Proposal to improve the calibration data for conversion electron measurements

I. INTRODUCTION

The accurate measurement of internal conversion coefficient is important to determine transition multipolarities. Conversion coefficients (α) most often determined from the measured electron and gamma-ray intensities and using one or more conversion coefficient from the literature or theory to determine α. As the measurement of gamma-rays and conversion electrons requires fundamentally different spectrometers or detectors. The calibration of the spectrometers is based on measurement of radioactive sources with well known emission energies and emission rates. While the decay data on X-ray and γ-ray calibration sources is relatively well established, see for example the 2007 update [1], there was much less effort to improve the data for electron spectroscopy. This proposal is aiming to improve the data on calibration standards for conversion electron and β-spectroscopy.

Following discussions at the ISTROS 2019 conference [2], a number of scientists using conversion electron, electron-positron pair and β-ray spectroscopy, agreed to participate in an international action to improve the decay data on calibration source. Confirmed participants include:

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II. SCOPE

Carry out conversion electron measurements in the participating laboratories to determine the intensities of a selected list of radioisotopes, applying recommended procedures for the calibration of the spectrometers, carry out the experiments and analyse the data. The recommended calibration data will be adopted from the reported intensities. All data will be shared and will be available for future users.

III. POTENTIAL RADIOACTIVE ISOTOPES

The requirements of the calibration of electron spectrometers could depend on a number of factors, including source and spectrometer geometry, the energy range of interest, half life, production using nuclear reactions, etc. For most applications the calibration source has to be very thin, usually an open source, and it has to be inserted into the vacuum space of the spectrometer.

The basic decay properties of the most commonly used calibration sources are listed below:

	$T_{1/2}$	Decay mode	Strongest γ-rays	Comments
^{7}Be	53.2 d	EC	477	Single line
^{51}Cr	27.7 d	EC	320	Single line
^{54}Mn	312 d	EC	835	Single line
^{60}Co	1925 d	β^-	1173, 1332	Weak CE lines
^{88}Y	107 d	β^+	898, 1836	Weak CE lines
^{109}Cd	462 d	EC	88	Single line
^{133}Ba	10.6 y	EC	53, 80, 81, 302, 356, 383	Many strong CE below 400 keV
^{137}Cs	30 y	β^-	662	Single line
^{152}Eu	13.5 y	β^- β^+	122, 244,...1408	Many strong CE below 1400 keV
^{154}Eu	8.6 y	β^-	123, 248, 591, 692, 723, ..1596	Many strong CE below 1600 keV
^{182}Ta	114.7 d	β^-	85, 100, 152, 222, 1121, 1189, 1221, 1231	Many strong CE below 1230 keV, but no γ between 230 and 1100 keV
^{203}Hg	46.6 d	β^-	279	Single line

IV. CURRENT STATUS OF CALIBRATION DATA

The selection of the isotopes for the present project should based on the evaluation of the existing calibration data in the literature. As an illustration, the data on ^{133}Ba, ^{152}Eu and ^{207}Bi are compiled in tables I, II and III. For each radioisotope the relative experimental electron intensities have been normalised to a particular conversion lines corresponding 100 radioactive decay of each parent isotopes. The γ-ray energies and intensities are taken from the latest ENSDF evaluations. The last column of each table, labelled as "ENSDF" is the expected electron intensities obtained using NUDAT2.

V. PROPOSAL FOR INTERNATIONAL EXERCISE TO DEDUCE RECOMMENDED CE INTENSITIES

Similar to the X-ray and gamma-ray calibration data, we propose to approach IAEA, if they willing to coordinate this effort. At least two meetings, one at the beginning to agree the policies and a second one to adopt calibration data and summarize the results would be required. All results, including spectra should be archived and stored for future reference. It is expected a large summary paper should be prepared for publication with the recommended calibration data. The main steps of the project is listed below.

