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Thoron Detection

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Introduction

- Residential radon progeny exposure is the second leading cause of lung cancer, after smoking.
- Uranium and thorium in the soil decay into radon, which can then seep into basements and low-lying areas of the house.
- The main radon isotopes are Rn-222 and Rn-220, which is also called thoron.
- Thoron has been ignored in the past as it has a relatively short half life and usually decays before reaching a house, however its decay products can reach living areas.

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- Environmental Instruments Canada (EIC) produces a Radon Sniffer which is used by radon mitigators and building scientists to find radon entry points.
- These sniffers currently assume all radon is Rn-222.
- The sniffer pumps in air through a filter, only passing in radon to the chamber.
- The sniffer only counts alpha particles, and cannot distinguish between decays of Rn-222, Rn-220, or their progeny.

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Problem Statement

Find a sampling schedule and algorithm to determine the concentrations of Rn-222 and Rn-220 that minimizes the variance in the estimated values.

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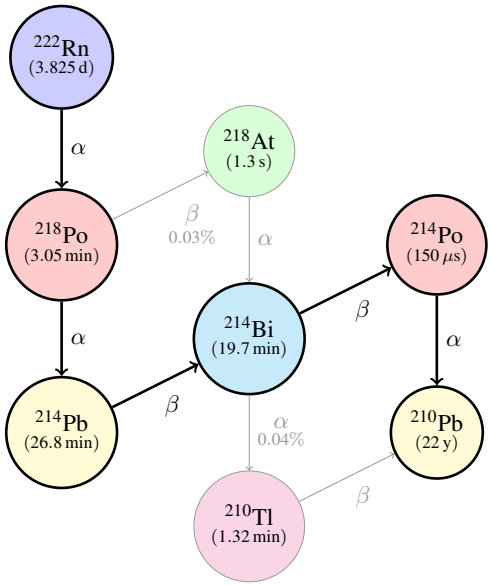
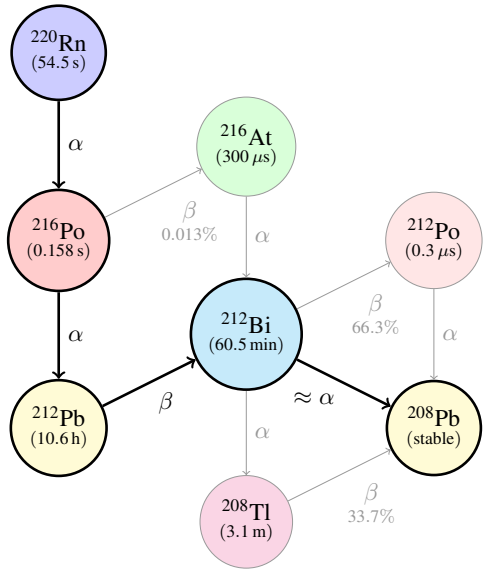
Decay Chains

We model the decay chain as an ordered sequence of nuclides. These nuclides decay either by emitting an alpha particle or a beta particle, with a half-life of $t_{1/2}$.





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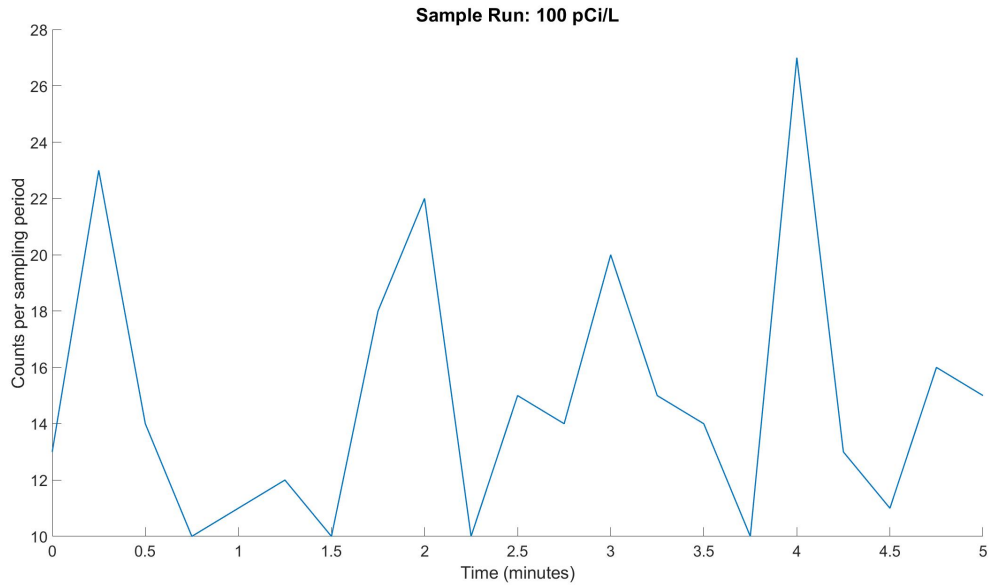
Generating Data

The decay times of an atom follow an exponential distribution with parameter $\lambda = \frac{\ln(2)}{t_{1/2}}$.

