Executive Summary

of

Minor Research Project

"XRF EXPERIMENTS USING REFRACTION TYPE OF GEOMETRY (2π-GEOMETRY) FOR LOW AND MEDIUM Z ELEMENTS AND COMPOUNDS"

MRP(S)-0404/13-14/KABA095/UGC-SWRO

Submitted

To

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Contextual studies on XRF parameters and its scope:

Ever since the discovery of photoelectric effect by Albert Einstein, several researchers have studied the effect of photon interaction with matter and their significances. One of the significance being X-ray fluorescence (XRF), the study of X-ray fluorescence parameters of pure elements and compounds finds importance in the fields of, atomic, nuclear, molecular physics, material and forensic sciences, electron conversion, internal conversion processes and many more. Literature review on the studies of X-ray fluorescence parameters have shown that, various methods and techniques have been used by researchers to determine the X-ray fluorescence parameters accurately from time and again involving radioactive sources of high strength, posing health hazards to the user and the surrounding. However, a simple method involving a 2π- geometrical configuration and a weak radioactive source (almost dead sources) suggested by Horakeri et al. (1997) and later developed by Gudennavar et al. (2003), Bennal et al. (2010) and Anand et al. (2014) have studied the characteristic X-ray fluorescence parameters for high and medium Z pure elements and have found that the experimental values are in close agreement with the theoretical and others' experimental values. But using this method, the studies on X-ray fluorescence parameters of elements in the low Z regime have not been studied. Hence, through this minor research project, a brief study on few of the X-ray fluorescence parameters like, the K X-ray intensity ratios and the K-L total vacancy transfer probabilities for pure low and medium Z elements have been studied. The measured values are tabulated and represented graphically showing the comparison of our values with the theoretical values for cobalt, nickel, copper, zinc, molybdenum, palladium, silver, platinum, gold and lead pure elements.

Experimentation:

The methodology involves a low energy high purity germanium (HPGe) detector coupled to a 16 k Multi Channel Analyser (MCA) and a weak gamma source (^{137}Cs and ^{57}Co) as shown in Fig. 1. The targets are 99.99% pure elements purchased from Alfa Aesar suppliers United Kingdom (UK). The detector is isolated from the source and a background spectrum is carefully acquired for a preset live time in the multichannel analyser. The spectrum is saved with a file name in the computer programmed to the MCA. The source is now placed on the face of the detector and a source plus the background spectrum is obtained for the same live time. The source plus background spectrum is saved with a different file name in the computer. The target under study is sandwiched between the source and the window of the detector and the transmitted spectrum is acquired for the same live time. The spectrum is saved with a unique file name in the computer. The procedure is repeated for four times and for the other target elements and recorded in the computer with different file names respectively. The source plus the background spectra is now subtracted from the transmitted spectrum of a target element for a clean K X-ray fluorescence spectrum using Origin software. Similarly, the other target elements were investigated. The K X-ray fluorescence spectra of the target elements investigated are shown in Fig. 2. The analysis of the spectra for the computation of K X-ray intensity ratio and K-L total vacancy transfer probability is made using suitable formulae discussed elsewhere in Anand et al.(2014).

Results and Discussion:

The findings for the X-ray fluorescence parameters for a few low and medium Z elements using the above mentioned method through this minor research project is been tabulated and presented in Table 1. It is been found that the method discussed above is suitable for the study of X-ray fluorescence parameters for low and medium Z elements. However, there is an uncertainty of about 2% associated with these measured values. It is found these uncertainties are due to the cascading effect viz. Efficiency of the detector, self-attenuation correction factor, counting statistics and target thickness. The measured values for the intensity ratios differ by less than 4% with the theoretical values of Scofield (1973) and K-L total vacancy transfer probabilities for the listed target elements, considering the fluorescence yield values from the tables of Hubbell et al.(1994) differ by 5% with the theoretical values of Schönfield and Janßen (1996). The comparison of the measured X-ray fluorescence parameters for the above mentioned target elements with the theoretical values have been graphically presented in Fig. 3.

Conclusions:

The 2π-geometrical configuration and weak gamma sources is definitely an alternate and simple method to study the X-ray fluorescence (XRF) parameters of pure elements. The drawback in the technique is the precision required in the thickness of target elements and the cost of these elements. If, the targets can be prepared in-house, the technique becomes the simplest yet reliable method to study the X-ray fluorescence parameters for pure elements. The work could not be extended to study these parameters for compound targets as the preparation of such targets did not meet the required target thickness.

