Research Article

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# K-Shell fluorescence yield for high Z elements

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**Abstract:**

The K-shell fluorescence yields $\omega_k$, of high Z elements Ir, W, Lu, Tm and Gd present in its compounds at incident photon energy of 0.123MeV were measured by adopting a nearly 2π geometry and employing NaI(Tl) Scintillation spectrometer. The experimental results are compared with the values of (Krause 1979, T. Yashoda 2002 and Hubbell et.al. 1994) are found to be in close agreement.

**Keywords**: K -shell fluorescence yield; X-ray fluorescence cross section and Photoeffect.

## Introduction:

The K X-ray fluorescence yield $\omega_k$, is an important parameter in radiation physics and radiation dosimetry. Several investigators have been measured the K-Shell fluorescence yield values adopting single and double reflection geometries with very strong radioactive isotopes. We outline here a simple method of measuring this parameter using an almost 2π geometry and employing usual laboratory radioactive sources which cover the entire face of the detector, so that the same number of photons that are measured as incident photons will pass through the target.

In the present measurements, we outline the $\omega_k$ of Ir, W, Lu, In & Gd by fluorescent excitation method to excite target elements. The results are compare with earlier experimental results obtain by other methods by (Krause 1979, Balakrishana 1994, Hubbell et.al.1994, Tirasogle 2008 and C. Castelerio 2010).

## Experimental details:

In the present measurement, a NaI(Tl) scintillations detector of size $1^3/_4$ x 2", coupled to a high stability photomultiplier tube, coupled to conventional amplifier & 16 k multichannel analyser. The scintillation detector spectrometer linearity is calibrated using several gamma ray sources covering the energy range 27-320 keV ($^{241}$AM, $^{57}$Co, $^{170}$Tm, $^{141}$Ce, and $^{51}$Cr).

The plastic disk type radioactive source $^{57}$Co of the order of about 1 μCi procured from BRIT, Mumbai, India, is kept on the face of the detector to check the percentage loss of pulses experienced by the electronics; this is indicated by a built-in dead time indicator in MCA. For the source strength we selected, the dead time was only about 1-2%, indicating only a marginal loss of pulses. However, to correct this we selected live time instead of real time in MCA operation. The experiment setup is shown in Fig.1. The target form spectro-scopically pure of thickness

ranging from 145 to 302 mg/cm$^2$ are used. The compound in fine powder form was filled in perpex plastic container, compounds & $IrCl_3$, $NaWO_4$, $Lu_2O_3$, $Tn_2O_3$ and $Gd_2O_3$ are used for targets.

## Results and discussion:

The fluorescence yield of an atomic shell is defined as the probability that a vacancy in that shell or subshell is filled through radioactive transitions.

$$\omega_k = \frac{I_k}{n_k} \qquad (1)$$

Where; $I_k$ is the total number of fluorescence K x-ray photons produced in the target and $n_k$ is the number of primary k-shell vacancies.

The number of vacancies $n_k$ created in the K-shell is given by

$$N_k = \frac{I_0 \tau_k N_A E}{A} \qquad (2)$$

Where;

$I_0$ is the number of incident photons, $\tau_k$ is the K-shell photoionisation cross section of the target atom at the incident photon energy and $n_a$, the of atoms, per cm$^2$ area of the target foil, $N_A$ (atoms per mole) is the Avogadro's number, t (g.cm$^{-2}$) is the thickness of the target and A (g.mol$^{-1}$) is the atomic weight of the target element. The values of $\tau_k$, were taken from (Scofiled 1973).

The fluorescence K x-rays produced by the incident radiation in the target are emitted isotropically. The number of these x-rays depends on the energy of the incident radiation and on the atomic number of the target. The estimation of the total number of fluorescence x-rays in the target itself during their passage from the sites of production through the remaining portion of the target (Horakeri et.al., 1997). A correction factor,

A perpex container of diameter 2.2cm with target compound is placed between sources and scintillation detector. The distance between source and detector is 8.5 cm and container is placed above 1.9 cm above detector.

β, termed as the self-attenuation correction factor for the target material, is given by

$$\beta = \frac{1-\exp[-(\mu_i + \mu_e)\, t]}{[(\mu_i + \mu_e)\, t]} \qquad (4)$$

Where;

$\mu_i$ and $\mu_e$ are the mass attenuation coefficients of the incident and emitted K x-ray photons,

$$I_k = \frac{I_k'}{\beta \omega_k} \qquad (5)$$

Where $I_k'$ is the measured K x-ray intensity and $E_k$ is detector efficiency at X-ray energy.

