and L X-ray intensities. ω_K and $\bar{\omega}_L$ are the K- and mean L-fluorescence yields and a_K is the K Auger yield.

The experimental study of the group intensities, $KLL{:}KLX{:}KXY$, does not require very high spectroscopic resolution in most cases and was therefore one of the first things to be measured in the study of the Auger effect using a β-spectrometer. Nevertheless, the experimental data show very large discrepancies, as can be seen from Fig. 1, which shows a compilation of the experimental $KLL{:}KLX{:}KXY$

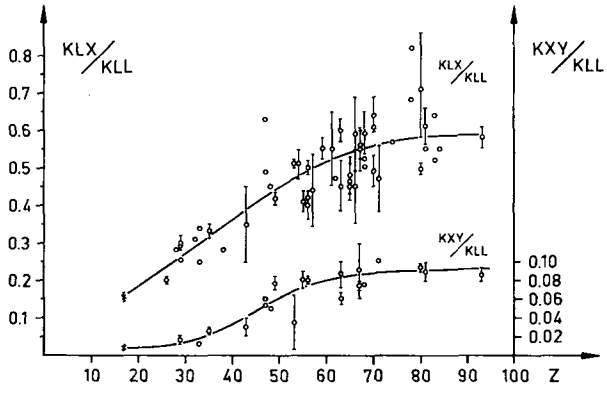

Fig. 1. Compilation of the experimental data of the K Auger group intensities. The cross marks denote the intensities for $Z = 17$ obtained in this work.

intensity ratios for different Z-values. The experimental points are mainly concentrated to the region $Z = 50 - 70$, while there are very few good measurements for $Z < 50$, and for $Z < 26$ there are no published measurements at all.

A theoretical calculation of the $KLL:KLX:KXY$ intensities is very tedious, especially if relativistic effects are taken into account. Pincherle [4] calculated the transition probabilities for KLL and some of the KLM, KLN, KMM, KMN and KNN groups. These calculations are, however, incomplete and do not contain significant transitions such as $(2s)(4d)$, $(2p)(4d)$ and $(3p)(4d)$. Geffrion and Nadeau [5] have computed the K Auger transition probabilities using hydrogen-like wave functions in a non-relativistic approximation. These calculations contain the most significant transitions KLL, KLM, KLN, KLO, KMM, KMN, KMO and KNN. The agreement with the calculations by Pincherle is good in the case of KLL, KLM and KLN transitions, while discrepancies occur for the other transitions. In Fig. 2 the ratio of the total K Auger intensity to the KLL intensity is plotted as a function

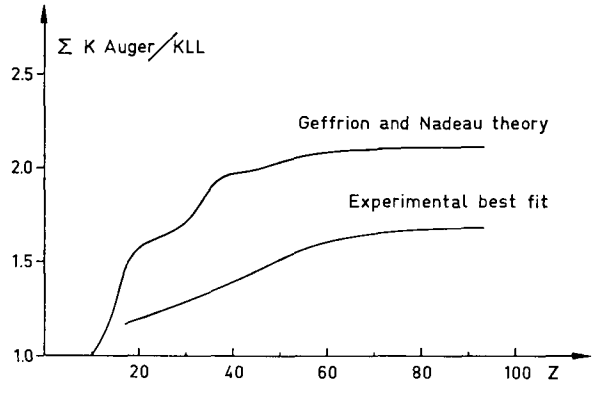

Fig. 2. Best fit of the experimental sum of the K Auger intensities (normalized to KLL) compared to the theoretical results of Geffrion and Nadeau [5].

