Precision measurement of ICCs of some pure E2 transitions for comparison with BRICC calculations

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Introduction

There are specific problems to overcome in decay data analysis; in particular, difficulties can arise in accounting for internal conversion when the internal conversion of a gamma ray transition is significant. If there are no experimental ICCs available, theoretical ICCs have to be adopted, and the evaluator is faced with having to choose a value from a number of comparable theoretical approaches. Hence it is of paramount importance to have both very precise experimental ICCs and also to know the accuracy with which any theoretical ICC can be accepted to use.

With the availability of BRICC calculations involving a complete picture of internal conversion process, there is a need to evaluate critically the situation as to how good are the calculations when tested on the closeness to the experimental values. Gerl et al [1], in an exhaustive compilation on ICCs of high multipole transitions, have almost confirmed and recommended the BRICC theoretical ICCs when compared to Hager and Seltzer [2] and Rosel et al [2] values showing the agreement with experiment within almost 1%.

As E1 transitions are often hindered strongly and M1 transitions often appear as mixed M1+E2 character with uncertain mixing, pure E2 transitions would be the testing ground for the goodness of the BRICC values for the ICCs.

Experiment:

In a campaign of precision measurements of internal conversion coefficients supported by DAE-BRNS research project, efforts have been made to measure internal conversion coefficients of a number of transitions experimentally in the following nuclei ^{75}As, ^{99}Tc, ^{125}Te, ^{131}Cs, ^{131}Xe, ^{147}Pm, ^{153}Eu, ^{169}Tm, ^{177}Lu, ^{175}Tm and ^{177}Hf. For this purpose radioactive sources ^{75}Se, ^{99}Mo, ^{125}Sb, ^{131}Ba, ^{131}I, ^{147}Nd, ^{153}Sm, ^{169}Yb, ^{177}Lu, ^{175}Yb and ^{177m}Lu which are relatively long lived have been procured from BRIT, BARC, Mumbai over a period of three years. Measurements were performed using the well calibrated and optimized gamma and electron spectroscopy systems.

A large volume 60 cc HPGe detector [FWHM=665 eV at 5.9 keV and 1.8 keV at 1.33 MeV] coupled to a PC based 8K Multichannel analyser was used for gamma energy and intensity measurements after optimization of its relative photo peak efficiency and linearity with IAEA standard sources. Gamma singles spectra were acquired at a source-detector distance of 25 cm for counting periods lasting for 4.5×10^5 seconds per spectrum on an average. The gamma spectra were analysed using computer codes FIT and GAMMA VISION.

Conversion electron measurements were carried out using an indigenously developed Mini-Orange spectrometer comprising of a window-less liquid nitrogen cooled Si(Li) detector (surface area=78 mm^3, sensitive depth=5.3 mm, FWHM= 2.0 keV at 624 keV) and a mini-orange filter of nine thin wedge shaped permanent magnets in a circular array in a brass frame of diameter 16.2 cm with a central absorber made of lead that prevents the direct exposure of the detector to the gamma rays from the source. The entire non-magnetic stainless steel (304L) casing to hold the filter and the source and the detector was maintained with a clean vacuum of about 10^{-7} torr using a turbo-molecular pump. Transmission curves for various source-magnets-detector distances obtained for

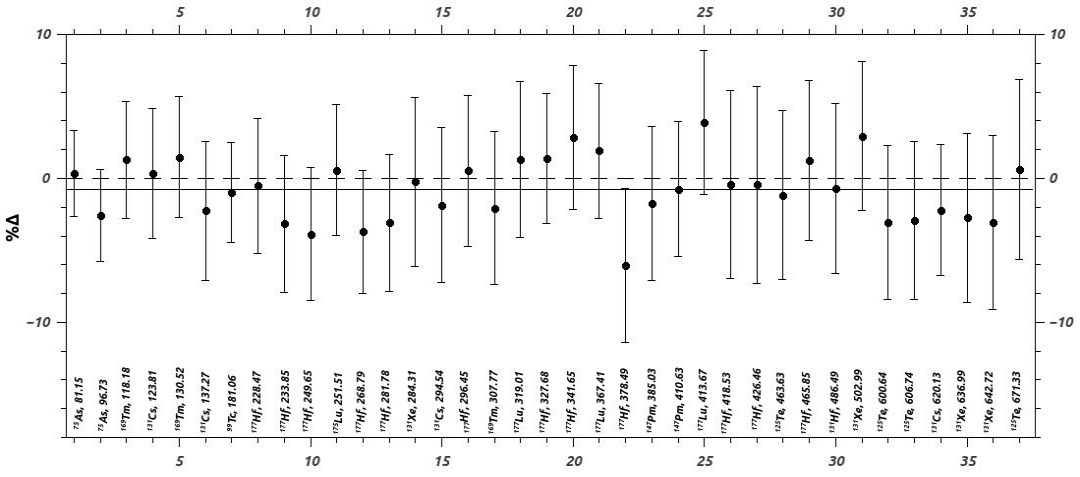
different ranges of electron energies were used for relative conversion electron intensity measurements. We used the Normalised Peak to Gamma (NPG) method for determining the internal conversion coefficients.