By sampling the decay time of the atoms of each nuclide from its distribution, and counting the total number of decays within a certain interval, we can generate simulated data.



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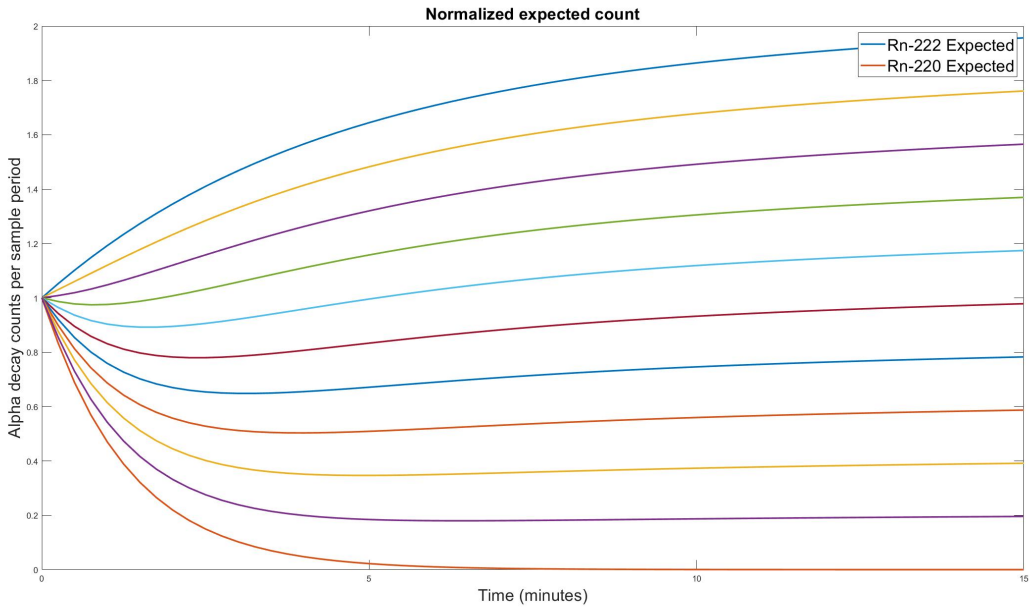
Normalized Count Rates

Normalizing to the expected count in the first sample period, we can see the difference in behaviour of different mixtures of radon and thoron.



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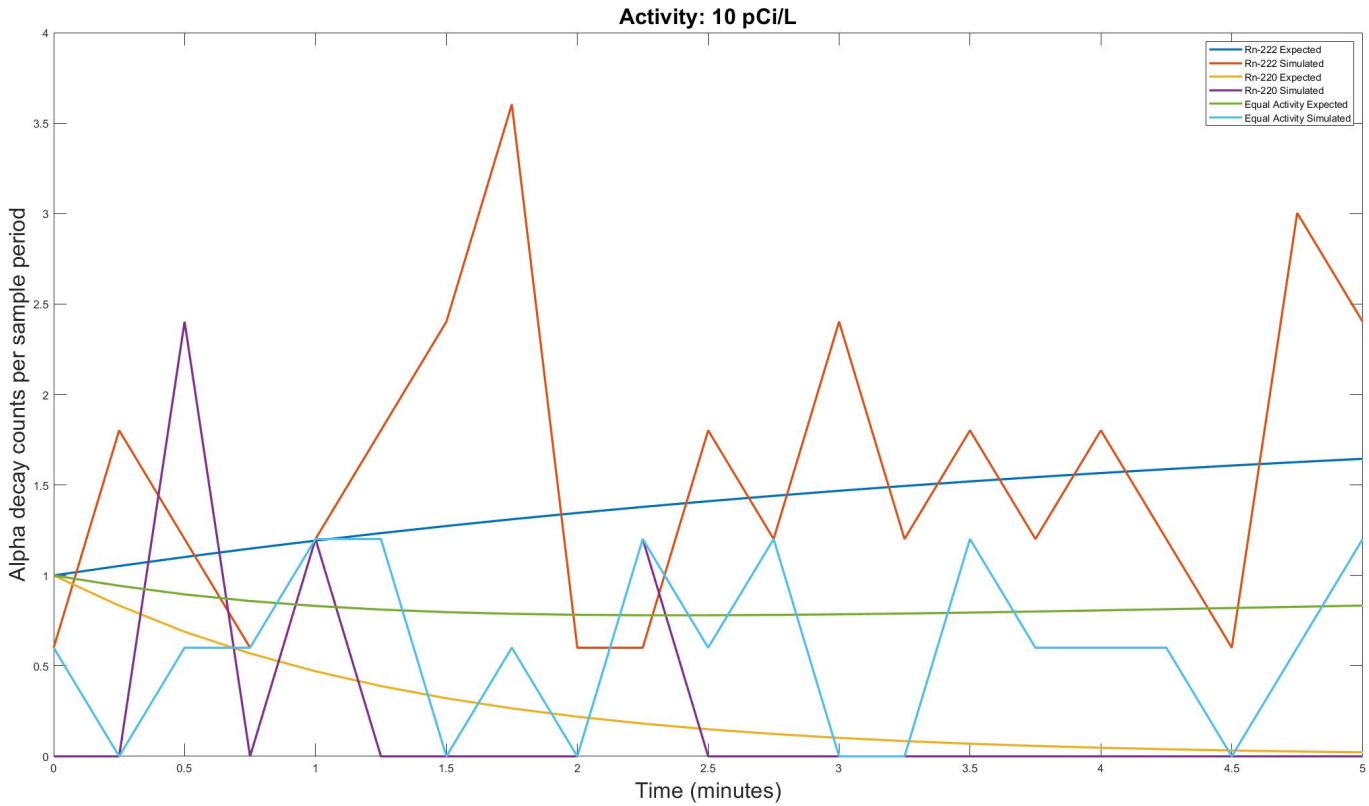
10 pCi/L



