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AUTHORS: Omer SOGUT,Adnan KUCUKONDER,Erdal KUCUKONDER,Hanife CAM

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Measurement of K X-Ray Cross-Sections for Elements with 22 ≤ Z ≤ 42 at Liquid Nitrogen Temperature

Ö. SÖĞÜT[1*], A. KÜÇÜKÖNDER[1], E. KÜÇÜKÖNDER[1], H. ÇAM[1]

[1]Kahramanmaraş Sütçü İmam University, Faculty of Arts and Sciences, Department of Physics 46100 Kahramanmaraş-Turkey.

ABSTRACT: X-ray production cross-sections for K_α and K_β x-Ray lines measured for Ti, V, Fe, Ni, Cu, Zn, Nb and Mo at a photon excitation energy of 59.5 keV at the liquid nitrogen temperature (-196 ^{0}C) using a high resolution Si(Li) detector. The values obtained were compared with the experimental values at ambient temperature (laboratory conditions) and theoretical values. The experimental values at liquid nitrogen temperature are smaller than that of the values at ambient temperature. No variations in the $\sigma_{K\alpha}$ and $\sigma_{K\beta}$ fluorescence cross-sections at liquid nitrogen temperature (-196 ^{0}C) are observed

Keywords: *X Ray, Cross-sections, K X Rays*

22 ≤ Z ≤ 42 Sıvı Azot Sıcaklığında Elementler için K X-Ray Kesitler ölçümü

ÖZET: K_α ve K_β X ışını çizgileri için X ışını tesir kesitleri yüksek çözünürlüklü Sİ(Lİ) detektör kullanılarak sıvı nitrojen sıcaklığında (-196 derecede) 59,5 keV lik bir uyarma foton enerjisinde Ti, V, Fe, Ni, Cu, Zn, Nb, ve Mo için ölçüldü. Elde edilen bu değerler teorik değerler ve ortam değerleri (laboratuar koşulları) deneysel değerlerle mukayese edildi. Sıvı nitrojen sıcaklığındaki deneysel değerler ortam sıcaklığındaki değerlerinkinden daha küçüktür. Sıvı nitrojen sıcaklığında (-196 derecede) $\sigma_{K\alpha}$ ve $\sigma_{K\beta}$ fluoresans tesir kesitlerinde hiçbir değişiklilik gözlemlenmemiştir.

Anahtar Kelimeler: *X Işını, Tesir Kesitleri, K X ışınları*

1. INTRODUCTION

The measurements of K, L and M shell/subshell X-ray fluorescence (XRF) cross-sections for different elements at various photoionisation energies are important tasks in atomic, molecular and radiation physics investigations, in non destructive testing, elemental analysis, medical research and irradiational processes [1-3]. In addition, comparison of measured X-ray fluorescence cross-sections with theoretical estimates provide a check on the validity of various physical parameters such as the photoionisation cross-section, fluorescence yield, X-ray emission rates and jump ratios [4]. The K X-ray emission lines are caused by transitions Kα=(K←L₂, L₃) Kβ=(K←M₂, M₃, M₄, M₅, N₂, N₃,...). The K_α and K_β X-ray fluorescence cross-sections of various elements were measured at different energies [5-8]. We studied the chemical effects [9-12], alloying effects [13], thickness effecst [14] on K emission lines intensity ratios. We also examined the alloying effects on K X-ray fluorescence cross-sections [15], and chemical effects on L X-ray emission lines intensity ratios and the L X-ray fluorescence cross-sections [16-18]. There are no studies on the temperature dependence of K X-ray fluorescence cross-sections have not been reported in the literature.

Photons induced for some elements with 22 ≤ Z ≤ 42 at 59.5 keV were measured at liquid nitrogen temperatures. The values obtained were compared with the experimental values at ambient temperatures, and theoretical values.

