Precise Measurement of a α_K for the 65.7 keV M4 Transition from ^{119m}Sn: A test of Internal Conversion Theory

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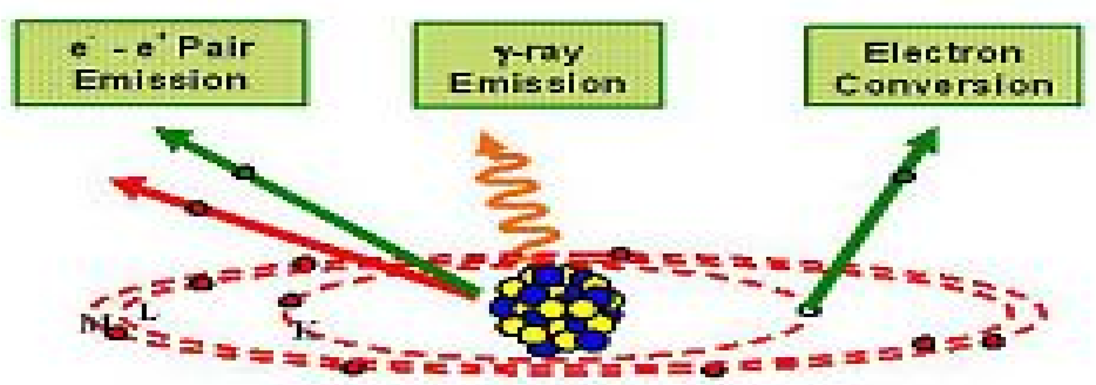
Introduction

• Internal conversion refers to the process by which the de-excitation energy of a nuclear energy level is released to an atomic electron.

•Competes with γ-emission.

•The nuclear de-excitation energy thus ejects an electron from one of the atomic shells. This results in an electron from a higher shell subsequently dropping in to fill the vacancy and releasing more energy in the form of an x-ray.



•The ratio of the number of emitted conversion electrons, N_e, to the number of emitted γ-rays, N_γ, is known as the internal-conversion coefficient (ICC), α: that is, $\alpha = N_e/N_\gamma$.

•We investigate ICCs to determine precisely the value of α_K (ICC in the K-shell) and to test theoretical values, particularly for the need to include the atomic vacancy in the calculation.

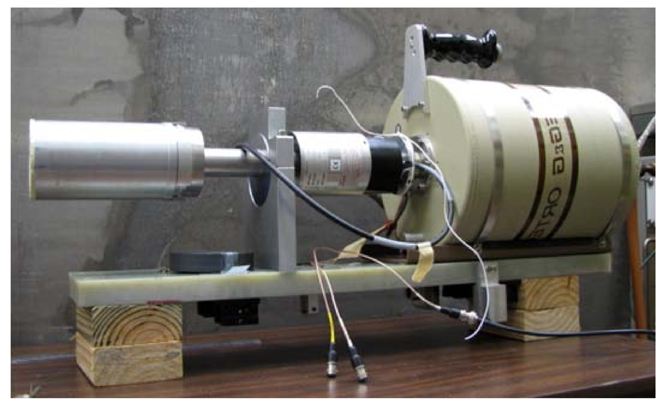
•A 2002 survey by Raman, et al. demonstrated that very few ICCs had been measured to high precision and that the various ICC calculations did not agree well with one another.

•Measuring the α_K for the 65.7 keV transition in ^{119}Sn allows us to test the importance of including the atomic vacancy in the calculation of the ICC since, in this case, α_K=1618 if the vacancy is included and α_K=1543 if it is not.

Setup

•We use a High Purity Germanium crystal detector (HPGe) capable of detecting x-rays and γ-rays above about 8 keV.

•The HPGe detector has been efficiency calibrated to have a relative uncertainty of ± 0.15% and a absolute uncertainty of ± 0.20% for efficiencies from 50 -1800 keV.



Experiment

Source

•For our experiment we used ^{119m}Sn, which had been produced by neutron activation of enriched ^{118}Sn at the Texas A&M TRIGA reactor.

- For this preliminary measurement we activated for only 16 hours. The source we produced was relatively weak, so we measured it at 79.0 mm as well as 151.0 mm.
- The detector calibration is well known at 151 mm but the rate is higher at 79 mm. We used Monte Carlo calculations to obtain the relative efficiencies at the closer distance.

Shielding

•In our efforts to reduce the effect of background radiation, we shielded the detector.

•The shielding consisted of three outer Pb cylinders, one inner Cu cylinder, and a Cu back shield. Cu was used to absorb x-rays from Pb.

•Each cylinder was ~4.0 mm thick and ~175 mm long.

•We manage to reduce the amount of background radiation by a factor of 5.

Spectra Analysis

•For spectrum analysis, we used software called Maestro, which allowed us to view the counts as a function of energy.