We can add a sample run of generated data onto the previous curves and compare the observed counts to the expected counts.

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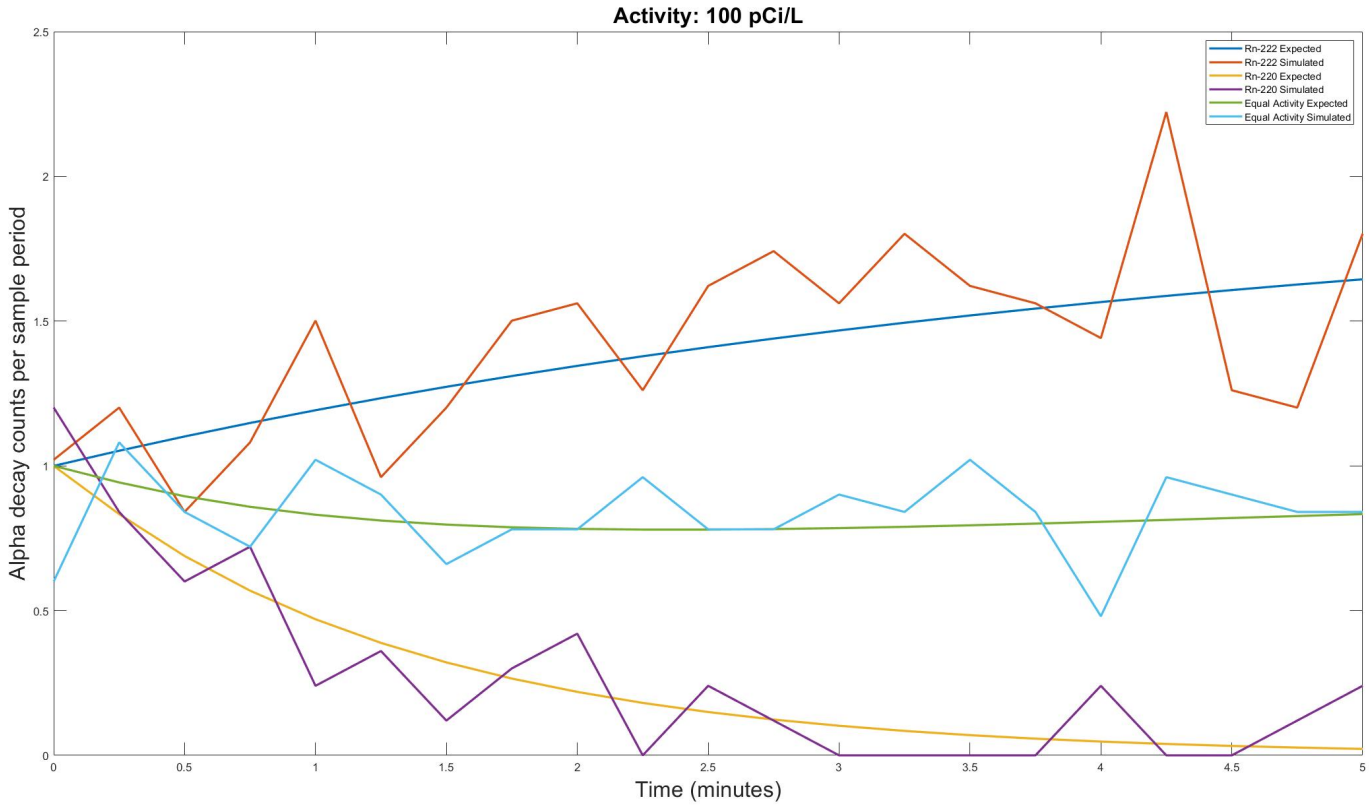
100 pCi/L