2.EXPERIMENTAL AND DATA ANALYSIS

Experimental measurements were carried out on the K characteristic radiations, stimulated by 59.5 keV γ photons of a 75 mCi ^{241}Am source in samples at liquid nitrogen and ambient temperatures. All of the samples of elements were in the foil form. The experimental setup for the measurements were liquid nitrogen temperatures and a typical K x-ray spectra of Mo are given in Fig.1 and Fig.2, respectively. The samples in the foil form were placed in the liquid nitrogen. Other measurements were carried out under laboratory conditions. Fluorescent X-ray spectra from the target were recorded by the collimated Si(Li) detector, with a resolution 155 eV at 5.9 keV. Possible sources of error include:

a- $I_0G\varepsilon$ determination (2%),

b- background determination (1%),

c- self-absorption correction factor (1%),

d- counting statistic (1%). Addition of these sources of error gives a total experimental relative error of 5%.The experimental K_α and K_β X-ray fluorescence cross-sections were calculated using the relation,

$$\sigma_{K_i} = \frac{N_{K_i}}{I_0 G \varepsilon_{K_i} \ \beta_{K_i} \ t} \qquad (1)$$

where N_{Ki} is the intensity observed for the K_i emission line of the element, I_0 is the intensity of exciting radiation, G is the geometry factor and t is the mass of the sample in g cm^{-2} ; β_{Ki} is the self absorption correction factor for both the incident and emitted radiation and ε_{Ki} is the detection efficiency of the detector at the energy of the K_i lines. The effective incident photon flux $I_0 G \varepsilon_K$ was determined by measuring the K_α X-ray yield from Ti, Fe, Ni, Cu, Mo and Ag in the same geometry. The measured $I_0 G \varepsilon_K$ factor was plotted as a function of the mean K_α X-ray energy. K_β is evaluated by using the following expression, obtained by assuming that the fluorescent X-rays are incident normally at the detector.
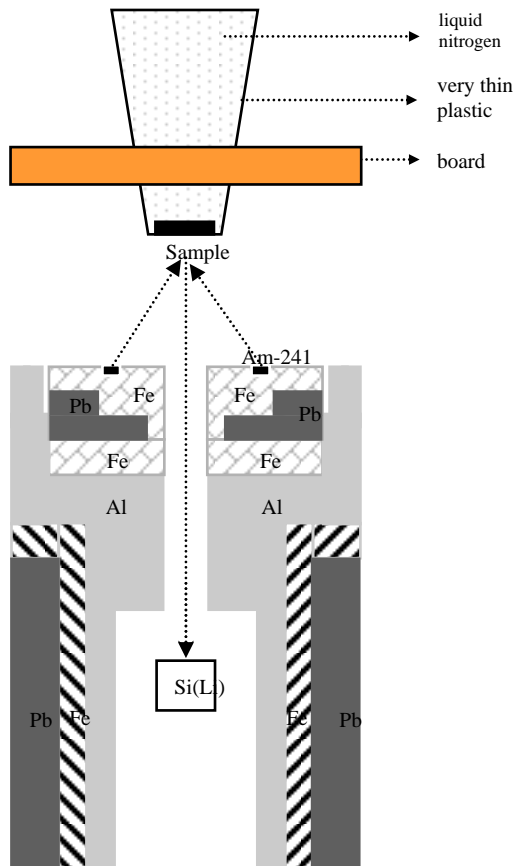

Figure1. Experimental setup

$$\beta = \frac{1-\exp\left[-\left(\mu_{inc} \ \sec\theta + \ \mu_{emt}\right) \ t\right]}{\left(\mu_{inc} \ \sec\theta + \ \mu_{emt}\right) \ t} \qquad (2)$$

where μ_{inc} (cm^2 g^{-1}) and μ_{emt} (cm^2 g^{-1}) are the total mass absorption coefficients of the incident and the emitted characteristic X-rays, respectively. These values were taken from the table of Hubbell and Seltzer [20]. Angle θ was calculated by using the following expression [21].

$$\theta = \arcsin\left[1 - \frac{mc^2}{E_0 \ E_s} \ \left(E_O - E_s\right)\right] \qquad (3)$$

where mc^2=511 keV, E_0 and E_s are the radioisotope energy and Compton scattering energy, respectively.
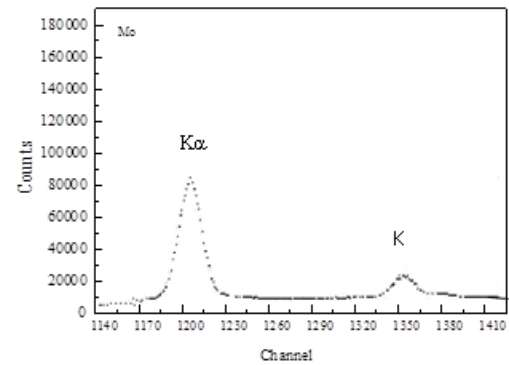

