Measurement Of K-shell Fluorescent Yield In Iridium - A Test Of Internal Conversion Theory

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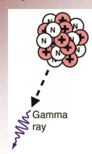
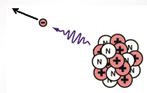
Research Experience for Undergraduates (REU), Summer 2004

Competing Forms of Nuclear De-excitation

- γ-ray emission



- Internal conversion



- Internal conversion coefficients (ICCs):
  - Ratio of probabilities → $\alpha = \frac{P_e}{P_\gamma}$

Internal Conversion (i)

$$\alpha = \alpha_K + \alpha_L + \alpha_M + \alpha_N + \ldots$$

$$P_{K_X} = \omega_K \cdot P_{e_K}$$

$\omega_K =$ Fluorescent yield

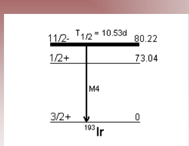
$$\alpha_K \omega_K = \frac{P_{K_X}}{P_\gamma}$$

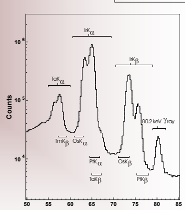
$$N_\gamma = P_\gamma \cdot \varepsilon_\gamma \qquad N_{K_X} = P_{K_X} \cdot \varepsilon_{K_X}$$

ICC, α_K

$$\alpha_K \omega_K = \frac{N_{K_X}}{N_\gamma} \cdot \frac{\varepsilon_\gamma}{\varepsilon_{K_X}}$$

- 2004:
  - Nica [1]→ ICC for iridium





- Value from systematics [2], $\omega_K = 0.958(4)$ → $\alpha_K = 103.0(8)$

$\Delta\alpha_K \leq 10\%$

[1] N. Nica, Submitted to Phys. Rev. C
[2] E. Schönfeld and H. Jassen, Nucl. Instrum. Methods Phys. Res. Sect A **369**, 527 (1996)

Why measure ICCs?

- General:
  - Essential role in analysis of nuclear decay schemes-
    - Spin, parity assignments
    - Transition rates
    - Branching ratios
- Specific:
  - Determine γ decay intensities (probabilities)-
    - Efficiency calibration of the ORTEC HPGe detector

Problems

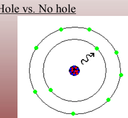
- Systematic differences-
  - Different theoretical approaches
  - Theoretical and experimental (2-3%)

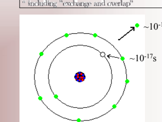
Theoretical values of α_K^{M4} for ${}^{193m}_{77}$Ir calculated in various models; also listed are the corresponding deviations, Δ, from the experimental result, $\alpha_K^{M4} = 103.0(8)$

Model	α_K^{M4}	Δ,%
No hole	92.0(3)	10.7(8)
Hole, frozen orbitals	103.3(3)	-0.3(8)
Hole, SCF of ion	99.6(3)	3.3(8)
Hole, SCF of ion corrected[a]	99.7(3)	3.2(8)

[a] including "exchange and overlap"

- Hole vs. No hole





- K-shell binding energy = 76.1-keV
  - ^{193m}Ir → transition energy = 80.2-keV
  - ^{191}Ir → transition energy = 129.4-keV

Experimental Method (i)

Source preparation:

A-series:

OsO_2 – Osmium (IV) Oxide

Series	Mass (mg)	Os Mass (mg)	Activity (MBq)	Pen. Frac. (X)	Pen Frac. (g)
A1	0.60	0.51	4.20	1.0000	1.0000
A3	1.52	1.30	10.70	0.9765	0.9800

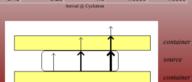
Arrival @ Cyclotron

C-series:

$OsCl_3 \cdot 3H_2O$ – Osmium (III) Chloride Trihydrate

Series	Mass (mg)	Os Mass (mg)	Activity (MBq)	Pen. Frac. (X)	Pen Frac. (g)
C3	0.48	0.26	1.6	1.0000	1.0000

Arrival @ Cyclotron



Experimental Method (ii)

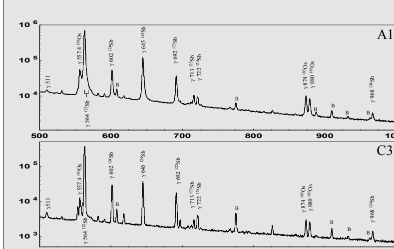
Thermal Neutron Activation:

- Sources irradiated at the TRIGA reactor in the Texas A&M University Nuclear Science Center.
  - Thermal neutron flux = $7 \times 10^{12}\ s^{-1}cm^{-2}$
  - Time = 6 h

Significant isotopes produced (C3):

^{184}Os → ^{185}Os	Λ_i = 8.5 kBq	$t_{1/2}$ = 93.6d
^{190}Os → ^{191}Os	Λ_i = 411 kBq	$t_{1/2}$ = 15.4d
→ ^{191m}Os	Λ_i = (counted with g.s.)	$t_{1/2}$ = 13.1h
^{192}Os → ^{193}Os	Λ_i = 226 kBq	$t_{1/2}$ = 30.5h

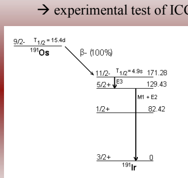
Sample spectra

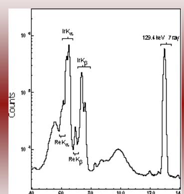


Fluorescent Yield, ω_K

$$\alpha_K \omega_K = \frac{N_{K_X}}{N_\gamma} \cdot \frac{\varepsilon_\gamma}{\varepsilon_{K_X}}$$

- Summer, 2004:
  - Montague, Nica
    → experimental test of ICC





- Preliminary ω_K = **0.948**(8) (calc. α_K for 129.4-keV trans. = 2.165 [3])
- Survey value, ω_K = 0.958(4)

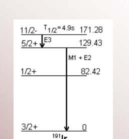
[3] M.B. Trzhaskovskaya, private communication

Corrections

- Coincidence summing:

SummingCor – V.E. Iacob

n	Energy (keV)	Correction Factor
2 --> 1	82.427	1.00476
3 --> 1	**129.431**	**1.00229**
3 --> 2	47.050	1.00991
4 --> 3	41.846	1.01037
K X-ray	**66.360**	**1.00230**
L X-ray	10.030	1.00916



- Preliminary impurity analysis:

Nuclei	T 1/2	Activity (Bq)	% Total Activ.
193Os	20.11 h	226239	0.2705
185Os	93.6 d	8544.6	0.0102
124Sb	60.2 d	9972.8	0.0119
122Sb	2.72 d	177062.8	0.2117

…more to come…

Conclusions

- This preliminary result for ω_K confirms our previously determined ^{193m}Ir α_K
- Confirms need to include 'hole' in theoretical calculations
- Future plans:
  - Continue analysis of ^{191}Os experimental data (impurities, additional spectra for decay curve analysis)
  - Complete similar experiments for cases with α_K sensitive to hole/no hole treatment (^{94}Nb)

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