The detector subtends a solid angle of almost 2π steradian. So that number of X-rays reaching the detector has to be multiplied by a factor of 2, to account for the total number of fluorescence x-rays produced in the target that are emitted isotropically. Hence the K-shell fluorescence yield, $\omega_k$, is given by

$$\omega_k = \frac{2I_k}{I_0 \varepsilon \tau_k \left(N_A t / A\right)} \qquad (6)$$

The weight A should be replaced by the molecular weight M of the compound and the $\mu_i$ and $\mu_e$ values are to be calculated using the mixture rule respectively, in the target; These values were computed from the tables of (Hubbell and Seltzer 1995) using the log-log interpolation scheme. Using the equation (4) we calculate the values of thickness of the target that would be suitable for the measurement of $\omega_k$ value. The corrected number of fluorescence K x-rays produced in the target is estimated using the equation.

**Table 1:** Comparison of K-fluorensce yield with other literature values percentage errors are shown with Hubbell (1994).

| Z | Element | $\omega_k$ Present | $\omega_k$ Others | % Error |
|---|---|---|---|---|
| 64 | Gd | 0.940 | 0.9329[(1)], 0.935[(3)], 0.934[(4)], 0.992[(7)], 0.966[(8)]. | 2.6915 |
| 69 | Tm | 0.955 | 0.947[(1)], 0.946[(3)], 0.945[(4)], 0.979[(8)]. | 2.4515 |
| 71 | Lu | 0.965 | 0.952[(1)], 0.953[(3)], 0.949[(4)], 0.981[(8)]. | 1.6309 |
| 74 | W | 0.977 | 0.957[(1)], 0.958[(3)], 0.954[(4)], 0.956[(7)], 0.983[(8)]. | 0.6104 |
| 77 | Ir | 0.972 | 0.962 [(1)], 0.962[(3)],0.958[(4)], 0.982[(8)]. | 1.0183 |

(1) Bambyneck, (3) Krause, (4) Bambynek, (7) Balakrishna , (8) Hubbell.

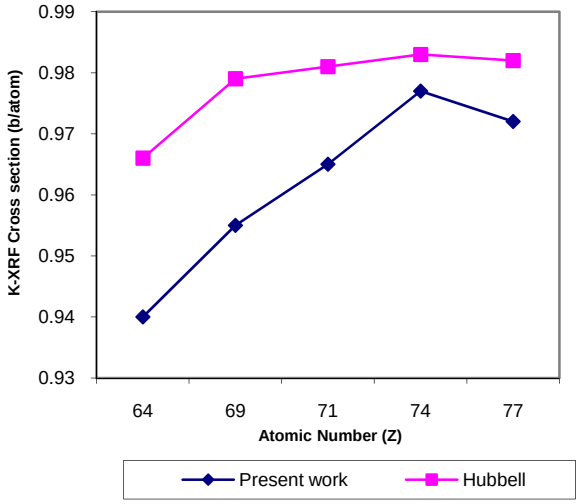


**Fig. 1. K-XRF cross sections**

## Conclusion:

The present experimental values of K-shell fluorescence yield of Ir, W, Lu, In & Gd is compare with the standard fitted values available in the literature. It is clear that our values are in close agreement with the semiempirical values of (Krause 1979), the standard fitted values of (Hubbell 1994, Balkrishna 1954). We must point out here that in the case of high Z elements compounds, are surrounded by different low Z elements namely oxygen, chlorine etc. We have selected the thickness of the target such that the attenuation of fluorescence x-rays in the target is very less. Since the measured values of $\omega_k$ for Ir, W, Lu, Tm and Gd are in close agreement with the standard value. Also the fluorescence x-rays produced due to interaction of incident photons with low Z elements present in the compound are not interfering in the region of interest as they are far away from it. From the table, it is clear that our values are in good agreement with other values except those of (Hubbell et.al. 1994) which are consistently higher than our values. the present method can easily be employed to determine the K-shell fluorescence yields for compound targets when the constituent elements except the interested element are of low Z values. From the above we can conclude that our method is suitable also to measure $\omega_k$ values of medium Z elements. The errors in measurements are due to non uniformity of sample and secondly large percentage of high-Z impurities or nearest Z elements present in the sample. Further experiments are in progress to determine $\omega_k$ values using scattered photon beams of energies close to absorption edges.

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