FIZIKA, 7 (1975) 91—95

K_α/K_β RATIO FOR Cu MEASURED BY DIFFERENT MODES OF EXCITATION

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10. Received 14 April 1975

Abstract: A measurement of the K_α/K_β ratio for copper has been performed using three different modes of excitation: Mo-x rays, electron capture, and low-energy protons. The ratios do not exhibit a dependence on the modes used.

1. Introduction

The determination of the K_α/K_β ratio is important from different points of view. From the fundamental point of view this ratio gives information about the electronic configuration of the atom formed by the interaction which created the K-vacancy. From the point of view of application it may also provide a rapid technique for the efficiency calibration of solid state detectors, a method for the thickness determination of thin films, and an additional parameter for the elemental analysis in the presence of complex spectra.

In order to treat the K_α/K_β ratios with confidence, it is necessary to ascertain that most frequently used techniques of excitation do not affect the value of the K_α/K_β ratio. Several authors have recently measured the K_α/K_β ratio for different elements. The results have been subject to a rather large scatter depending on the mode of excitation, as seen from Table 1. It is very difficult to reconcile the existing discrepancies, and we therefore performed a measurement of the K_α/K_β ratio for copper by three different techniques of excitation but using the same detector system and the same evaluation procedure. The excitations used were:

— electron-capture mode,
— bremsstrahlung spectrum + Mo K-x rays at $E_{el} = 30\,kV$, and
— protons of 162 keV.

2. *Experimental methods*

K_α and K_β rays were measured by use of a Si(Li) detector with an energy resolution of 195 eV at 5.9 keV. The detector area was 15 mm^2. The relative efficiency of the detector was measured. The ratio of efficiencies $\varepsilon_\alpha/\varepsilon_\beta$ was found to be equal to 0.988 ± 0.003 for the energies measured. The counting rate was kept under 1000 c/s in order to benefit from the best possible resolution.

TABLE 1

LITERATURE REVIEW OF EXISTING DATA

Mode of excitation	K_α/K_β
Electrons	7.33[1]
Electrons	7.78 ± 0.54[2]
x-rays	7.46 ± 0.15[3]
x-rays	6.81 ± 0.34[4]
x-rays	7.23 ± 0.07[5]
Deuterons	7.46 ± 0.26[6]
Prorons	7.8 ± 0.1[7]
Alphas	7.30 ± 0.22[6]

Spectra were recorded with a 1024-channel analyzer. The background was, typically, 400 times smaller than the K_β peak for excitation by x-rays and electron capture. For proton excitation, this ratio was 100. A typical spectrum for 162-keV protons is shown in Fig. 1.

The excitation mode of vacancies was as follows:

X-ray mode. An x-ray tube with a molybdenum anticathode was used. The tube was operated at 30 kV. The x-ray beam was collimated with lead diaphragm of 2 mm in diameter.

The target was a 2-mg/cm^2 copper foil placed at 45° to the incoming beam. No filtration of the incoming beam was performed except the filtration through the Al window on the tube.

K-electron-capture mode. A carrier-free, cyclotron-produced Zn^{65} thin source was used. The source backing was a thin aluminium foil. In order to keep the counting rate within the limit of 1000 c/s, the source-detector distance used was 7 cm. The correction for the air layer was introduced.

Proton-bombardment mode. A 20-mg/cm^2 copper target was bombarded with a 500-nA analyzed H^+ beam from a standard 300-kV accelerator. The target thickness is irrelevant in this case, since the range of 162-keV protons in copper is 0.75 mg/cm^2 and moreover, the cross section to produce K-vacancies rapidly decreases with energy, reducing the effectively contributing thickness to a value which is even lower.

