PHYSICS
COLORADO STATE UNIVERSITY

RADIOACTIVE DECAY OF RADON GAS

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OUTLINE

- I will be modeling the decay chain / progeny behavior of radon gas into its daughters, Polonium-218, Lead-214, Bismuth-214 and Polonium-214 (or Radium A, B, C and D).
- Then I will predict the quantities of alpha particle and gamma ray emissions from this decay series.
- These predictions will be compared to real data taken from a sample of radon gas (detecting alphas in a Lucas Cell) and air pumped through a filter (detecting gamma rays in a Geiger tube).

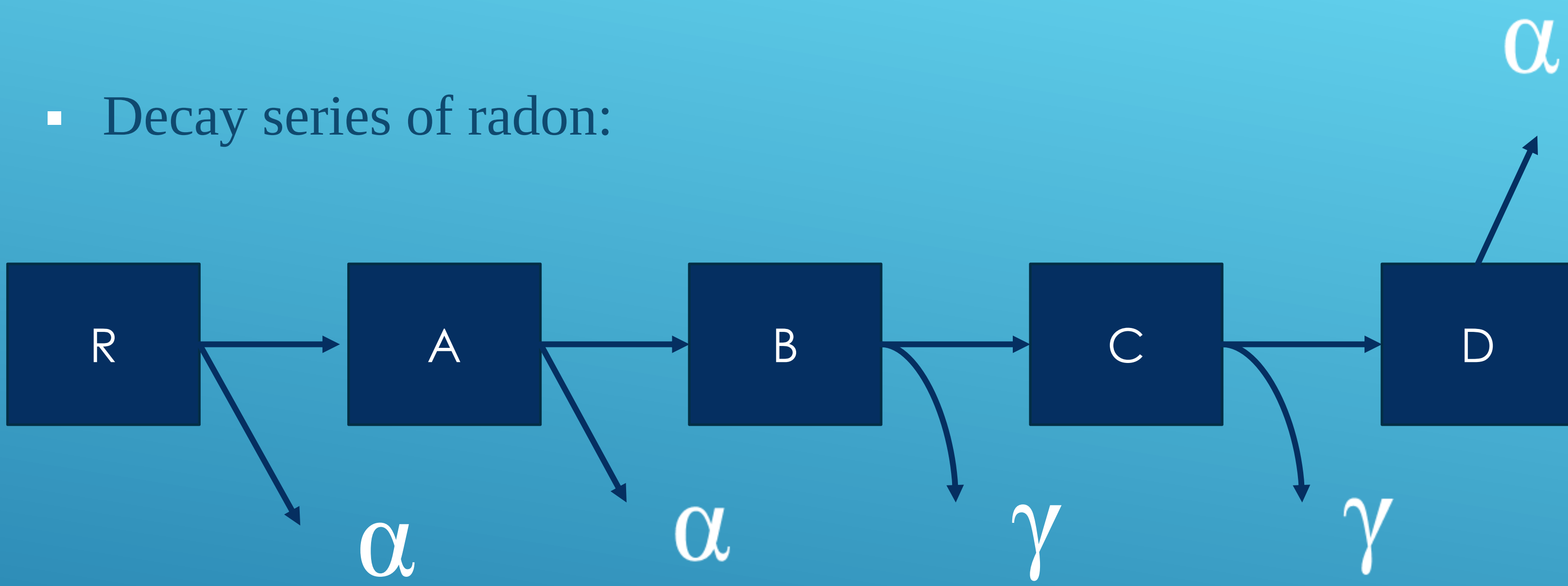
INTRODUCTION

- In 1896, X-rays had recently been discovered, and a man named Henri Bequerel was searching for them in Uranium salts. He noticed that this uranium was giving off a new/different kind of radiation.
- Marie Curie and her husband delved into this phenomenon and proposed that this radiation was coming from individual atoms. Their studies eventually led to the discovery of two new elements (Radium and Pollonium).