(a): Develop procedures for the calibration, measurement of the spectrometers and data analysis. The efficiency calibration of the spectrometers should be based on combination of experiments, for example using a continuous

beta source and detailed simulations with GEANT4, Penelope, etc. Develop form of reports to make sure histocompatibility

(b): Review calibration data of potential calibration sources.

(c): Adopt procedures from (a) and list of radioisotopes (b), agree on work-plan.

(d): All sources should be prepared in a single laboratory

(e): Carry out experiments and prepare reports

(f): Prepare summary report and recommended calibration data

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TABLE I: Calibration data for ^{133}Ba from 1966Th09 [4], 1967He09 [5], 1968Bo04 [6] and 1970To01 [7]. Intensities are given for 100 decays. The expected values from ENSDF were obtained from NuDat2. All reported intensities are normalised to the expected intensity of the 356.0129 keV K-shell conversion line.

E_γ	I_γ	Shell	E_γ	I_{CE}					
[keV]			[keV]	1966Th09	1967He09	1968Bo04	1970To01[a]	1970To01[b]	ENSDF
53.1622(6)	2.141(32)	K	17.18	11.0(21)					10.7(21)
		L1		1.34(9)	1.11(16)				1.31(26)
79.6142(12)	2.65(5)	K	43.63	3.83(31)	3.4(5)				3.96(10)
		L	73.90	0.53(18)				0.57(4)	0.575(19)
80.9979(11)	32.95(33)	K	45.01	44.5(16)	38(5)				47.1(8)
		L1						6.60(0.17	5.69((10)
160.6120(16)	0.638(5)	K	124.63	0.22(6)	0.144(18)	0.113(4)	0.149(4)	0.1428(34)	0.149(3)
		L	154.90			0.029(5)		0.0278(15)	0.0300(9)
223.2368(13)	0.4530(3)	K	187.25		0.034(4)	0.024(5)	0.0325(11)		0.0379(6)
276.3989(12)	7.16(5)	K	240.41		0.33(4)	0.291(8)			0.329(5)
		L	270.68			0.0733(17)			0.0603(1)
302.8508(5)	18.34(13)	K	266.87		0.69(7)	0.647(11)			0.684(12)
		L	297.14			0.107(4)			0.0887(14)
356.0129(7)	62.05(19)	K	320.03	1.31(7)	1.309(19)	1.309(19)	1.309(19)	1.309(19)	1.309
		L	350.30			0.262(26)			0.215
383.8485(12)	8.94(6)	K	347.86		0.154(17)	0.223(26)			0.1506(24)
		L	378.13			0.0458(15)			0.0241(4)

[a] Magnetic lens spectrometer

[b] Double focussing spectrometer

TABLE II: Calibration data for ^{152}Eu from 1960Sc14 [8], 1960Mu05 [9], 1967Ma29 [10], 1979De22 [11], 1981Ka40 [12] and 1985Ca08 [13]. Intensities are given for 100 decays. The expected values from ENSDF were obtained from NuDat2. All reported intensities are normalised to the expected intensity of the 344.2785 keV K-shell conversion line.

