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Spectral Region-of-Interest Methods Used in Net Count Calculations

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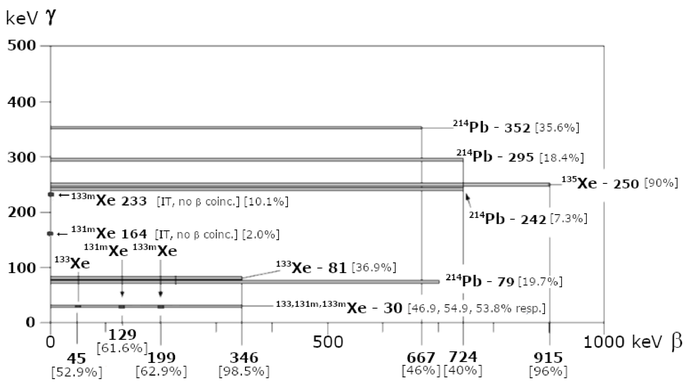
Abstract: There are multiple approaches to radioxenon data analysis using the net count calculation (NCC) method. This presentation focuses on the 10- and 7-regions-of-interest (ROI) approaches. Analysis of radioxenon data from the Xenon International, a new system developed by Pacific Northwest National Laboratory in partnership with Teledyne Brown Engineering, uses the 7-ROI approach, whereas the Swedish Automatic Unit for Noble gas Acquisition uses the 10-ROI approach. The similarities and differences between the two approaches will be presented, along with considerations for improvements and standardization for software sustainability.

Goals and Objectives

- Next generation systems (e.g., Xenon International, SAUNA III, SPALAX NG, and MIKS) are undergoing testing to be accepted as potential replacements/upgrades to current IMS operational systems. As these future systems become accepted it is important to review, and potentially standardize, the analysis methods. The primary analysis uses the net count calculation method.
- Compare spectral regions-of-interest (ROI) definitions between 7- and 10-ROI
- Interference term definition and usage
- Detector calibration

Regions-of-Interest (ROI)

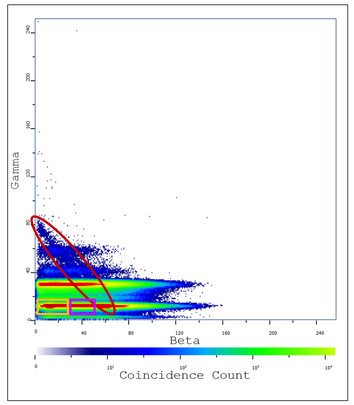


Beta-gamma representation of four xenon isotopes and radon daughter, Pb-214, with labeled energies for branching ratios larger than five percent. [1]

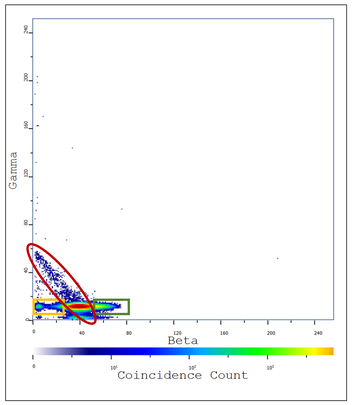
ROI	7 ROI Definition	10-ROI Isotopes
1	^{214}Pb (352 keV)	^{214}Pb (352 keV)
2	^{135}Xe (250 keV)	^{135}Xe (250 keV)
3	^{133}Xe (81 keV)	^{133}Xe (81 keV)
4	^{133}Xe (32 keV)	^{133}Xe (32 keV)
5	^{131m}Xe (30 keV)	^{131m}Xe (30 keV)
6	^{133m}Xe (30 keV)	^{133m}Xe (30 keV)
7	^{133}Xe (used to exclude ^{131m}Xe and ^{133m}Xe) Equivalent to the 10-ROI 7+8	^{133}Xe
8	N/A	^{133}Xe
9	N/A	^{133}Xe
10	N/A	^{133}Xe

Interference Terms

- Interference terms are handled nearly the same between the 7- and 10-ROI methods.
- 7-ROI
  - Xe-133 interference terms are handled uniquely
    - Uses $R_{5/3}$ and $R_{6/3}$ to include both scatter and primary Xe-133 events
    - Other ratios 4:3 and 7:3 are set to zero so that Xe-133 is not subtracted from itself
  - Assumes all interferences are present (no binary decision)
- 10-ROI
  - Xe-133 interference terms are handled uniquely
    - Uses the standard 5:3 and 6:3
    - For the other interference terms (4:3, 7:3, 8:3, 9:3, and 10:3) the numerator does not include the x-ray events (i.e., only the scatter events are included).
  - Currently uses binary decision based on L_C to determine the presence or absence of the interfering isotope and whether the interference terms should be used
    - Adds a slight bias
    - Maximizes the counting statistics
- Unaccounted for interferences
  - Xe-133m interference on
    - Xe-131m (boxed in purple)
    - Xe-133 (30 keV: boxed in yellow, 80 keV: circled in red)
    - minor interference on Xe-135 (circled in red)
  - Xe-131m interference on
    - Xe-133m (boxed in green)
    - Xe-133 (30 keV: boxed in yellow, 80 keV: circled in red)



Xe-133m and Xe-133 with Xe-133m interferences marked



Xe-131m with interferences marked

Other Analysis Terms/Uncertainty

- 7-ROI does have corrections to Xe-133 due to ingrowth from Xe-133m, however it is not currently implemented on the Xenon International system
- 10-ROI does include the correction to Xe-133
- Half-life uncertainty is not accounted for in 7- and 10-ROI methods
  - Becomes important for decay corrections over multiple half-lives
- MDC calculations do not include volume uncertainty
- Calibration methodologies
  - Source uncertainty
    - Calibration source uncertainty to account for sample transfer loss or other changes to the sample

Conclusions

- There are some fundamental differences between 7- and 10-ROI methods
  - Number of ROI
  - Definition of interference ratios within the 30-keV gamma band
  - When to apply interference ratios
- There are also several common areas that need to be addressed
  - Interference terms for the metastable xenon isotopes
  - Additional uncertainty terms
    - Half-life
    - Volume uncertainty applied to MDC
- What changes to the calculations will be needed to optimize analysis for new systems?
- Standardizing the analysis method and what the method accounts for is extremely important.

Reference

Cooper MW, Auer M, Bowyer TW, Casey LA, Elmgren K, Ely JH, Foxe MP, Gheddou A, Gohla H, Hayes JC, Johnson CM, Kalinowski M, Klingberg FJ, Liu B, Mayer MF, McIntyre JI, Plenteda R, Popov V, Zahringer M (2019) Radioxenon Net Count Calculations Revisited. Journal of Radioanalytical & Nuclear Chemistry. doi:10.1007/s10967-019-06565-y. (in publication).

Acknowledgement

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