- Moszkowski, S.A., and C.W. Wong. *Early Nuclear Physics*, www.physics.ucla.edu/~moszkowski/histnucl/earlynp/earlynp.htm
- "Marie Curie the Scientist." Marie Curie, 2020, www.mariecurie.org.uk/who/our-history/marie-curie-the-scientist

INTRODUCTION

- Decay series of radon:

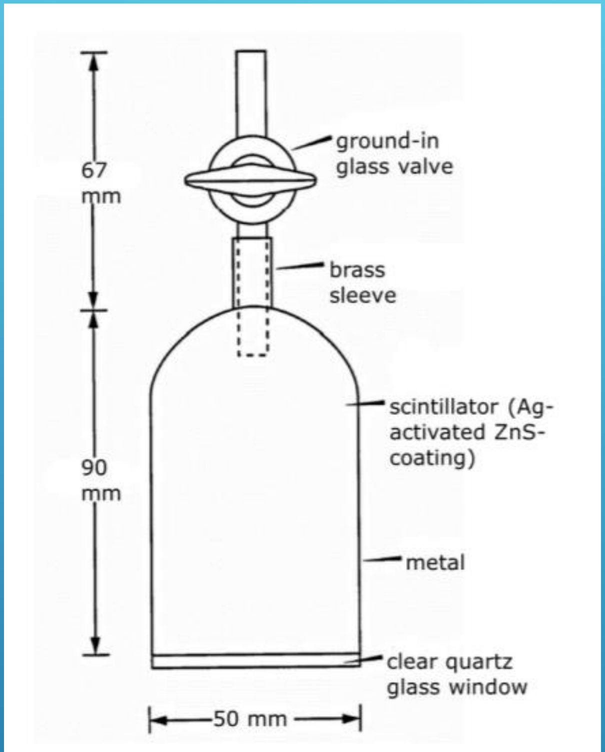


- Half-lives:
  - R = 3.824 days
  - A = 3.1 min
  - B = 26.8 min
  - C = 19.9 min
  - **D = <u>0.000164 sec</u>**

- Lonnquist, Kenneth, and Brian Jones. Reinventing the Universe: Critical experiments from the Birth of Modern Physics. Spring 2020 ed., Department of Physics, 2020, pp. 13, 25.
- Maughan, Weston, actor. *PH315 Radioactivity Tutorial*, directed by Daniel Shaw2020 www.youtube.com/watch?v=rTzFeGQq_K0&feature=youtu.be

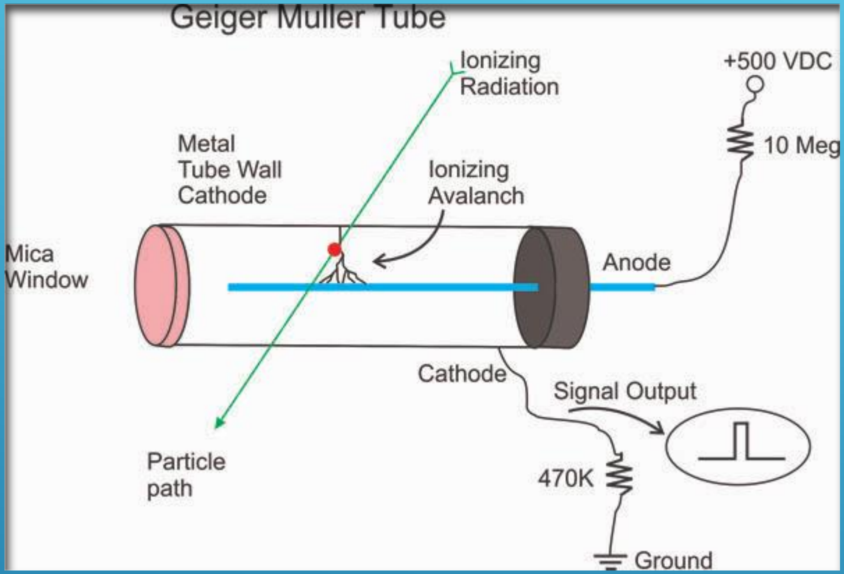
EXPERIMENTAL PROCEDURE

- **[Detecting alpha particles](#)** using a Lucas Cell / Photomultiplier Tube (PMT)
  - Vacuum cell coated with a scintillator, hooked up to a PMT.