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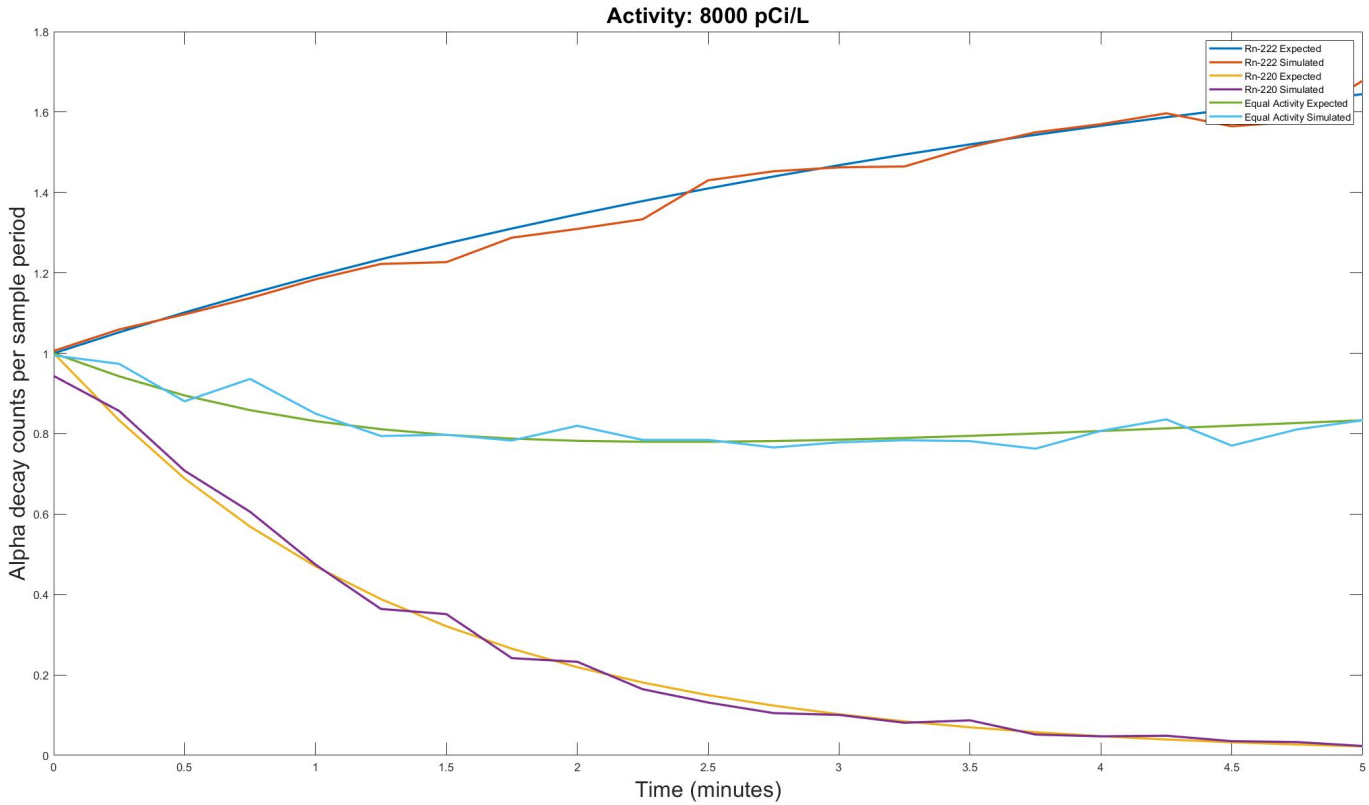
8000 pCi/L



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Progress

Using the expected number of decays and the observed counts, we use a linear regression model to estimate our initial amount of each isotope. Thus we can fit the model:

$$y_t = N_{222}X_{t1} + N_{220}X_{t2} + \epsilon_t$$

We can simulate this model thousands of times with a given set of concentrations and calculate the mean and standard deviation of the estimated initial quantities.

At the moment we find that sampling for 5 minutes with $15s$ intervals is able to give us the best prediction, as evaluated by the variance in the estimated amounts.

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Next Steps

- Thus far, we have assumed that there is no radon progeny at the beginning of the sampling period.
- We will have to update the model to incorporate the inclusion of the radon decaying while the air is pumped into the device.
- This will change the initial conditions of our differential equation and we will need to estimate more terms to be able to accurately predict the concentrations of each isotope.
- From here we can find a sampling scheme in the data that would minimize the variance in our estimated coefficients.