For normalization, we have used the theoretical α_ks of the most intense transitions of the respective nuclei. The experimental uncertainties include only the uncertainties in the relative gamma and conversion intensities.

Out of the many transitions for which the ICCs have been determined in the present work we have selected only pure E2 transitions for which the precision of the measurement is about 5% for comparison with the BRICC values. The relative percentage deviations (%Δ) have been calculated using the definition $\%\Delta = \frac{\alpha_{k\,exp.} - \alpha_{k\,BRICC}}{\alpha_{k\,BRICC}} \times 100$.

Table shows the nuclei, the transitions, α_k experimental, experimental uncertainty, α_k BRICC and the percentage deviation, %Δ. Figure shows the percentage deviations. The global average of the %Δ is found to be –0.7% showing a better agreement with the BRICC values.

Nucleus	E_γ	2*Transition	α_{kexp}	BRICC	%Δ
^{75}As	81.15	$5^- \rightarrow 1^-$	1.477(44)	1.472	0.34
^{75}As	96.73	$5^+ \rightarrow 9^+$	0.752(24)	0.772	-2.59
^{169}Tm	118.18	$5^+ \rightarrow 1^+$	0.710(29)	0.701	1.28
^{131}Cs	123.81	$1^+ \rightarrow 5^+$	0.621(28)	0.619	0.32
^{169}Tm	130.52	$7^+ \rightarrow 3^+$	0.549(23)	0.541	1.48
^{131}Cs	137.27	$3^+ \rightarrow 7^+$	0.434(21)	0.444	-2.25
^{99}Tc	181.06	$5^+ \rightarrow 9^+$	0.1240(43)	0.1252	-0.96
^{177}Hf	228.47	$23^+ \rightarrow 19^+$	0.1150(34)	0.1156	-0.52
^{177}Hf	233.85	$13^+ \rightarrow 9^+$	0.105(5)	0.1084	-3.14
^{177}Hf	249.65	$11^- \rightarrow 7^-$	0.087(4)	0.0905	-3.87
^{175}Lu	251.51	$11^+ \rightarrow 7^+$	0.088(4)	0.0875	0.57
^{177}Lu	268.79	$11^+ \rightarrow 7^+$	0.070(3)	0.0727	-3.71
^{177}Hf	281.78	$15^+ \rightarrow 11^+$	0.063(3)	0.065	-3.08
^{131}Xe	284.31	$7^+ \rightarrow 3^+$	0.0407(24)	0.0408	-0.25
^{131}Cs	294.54	$3^+ \rightarrow 7^+$	0.037(2)	0.0377	-1.86
^{177}Hf	296.45	$13^- \rightarrow 9^-$	0.057(3)	0.0567	0.53
^{169}Tm	307.77	$7^+ \rightarrow 3^+$	0.0470(25)	0.048	-2.08
^{169}Tm	319.01	$13^+ \rightarrow 9^+$	0.0462(25)	0.0456	1.32
^{177}Hf	327.68	$17^+ \rightarrow 13^+$	0.044(2)	0.0434	1.38
^{177}Hf	341.65	$15^- \rightarrow 11^-$	0.040(2)	0.0389	2.83
^{177}Lu	367.41	$15^+ \rightarrow 11^+$	0.0320(15)	0.0314	1.91
^{177}Hf	378.49	$19^+ \rightarrow 15^+$	0.0280(15)	0.0298	-6.04
^{147}Pm	385.03	$17^- \rightarrow 13^-$	0.0280(15)	0.0285	-1.75
^{147}Pm	410.63	$5^+ \rightarrow 1^+$	0.0171(8)	0.01723	-0.75
^{177}Lu	413.67	$17^+ \rightarrow 13^+$	0.0240(12)	0.0231	3.90
^{177}Hf	418.53	$21^+ \rightarrow 17^+$	0.0230(15)	0.0231	-0.43
^{177}Hf	426.46	$19^- \rightarrow 15-$	0.0220(15)	0.0221	-0.45
^{125}Te	463.63	$5^+ \rightarrow 1^+$	0.0085(5)	0.0086	-1.16
^{177}Hf	465.85	$21^- \rightarrow 17^-$	0.018(1)	0.01778	1.24
^{131}Cs	486.49	$1^+ \rightarrow 5^+$	0.0085(5)	0.00856	-0.70
^{131}Xe	502.99	$7^- \rightarrow 11^-$	0.0077(4)	0.00748	2.94
^{125}Te	600.64	$5^+ \rightarrow 1^+$	0.0041(2)	0.00423	-3.07
^{125}Te	606.74	$7^+ \rightarrow 3^+$	0.0040(2)	0.00412	-2.91
^{131}Cs	620.13	$1^+ \rightarrow 5^+$	0.0044(3)	0.0045	-2.22
^{131}Xe	636.99	$7^+ \rightarrow 3^+$	0.00390(23)	0.00401	-2.74
^{131}Xe	642.72	$5^+ \rightarrow 1^+$	0.0038(2)	0.00392	-3.06
^{125}Te	671.33	$5^+ \rightarrow 1^+$	0.0032(2)	0.00318	0.63



References:

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