- Maughan, Weston, actor. *PH315 Radioactivity Tutorial*. , directed by Daniel Shaw2020, www.youtube.com/watch?v=rTzFeGQq_K0&feature=youtu.be
- Bünger, Th., and H. Rühle. "Procedure for determining radium-226 in drinking water and groundwater." Sept. 1992, www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Strahlenschutz/leitstelle_h_ra_226_twass_01_v1992_09_en.pdf

EXPERIMENTAL PROCEDURE

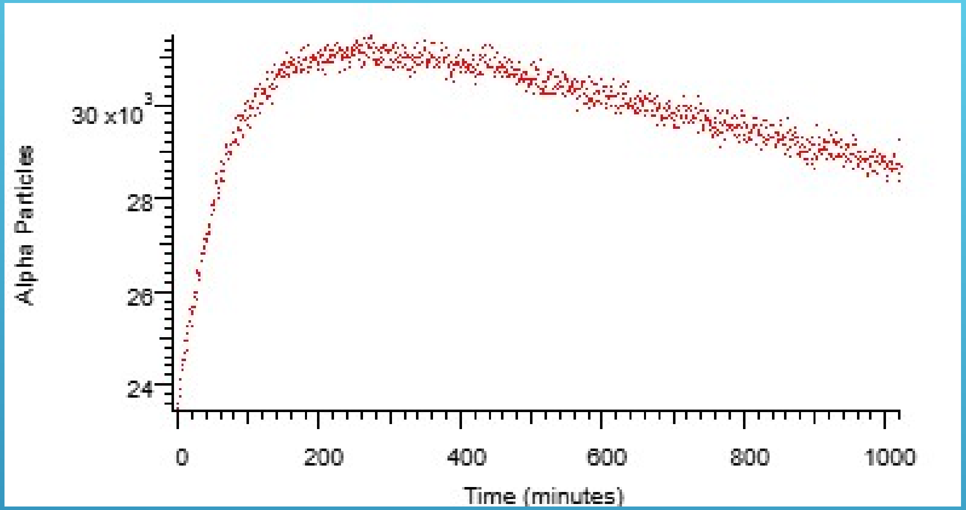


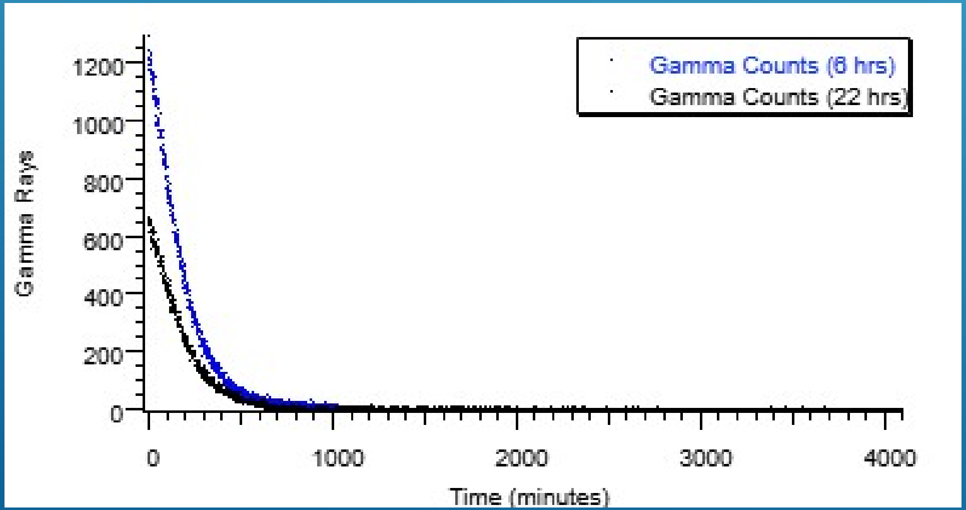
- **<u>Detecting gamma rays</u>** using a Geiger Muller Tube
  - Gas-filled tube with central wire; gamma rays enter tube and interact with gas, sending a spark through the wire.
  - Our source is a coffee filter, coated in air from the basement.