Table 1. Experimentally computed and the theoretical values of K X-ray intensity ratios and total vacancy transfer probability of Co, Ni, Cu, Zn, Mo, Pd, Ag, Pt, Au and Pb

Target Element	Z	$\frac{I_{K\beta}}{I_{K\alpha}}$		η_{KL}	
		Present	Theory[a]	Present	Theory[b]
Cobalt	**27**	0.1233±0.0083	0.1218	1.4540±0.0983	1.418
Nickel	**28**	0.1246±0.0040	0.1227	1.4120±0.0475	1.388
Copper	**29**	0.1241±0.0090	0.1216	1.3859±0.1053	1.357
Zinc	**30**	0.1266±0.0040	0.1241	1.3522±0.0432	1.326
Molybdenum	**42**	0.1772±0.0819	0.1809	1.0432±0.1121	1.029
Palladium	**46**	0.1863±0.0211	0.1933	1.0057±0.1110	0.975
Silver	**47**	0.1964±0.0216	0.1964	0.9796±0.1080	0.964
Platinum	**78**	0.2835±0.0365	0.2631	0.8225±0.0583	0.818
Gold	**79**	0.2854±0.0442	0.2646	0.8081±0.0412	0.816
Lead	**82**	0.3114±0.0432	0.2696	0.8044±0.0411	0.811

[a]Scofiled (1974), [b] Schönfield and Janßen (1996)

Fig. 1. Experimental setup

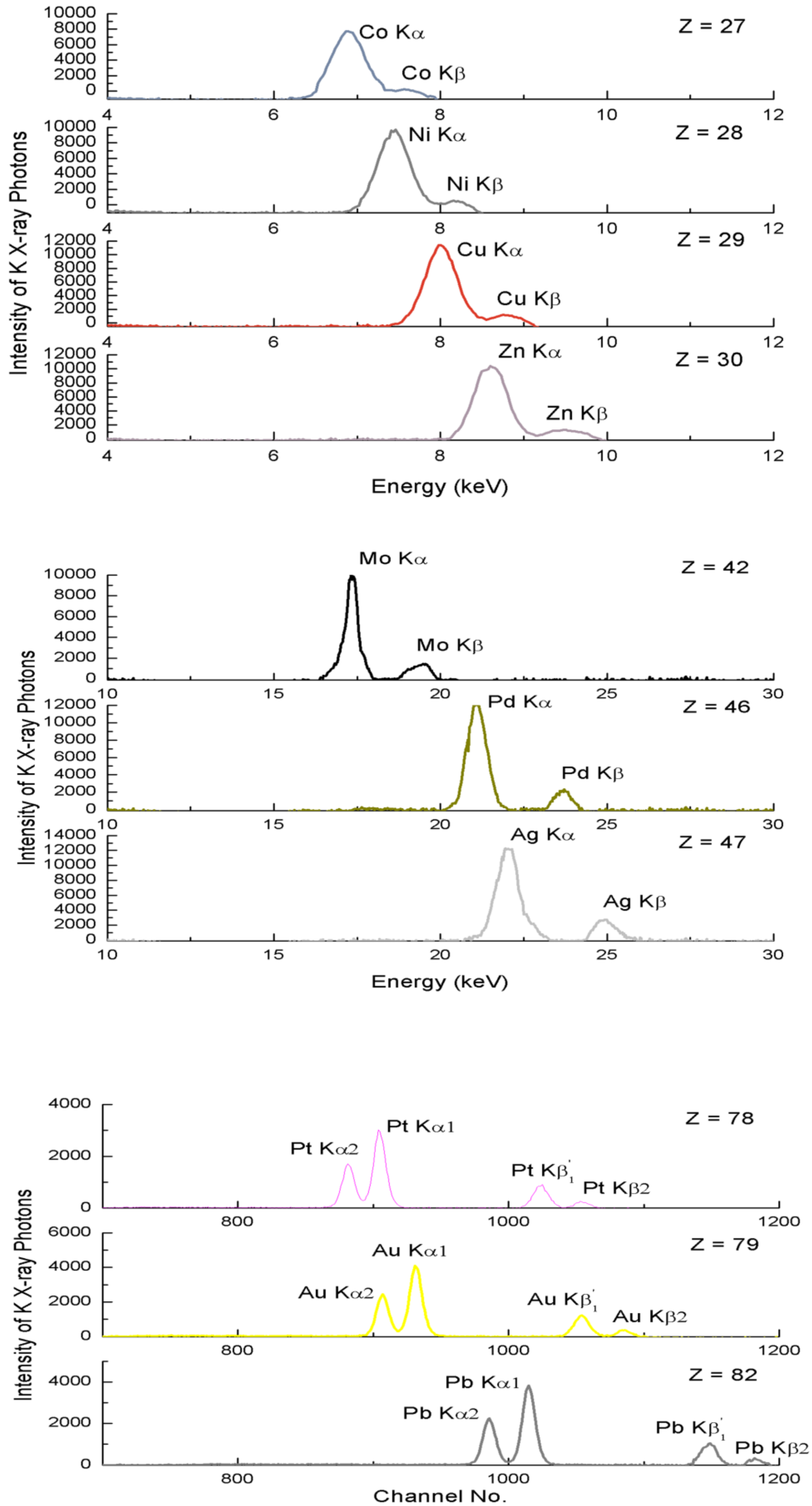

Fig. 2. K X-ray fluorescence spectra of Co, Ni, Cu, Zn, Mo, Pd, Ag, Pt, Au and Pb