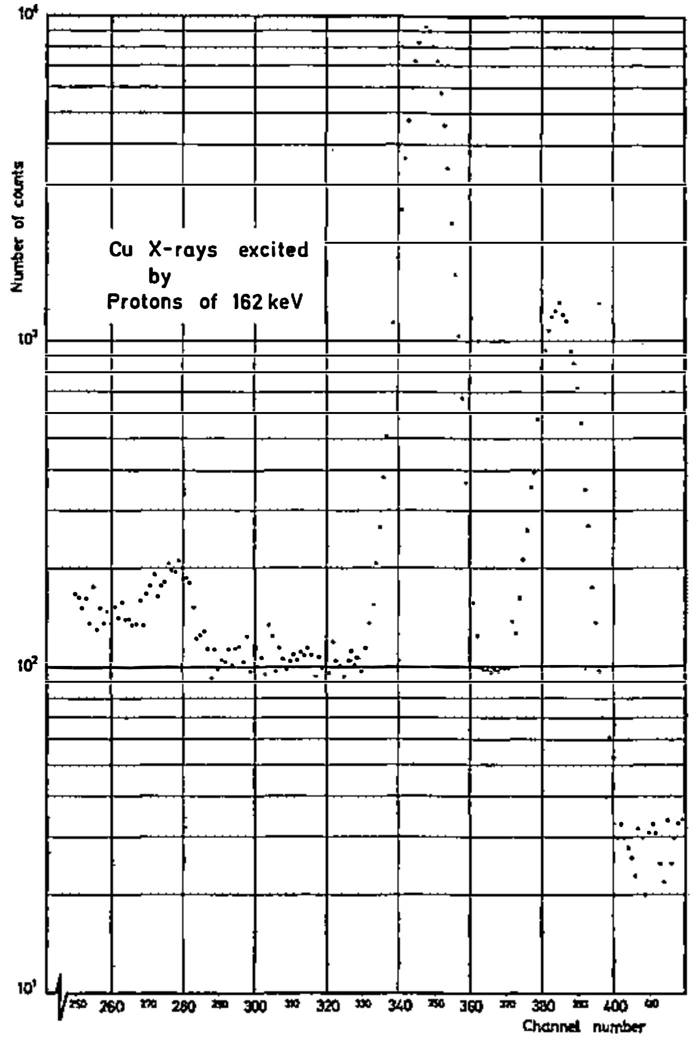

Fig. 1. K. x-ray spectrum for 162-keV protons on a Cu target.

The x-ray detector viewed the target through a 0.0025-cm thick kapton H foil window.

The corrections were introduced:

— for the air path photons had to travel before entering the detector, and
— for the thickness of the copper foil in the case of the x-ray excitation mode.

The background in the spectra was subtracted assuming a linear behaviour in the region under both peaks.

Besides the statistical errors, the error in the relative efficiency of the detector was taken into account and was included in the error quoted in the results. The uncertainty in the background subtraction was also evaluated and included in the error.

Several measurements were performed for each mode of excitation. The results obtained are shown in Table 2.

TABLE 2.

K_α/K_β RATIOS MEASURED IN THE PRESENT EXPERIMENT.

Mode of excitation	K_α/K_β
Mo-x ray + bremsstrahlung	7.33 ± 0.08
Electron capture	7.34 ± 0.09
Proton excitation $E_p = 162$ keV	7.23 ± 0.20

3. Conclusion

The data as determined from the present experiment are in agreement with the latest theoretical estimate of Scofield[8], which included the effect of nonzero overlap of the wave functions from different subshells. That treatment yields a K_α/K_β ratio of 7.24. The present experiment yields equal values for K_α/K_β ratios obtained from x-ray excitation and electron capture with $\cong 1$ percent errors. Such precision in the knowledge of K_α/K_β makes the use of these ratios for applied purposes such as detector efficiency determinations and thickness measurements. The relatively important error in proton excitation data prevents us from drawing the conclusion whether the lower K_α/K_β ratio is due to the higher probability for the formation of multiple vacancies, as observed for heavy ions at higher energies[6].

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K_α/K_β OMJER ZA Cu MJEREN RAZLIČITIM METODAMA UZBUDE

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Sadržaj

Širok raspon omjera K_α/K_β u literaturi u slučajevima različitih metoda stvaranja šupljina u K ljusci navela nas je da pokušamo s istim detekcionim sistemom i istim kriterijima analize vrhova u spektru izmjeriti K_α/K_β omjere. Taj smo omjer izmjerili za bakar za slučaj stvaranja K šupljine slijedećim metodama: x-zrakama dobivenim u cijevi s Mo-antikatodom, zahvatom K elektrona u Zn^{65} i niskoenergetskim protonima. Dobiveni rezultati prikazani u Tabeli 2. ukazuju da za bakar u ovim mjerenjima nije uočena ovisnost K_α/K_β omjera o načinu uzbude K šupljina.