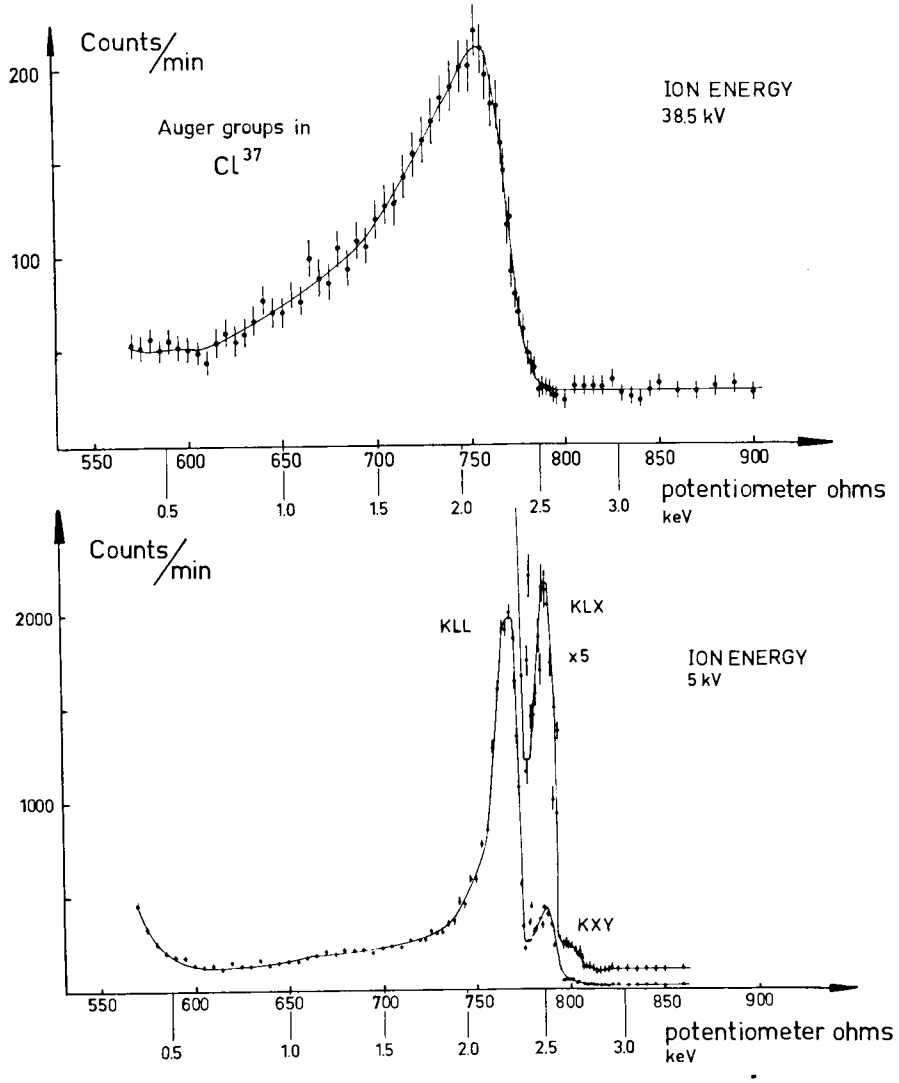

Fig. 3. The K Auger groups in Cl^{37} all measured in a double focusing spectrometer with the same slit settings. The upper curve is obtained from a source produced at 38.5 keV ion deposition energy, the lower is from a source deposited at 5 keV.

of Z. The upper curve is obtained from Geffrion and Nadeau [5] by adding the different transition probabilities in accordance with the known electron configurations. The lower curve is the experimental best fit according to Fig. 1. There are large discrepancies between the two curves; the theoretical values are systematically higher. Relativistic effects should be appreciable by $Z \rightarrow 50$. For instance, Asaad [6] found that for $Z = 80$ relativistic effects increased the KLL intensities by about 84 % compared to a non-relativistic treatment. However, if we assume the relativistic