•Using Maestro, we obtained the area under the curve for two K x-ray peaks at 25.12 keV and 29.57 keV, and the γ-ray peak at 65.7 keV. Background radiation was also taken into account and subtracted

Area	25.12 keV (counts), K_α	29.57 keV (counts), K_β	65.7 keV (counts), 66_γ
151.0mm	2620714	615023	3106
79.0mm	7513840	1721786	9888

Impurity Analysis

•Through the process of neutron activation, activities such as ^{117m}Sn, ^{113}Sn, and ^{182}Ta were also created.

•These impurities were taken into account and their contributions subtracted from our peaks of interest .

Corrected	^{117M}Sn (counts) at 158.5 keV	^{113}Sn (counts) at 391.96 keV	^{182}Ta (counts) at 68.0 keV
151.0mm	80600	12659	11320
79.0mm	118860	30040	24575

Calculations

$$I_{SnK_x} = \frac{Area(K_x)}{Efficiency(K_x)} = \frac{Area(K_\alpha)}{Eff(K_\alpha)} + \frac{Area(K_\alpha)}{Eff(K_\alpha)}$$

$$I_{66_\gamma} = \frac{Area(66_\gamma)}{Efficiency(66_\gamma)}$$

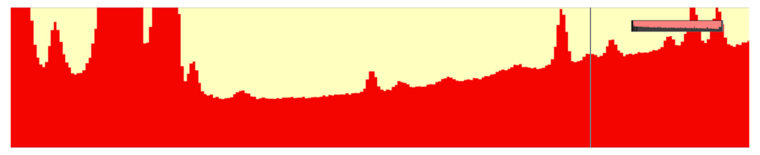
$$I_{corr} = \frac{Area(corrected)}{Theory(intensity) * Eff(corr)} * \Sigma Theory\ Eff$$

$$\alpha_K = \frac{1}{\omega_K} \frac{I_{SnK_x} - I_{corr}}{I_{66_\gamma} - I_{corr}}$$

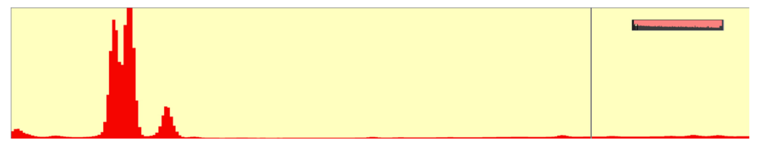
Efficiency	79.0mm	151.0mm
25.19 keV	2.8773(14)%	0.9519(14)%
28.57 keV	2.9451(14)%	0.9773(14)%
65.66 keV	3.0696(14)%	1.0224(14)%
67.75 keV	3.0623(14)%	1.0201(14)%
158.56 keV	2.4859(14)%	0.8562(14)%
361.69	1.3917(14)%	0.4714(14)%

Spectra Graphs

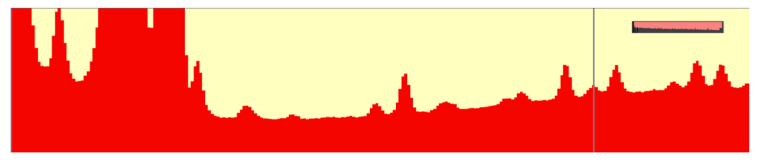
119Sn_jul13_22_7_66g



119Sn_jul13_22_7_SnKx



119Sn_jul26_23_1_66g_



119Sn_jul26_23_1_SnKX

Results

	I Sn $_{Kx}$	I 66_γ	α_K	I Sn $_{Kx}$ (corrected)	I 66_γ (corrected)	α_K (corrected)
At 79.0mm	313592951	267532	1363	389849457	267020	1698
At 151.0mm	3382338	3038	1295	3267775	2521	1507

	^{117m}Sn	^{113}Sn	^{183}Ta
Percent Corrected	~2.2%	~0.6%	~20.6%

•The efficiency correction for 66.0 keV was ignored in our calculation because it did not effect our calculations

•The results for the two distances were combined to yield an overall result for α_K of 1600(300).

•Although Maestro is quite user friendly, it is limited in the evaluation of peak areas. It does not allow a precise fit to the background under each peak. This also affects the precision with which background peaks can be subtracted.

•The location we used for our measurement left much to be desired. The detector was located on top of the shielding blocks above the MARS spectrometer and, when that device was in use, the background activities increased.

Conclusion

•Despite its large uncertainty, our result points the way to a more precise measurement in future.

•.A new ^{119m}Sn source is being prepared with a much longer neutron activation. We will also use a different location for the measurement.

•The Radware code will be used to do the data analysis. This software allows the user to fit individual peaks and background in a more precise and reproducible way.

Acknowledgements

•Dunlap, Richard. *The Physics of Nuclei and Particles*. 1st. Belmont: David Harris, 2004. 136-40.

• North Holland, *Gamma- and X-Ray Spectrometry with Semiconductor Detector*. Idaho Falls: EG&G Idaho, 2001. 28-30.

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