E_γ	I_γ	Shell	E_γ	I_{CE}						
[keV]			[keV]	1960Sc14	1960Mu05	1967Ma29	1979De22	1981Ka40	1985Ca08	ENSDF
121.7817(3)	28.53(16)	K	74.95	24.2(13)	24.2(25)	18.0(7)	20.2(11)	18.7(5)		19.3(3)
		L	114.04	12.9(7)	13.9(14)	14.0(6)	11.9(6)	11.05(26)		10.56(18)
244.6974(8)	7.55(4)	K	197.86	0.668(35)	0.63(7)	0.610(27)	0.651(35)	0.635(23)	0.582(23)	0.610(10)
		L	236.96	0.198(10)	0.198(20)	0.151(11)	0.162(9)	0.157(4)	0.157(7)	0.1563(24)
344.2785(12)	26.59(20)	K	294.04	0.824(15)	0.824(15)	0.824(15)	0.824(15)	0.824(15)	0.82(4)	0.824(15)
		L	335.90	0.240(13)	0.206(21)	0.198(17)	0.180(16)	0.181(7)	0.191(8)	0.180(3)
411.1165(12)	2.237(13)	K	360.88	0.0371(26)	0.041(4)	0.0404(34)	0.0420(26)	0.049(4)	0.0441(23)	0.0425(7)
443.9606(16)	2.827(14)	K	397.13	0.0289(33)	0.0247(25)	0.0138(12)	0.0176(10)	0.0223(9)	0.0194(11)	0.0144(4)
586.2648(26)	0.455(4)	K	536.03	0.0338(34)		0.0125(25)	0.0082(8)		0.0103(6)	0.0050(18)
615.41(5)	$E0$	K	565.17	0.030(4)	0.0066(7)	0.0127(17)	0.0074(8)		0.0090(5)	0.0100
656.489(5)	0.1441(22)	K	609.66	0.029(4)	0.0099(10)	0.0091(12)	0.0068(7)		0.0075(4)	0.00708(24)
688.670(5)	0.856(6)	K	641.84	0.065(10)	0.044(4)	0.0297(25)	0.0272(17)	0.0326(14)	0.0325(16)	0.0305(10)
		L	680.93					0.0082(8)		0.00437(17)
778.9045(24)	12.93(8)	K	728.67	0.0223(33)	0.0313(33)	0.0214(25)	0.0183(10)	0.0204(11)	0.0218(11)	0.0204(3)
867.380(3)	4.23(3)	K	820.55	0.0132(17)	0.0074(8)	0.0115(12)	0.0112(7)	0.0185(10)	0.0136(7)	0.01226(19)
964.057(5)	14.51(7)	K	917.22	0.038(6)	0.0321(33)	0.0330(25)	0.0305(17)	0.0354(18)	0.0373(20)	0.0332(5)
		L	956.32							0.00472(8)
1085.837(10)	10.11(5)	K	1039.00	0.0239(33)	0.0107(17)	0.0198(25)	0.0195(12)	0.0214(9)	0.0202(11)	0.0180(3)
1112.076(3)	13.67(8)	K	1065.24	0.030(4)	0.0223(25)	0.0231(25)	0.0207(13)	0.0280(17)	0.0263(14)	0.0233(4)
1408.013(3)	20.87(9)	K	1361.18	0.0140(25)	0.0082(8)	0.0094(7)	0.0094(06)	0.0125(8)	0.0109(6)	0.01014(15)

TABLE III: Calibration data for ^{207}Bi from 1969He19 [14], 1974Av03 [15] and 1988Fu05 [16]. Intensities are given for 100 decays. The calculated values in the ENSDF column were obtained from NuDat2. All reported intensities are normalised to the expected intensity of the 569.698 keV K-shell conversion line.

E_γ	I_γ	Shell	E_γ	I_{CE}			
[keV]			[keV]	1969He19	1974Av03	1988Fu05	ENSDF
569.698(2)	97.75(3)	K	481.69	1.55(5)	1.547(22)	1.547(22)	1.537(22)
		L	554.41	0.445(16)	0.467(20)	0.432(9)	0.442(6)
		MNO	566.06	0.141(7)	0.161(10)	0.141(4)	0.111(5)
1063.656(3)	74.5(3)	K	975.65	7.03(24)	7.13(24)	7.33(28)	7.08(17)
		L	1048.10	1.88(8)	1.69(7)	1.87(8)	1.84(5)
		MNO	1059.52	0.584(32)	0.543(35)	0.605(23)	0.44(3)
1770.228(9)	6.87(3)	K	1682.22		0.0195(22)	0.0246(14)	0.0238(12)
		L	1754.43		0.00266(30)	0.00387(31)	0.0034(5)
		MNO	1766.41		0.00062(9)	0.00107(11)	0.0010(2)