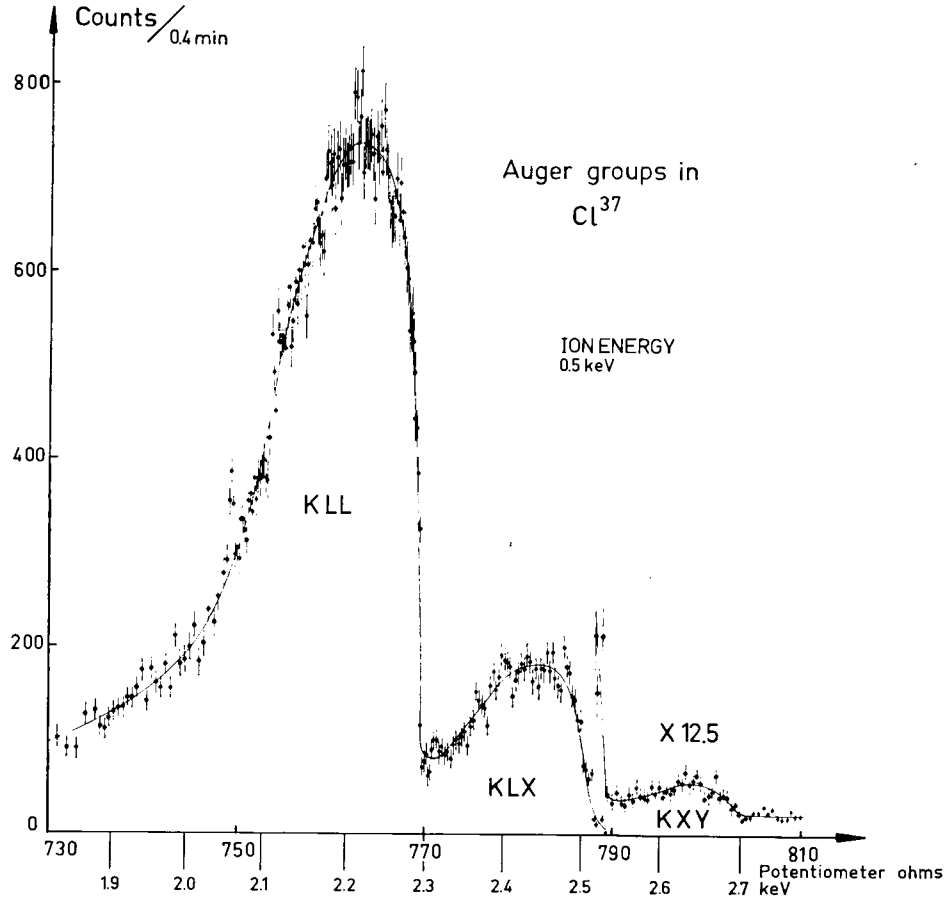

Fig. 4. The K Auger groups in Cl^{37}. The source is produced at 0.5 keV ion deposition energy.

correction to be about the same for all the K Auger transitions in light elements, the ratios plotted in Fig. 2 are not sensitive to relativistic effects in this case. The discrepancies therefore probably call for a use of more accurate wave functions.

Because of the difficulty in making theoretical calculations, it would therefore be of value to increase the accuracy of the experimental data as compared to those shown in Fig. 1 and to extend the measurements to the region $Z<26$. In this work we describe a measurement of the K Auger group intensities in Cl^{37} ($Z=17$).

Experimental procedure

The Cl^{37} activity is produced in the 35 d electron capture decay of Ar^{37}. This is obtained by fast neutron irradiation by the reaction $Ca^{40}(n,\alpha)Ar^{37}$. A total of 100 g CaF_2 was irradiated for 6 weeks in the MTR reactor at Idaho Falls. The total number of fast neutrons incident on the sample was approximately $1 \cdot 10^{20}$. The Ar^{37} was released after irradiation by vacuum melting the CaF_2 in the presence of a small

amount of stable Ar carrier. The Ar^{37} activity in the form of gas was then fed into the ion source of the isotope separator of the Nobel Institute.