- Lonnquist, Kenneth, and Brian Jones. Reinventing the Universe: Critical experiments from the Birth of Modern Physics. Spring 2020 ed., Department of Physics, 2020, pp. 13, 25.
- "Geiger Counter Tube." *Images Scientific Instruments*, Images SI, Inc., 2020, www.imagesco.com/geiger/geiger-counter-tube.html

DATA AND ANALYSIS

- **<u>Alpha emissions</u>** as a function of time (20-second bins)





- **<u>Gamma ray emissions</u>** as a function of time (20-second bins)

DATA AND ANALYSIS

- Following this slide is a table that represents my model of the decay series of radon gas into its daughter species.
- To create this model, I used the following relationships to explain the changes in each species with time.

$$N_R(t) = N_R(0)e^{\frac{-t}{\tau_R}} \tag{1}$$

$$\Delta N_R = \frac{-\Delta t N_R}{\tau_R} \tag{2}$$

$$\Delta N_A = \frac{-\Delta t N_A}{\tau_A} + \frac{\Delta t N_R}{\tau_R} \tag{3}$$

$$\Delta N_B = \frac{-\Delta t N_B}{\tau_B} + \frac{\Delta t N_A}{\tau_A} \tag{4}$$

$$\Delta N_C = \frac{-\Delta t N_C}{\tau_C} + \frac{\Delta t N_B}{\tau_B} \tag{5}$$

- Lonnquist, Kenneth, and Brian Jones. Reinventing the Universe: Critical experiments from the Birth of Modern Physics. Spring 2020 ed., Department of Physics, 2020, pp. 13, 25.