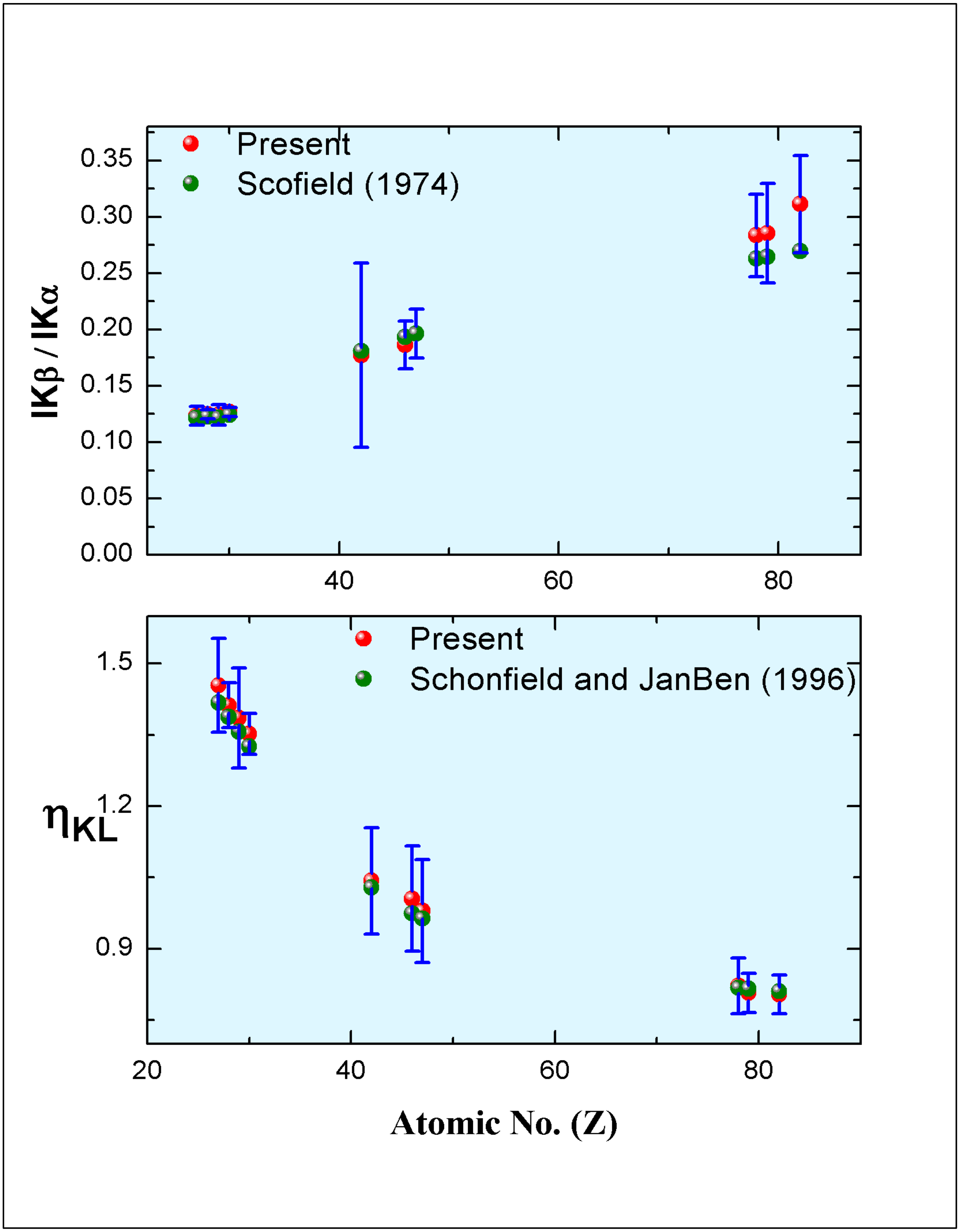

Fig. 3. Present and Theoretical values of K X-ray fluorescence parameters for Co, Ni, Cu, Zn, Mo, Pd, Ag, Pt, Au, and Pb target elements.

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Publications:

a. **Journal**

1. **K_{β} to K_{α} X-ray intensity ratios and K to L shell vacancy transfer probabilities of Co, Ni, Cu and Zn**
   Accepted for publication in Journal of Experimental and Theoretical Physics (JETP) - DOI:10.7868/S0044451015120000
2. **Measurement of K x-ray intensity ratios and vacancy transfer probability**
   Communicated - American Journal of Physics

b. **Proceedings in Seminars and Conferences**

1. **$K\beta/K\alpha$ intensity ratio of 3d transition elements Co and Ni by 2π- geometry and a weak radioisotope- Paper presented in National Conference held between 8^{th} to 10^{th} Jan-2015 at Vijaya College, Basavangudi, Bengaluru, Karnataka.**
2. **K x-ray intensity ratio and total vacancy transfer probability of Palladium pure element by 2π-geometry and a weak gamma source – Paper accepted for presentation at National symposium on Radiation Physics (NSRP-20), that would be held between 28^{th} to 30^{th} Oct-2015 at Mangalore University, Mangaluru, Karnataka.**