The *KLL* Auger group of Cl^{37} has an energy of about 2 keV. This means that some difficulties will occur in the experimental study. First of all the source has to be extremely thin. In order to avoid line broadening due to thickness effect, it is clear from Fig. 2 in ref. [7] that the energy of the Ar^{37}-ions should be less than 2 keV when they are shot into the backing material. For this purpose it is necessary to use ion retardation equipment in the isotope separator [8]. The measurements were carried out in the 50 cm double focusing spectrometer of the Nobel Institute. As detector for the very low energy electrons, a side window G-M counter was used. The counter window was a 30 $\mu g/cm^2$ Al-coated formvar film and a pre- and postacceleration system (described in ref. [9]) was applied to increase the transmission of the system. The pre- and postacceleration voltages were 2.8 and 2.5 kV, respectively. In this way the window absorption at the position of the Auger lines was less than 15 %.

Fig. 3 shows two records of the *K* Auger groups in Cl^{37} made with the same spectrometer setting. The upper curve is obtained from a source produced at an ion deposition energy of 38.5 keV, the lower curve results from using 5 keV. The difference is very large, which shows that the "normal" deposition energy of about 40 keV is quite too high. In this case all the groups are hidden in the enormous low energy tails resulting from the thickness of the source. If 5 keV ion energy is used instead, the source becomes much thinner and the three *K* Auger groups are resolved as seen in the lower curve of Fig. 3. The thickness effect should, however, still be considerable, and Fig. 4 shows a better record obtained from a source produced at 0.5 keV ion energy.

Results

From Fig. 4 it is possible to make an accurate determination of the *KLL*:*KLX*:*KXY* group intensities. The mean values of ten runs are shown in Table 1.

Table 1. *K* Auger group intensities in Cl^{37} ($Z=17$).

	KLL	*KLX*	*KXY*
Exp. this work	1	0.156 ± 0.010	0.009 ± 0.001
Theor. Geffrion & Nadeau [5]	1	0.408	0.035

These experimental results are the points cross marked in Fig. 1. Evidently the *KLX*/*KLL* curve continues rather straight even for $Z<26$. On the other hand the *KXY*/*KLL* curve bends at about $Z=30$ and then obtains an almost constant value. The statistics of the experimental best fit shown in Fig. 2 is not good enough to show up the oscillations which are predicted by the theory of Geffrion and Nadeau.

ACKNOWLEDGEMENTS

Two of us (E.C.O.B. and J.R.) who have been on leave of absence from Instituto de Física, Bariloche and Comisión Nacional de Energía Atómica, Buenos Aires, Argentina, respectively would like to acknowledge scholarships granted by the Comisión Nacional de Energia Atómica. This work has been supported, in part, by the United States Atomic Energy Commission.

Nobel Institute of Physics, Stockholm 50 and Lawrence Radiation Laboratory, Livermore, Calif., USA.

REFERENCES

1. ROBINSON, B. L., and FINK, R. W., Rev. Mod. Phys. *32*, 117 (1960).
2. CALLAN, E. J., Aeronautical Research Lab., Wright-Patterson AFB. Dayton. Ohio. Report 1963 (unpublished).
3. BRYSK, H., and ROSE, M. E., Rev. Mod Phys *30*, 1169 (1958).
4. PINCHERLE, L., Nuovo Cimento *12*, 81 (1935).
5. GEFFRION, C., and NADEAU, G., Contract No. AF-18 (600)-1574 (1959). Office of Scientific Research, Air Research and Development Command, Quebec (unpublished).
6. ASAAD, W. N., Proc. Roy. Soc. *A249*, 555 (1959).
7. ERMAN, P., BONACALZA, E. C. O., and ROSSI, J., Arkiv Fysik *26*, 35 (1964).
8. UHLER, J., Arkiv Fysik *24*, 349 (1963).
9. ERMAN, P. and SUJKOWSKI, Z., Arkiv Fysik *20*, 209 (1961).

Tryckt den 12 februari 1964

Uppsala 1964. Almqvist & Wiksells Boktryckeri AB