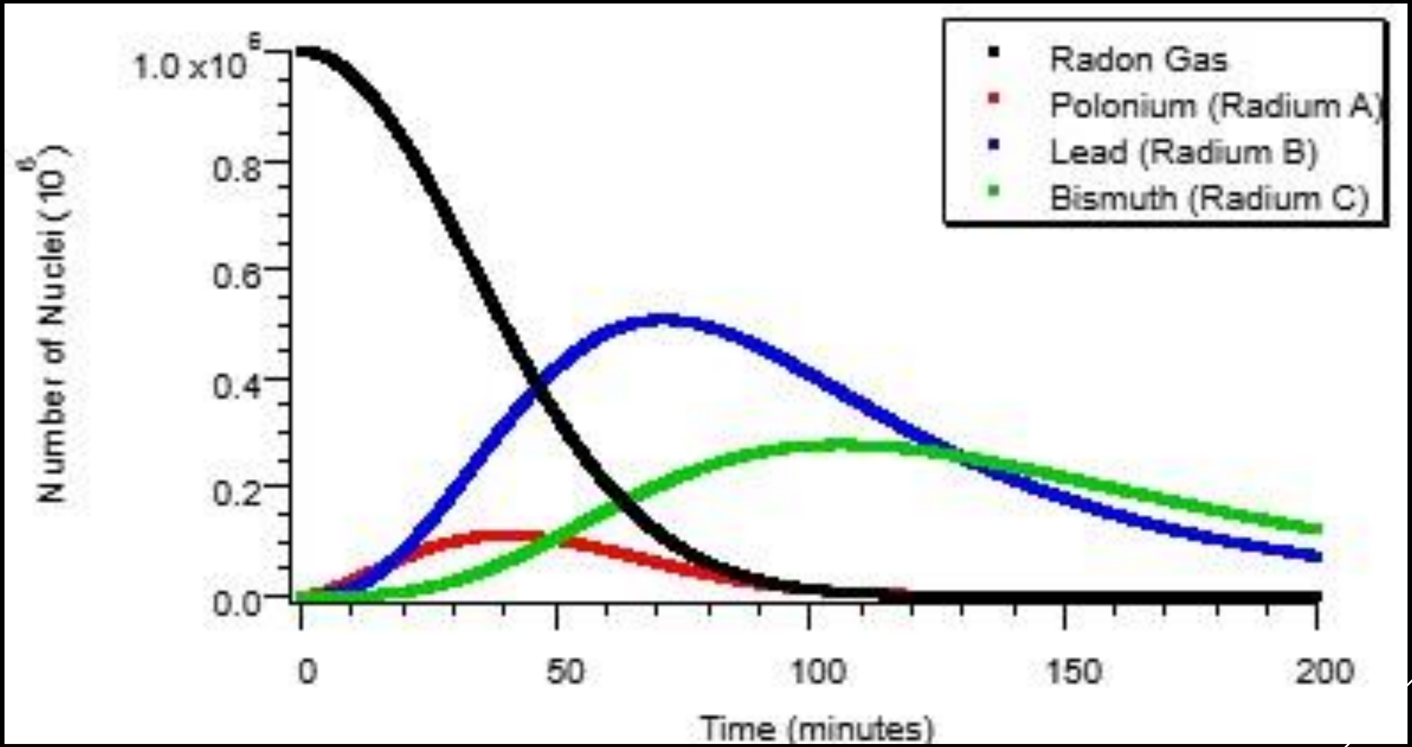
DATA AND ANALYSIS

Time (min)	Radon	Radium A	Radium B	Radium C
0	1000000	0	0	0
0.1	999991.2746	8.72537961	0	0
0.2	999973.8241	26.0406091	0.13530139	0
0.3	999947.6489	51.8120318	0.53886162	0.00024234
0.4	999912.7496	85.9078354	1.34132744	0.00120689
0.5	999869.1273	128.198023	2.67106761	0.0036064
0.6	999816.783	178.554386	4.65420518	0.00838178
0.7	999755.7181	236.850474	7.4146492	0.01669758
0.8	999685.9343	302.961571	11.074126	0.02993747
0.9	999607.4333	376.764666	15.7522099	0.04969979
1	999520.2172	458.138428	21.5663537	0.07779319
1.1	999424.2882	546.963178	28.6319181	0.11623233
1.2	999319.649	643.120866	37.0622018	0.16723361
1.3	999206.3021	746.495046	46.9684696	0.23321101
1.4	999084.2507	856.970848	58.4599816	0.31677197
1.5	998953.4978	974.434956	71.6440208	0.4207133
1.6	998814.047	1098.77559	86.6259209	0.54801725
1.7	998665.9018	1229.88246	103.509094	0.70184748
1.8	998509.0661	1367.64677	122.395056	0.88554528
1.9	998343.5441	1511.9612	143.383454	1.10262565
2	998169.34	1662.71984	166.572094	1.35677359

- Lonnquist, Kenneth, and Brian Jones. Reinventing the Universe: Critical experiments from the Birth of Modern Physics. Spring 2020 ed., Department of Physics, 2020, pp. 13, 25.