Figure 2. A typical spectrum of Mo

The theoretical values of K X-ray

fluorescence cross-sections $\sigma_{K\alpha}$ and $\sigma_{K\beta}$ were calculated using the following equation,

$$\sigma_{K\alpha} = \sigma_K(E) \ \omega_K \ f_{K\alpha} \qquad (4)$$
$$\sigma_{K\beta} = \sigma_K(E) \ \omega_K \ f_{K\beta} \qquad (5)$$

where $\sigma_K(E)$ is the K shell photoionisation cross-section for the given element at the excitation energy E, ω_K is the K shell fluorescence yield and $f_{K\alpha}$ and $f_{K\beta}$ are fractional X-ray emission rates for K_α and K_β X-rays, and are defined as

$$F_{K\alpha} = [1 + I_{K\beta} / I_{K\alpha}]^{-1} \qquad (6)$$

$$F_{K\beta} = [1 + I_{K\alpha} / I_{K\beta}]^{-1} \qquad (7)$$

where $I_{K\beta} / I_{K\alpha}$ is the K_β to K_α X-ray intensity ratios. In the present calculations, the values of $\sigma_K(E)$ were taken from Scofield [22] based on Hartree-Slater

potential theory, and the values of ω_K were taken from the tables of Hubbell et al.[1] and Hubbell [3].

3. RESULTS AND DISCUSSION

According to classical mechanics where $E=3/2kT$ and absolute zero temperature $(T=0 \ ^0K)$ all the movement of atoms is halted. In other words, it is understood the there is no motion. Therefore, when temperature approaches absolute temperature $(T=0 \ ^0K)$ all atomic electrons and their transitions slow down. However, according to Quantum mechanics where $E=(n+1/2) \ \hbar\omega$ even if n=0, for the relationship $E_0=1/2\hbar\omega$ all the movement of atoms would not stop and there would bear no relevance to temperature. Further, in Quantum mechanics, even if the temperature was brought down to absolute temperature $(T=0 \ ^0K)$, the system still would have E_0 energy and this energy would sufficient for the vibrations of atoms. In Quantum mechanics, this concept of zero level energy is one of the important differences between classical mechanics and Quantum mechanics.

The measured values of the K X-ray fluorescence cross-sections at liquid nitrogen temperature $(-196 \ ^0C)$, ambient temperature in water, ambient temperature and theoretical values are given in Table 1, 2. As shown in Tables 1 and 2, the experimental values at liquid nitrogen temperature are smaller than that of values at ambient temperature (in air). To check the measured values, the same experiment was done under at the same conditions at ambient temperature, again in water. The results obtained were too interesting. Because K X-ray fluorescence cross-sections at liquid nitrogen temperature

$(-196 \ ^0C)$ and ambient temperature in water were about the same; it is explicitly stated that the K X-ray fluorescence cross-section of the studied elements, at liquid nitrogen temperature and ambient temperature in water has an effect on the chemical structure change compared to the K X-ray fluorescence cross-section measured at ambient temperature in air. The experimental values at liquid nitrogen temperature are smaller than that of the values at ambient temperature. The reason for this may be because of the scattering of characteristic K X-rays of emission from sample in the liquid nitrogen and water. As a result, no change in chemical structure of the studied elements at liquid nitrogen temperature $(-196 \ ^0C)$ is observed. Therefore, no variations in the $\sigma_{K\alpha}$ and $\sigma_{K\beta}$ fluorescence cross-sections at liquid nitrogen temperature $(-196 \ ^0C)$ are observed.

Table 1. $\sigma_{K\alpha}$ fluorescence cross-sections (in b/atom)

Element	at liquid nitrogen temperature	at ambient temperature in water	at ambient temperature	Calculated
Ti	0.47 ±0.02	0.49 ±0.02	8.03 ±0.40	7.10
V	0.95 ±0.04	0.99 ±0.05	8.33 ±0.42	11.29
Fe	7.340 ±0.36	7.52 ±0.37	25.46 ±0.92	26.11
Ni	23.98 ±1.19	23.65 ±1.18	40.81 ±2.04	42.57
Cu	18.78 ±0.94	18.90 ±0.95	56.80 ±2.84	52.07
Zn	21.79 ±1.09	21.76 ±1.09	61.64 ±3.08	65.68
Nb	280.71 ±14.03	282.33 ±14.11	341.90 ±15.59	328.65
Mo	296.87 ±14.08	298.45 ±14.91	338.88 ±16.94	366.11

Table 2. $\sigma_{K\beta}$ fluorescence cross-sections (in b/atom)

Element	at liquid nitrogen temperature	at ambient temperature in water	at ambient temperature	Calculated
Ti	0.13 ±0.01	0.14 ±0.007	0.70 ±0.03	0.90
V	0.22 ±0.02	0.23 ±0.01	1.02 ±0.05	1.31
Fe	1.35 ±0.06	1.38 ±0.07	2.64 ±0.13	3.16
Ni	2.63 ±0.13	2.61 ±0.13	5.26 ±0.26	5.15
Cu	2.37 ±0.11	2.39 ±0.12	7.81 ±0.39	6.30
Zn	2.51 ±0.12	2.58 ±0.13	6.14 ±0.30	8.11
Nb	21.18 ±1.05	22.09 ±1.10	51.52 ±2.57	57.99
Mo	17.55 ±0.87	18.55. ±0.93	53.41 ±2.67	66.13

REFERENCES

[1]. J.H. Hubbell, P.N. Trehan, N. Singh, B. Chand, D. Mehta, M.L. Garg, R.R. Garg, S. Singh, and S., Puri, J. Phys. Chem. Ref. Data 23, 339 (1994).

[2]. K.M. Balakrishna, N.G. Nayak, N. Lingappa and K. Siddappa, J. Phys. B: At. Mol. Opt. Phys. 27, 715 (1994).

[3]. J.H. Hubbell, Bibliography and current status of K, L and higher shell fluorescence yields for computations of photons energy-absorption coefficients, NISTIR 89-4144 (1989).

[4]. R. Durak, and Y. Şahin, Nucl. Instr. Meth. B 124, 1 (1997).

[5]. S. Puri, D. Mehta, N. Singh and P.N. Trehan, Phys. Rev. A 54, 617 (1996).

[6]. J.K. Sharma, N., Singh, R. Mittal, B.S. Sood and K.L. Allawadhi, X-Ray Spectrom. 25, 239 (1996).

[7]. D.V. Rao, R. Cesareo and G.E. Gigante, X-Ray Spectrom. 25, 74 (1996).

[8]. R. Durak, S. Erzeneoğlu, Y. Kurucu and Y. Şahin, Radiat. Phys. Chem. 51, 45 (1998).

[9]. A. Küçükönder, Y. Şahin, E. Büyükkasap, J. Radioanal. Nucl. Chem. 170, 125 (1993).

[10]. A. Küçükönder, Y. Şahin, E. Büyükkasap, A. Kopya, J Phys. B26, 101 (1993).

[11]. A. Küçükönder, Y. Şahin, E. Büyükkasap, Nuova Cimento D15, 1295 (1993).

[12]. A. Küçükönder, E. Büyükkasap, R. Yılmaz, Y. Şahin, Acta Phsica Polonica A95, 243 (1999).

[13]. Ö. Söğüt, E. Büyükkasap, A. Küçükönder, M. Ertuğrul, Ö. Şimşek, Appl. Spect. Rev. 30, 175 (1995).

[14]. E. Büyükkasap, Appl. Spect. Rev. 32, 151 (1997).

[15]. E. Büyükkasap, Acta Physica Polonica A93, 701 (1998).

[16]. Ö. Söğüt, E. Büyükkasap, A. Küçükönder, M. Ertuğrul, Appl. Spect. Rev. 32, 167 (1997).

[17]. E. Büyükkasap, Spectrochim. Acta, B 52, 1167 (1997).

[18]. E. Baydaş, Ö. Söğüt, Y. Şahin, E. Büyükkasap, Radiat. Phys. and Chem. 54, 217 (1999).

[19]. S. Puri, D. Mehta, B. Chand, N. Singh and P.N. Trehan, Nucl. Instr. Meth. B74, 347 (1993).

[20]. 20.J.H. Hubbell, S.M. Seltzer, Laboratory Report, US, Department of Commerce Technology Administration, National Institute of Standards and Technology Physics Laboratory, NISTIR-5632 (1995).

[21]. 21. E.D. Greaves, S. Bohus, L. Marco and M. Alvarez, X-Ray Spectrom. 21, 127 (1992).

[22]. 22. J.H. Scofield, Lawrence Livermore Laboratory, Livermore, Report UCRL 51326 (1973).