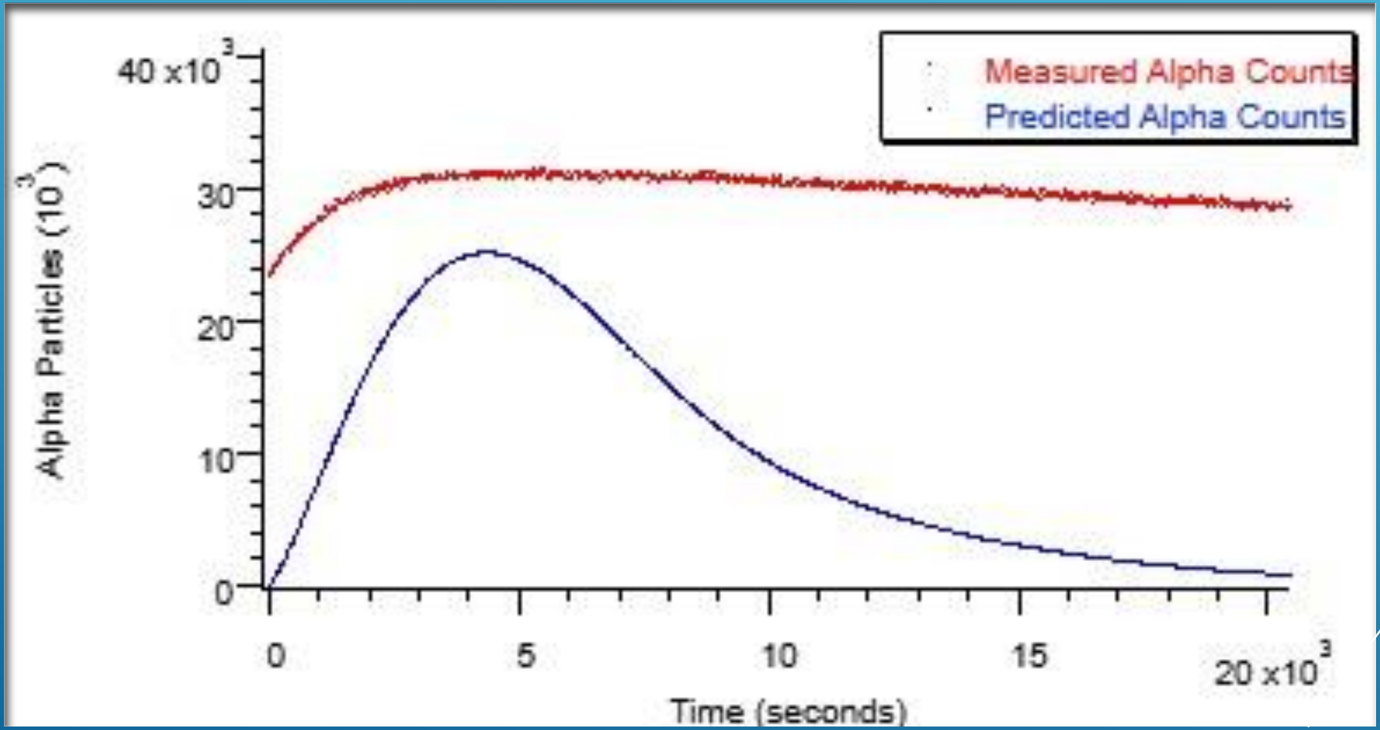
DATA AND ANALYSIS

- Exponential decay of the radon gas (black).
- Radium C last species remaining.
- Radium A in small quantity due to relatively short half-life.



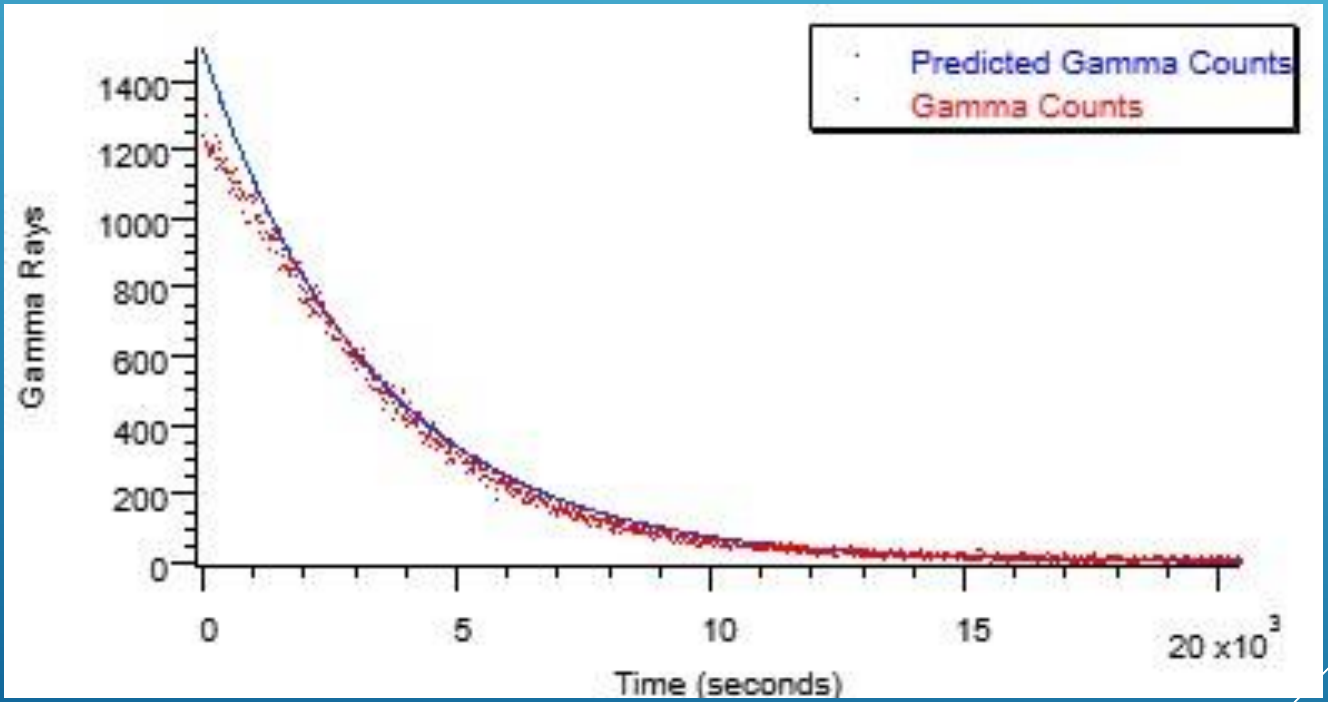
DATA AND ANALYSIS

- Measured alpha counts versus predicted alpha counts.
- Adjusted initial radon nuclei to yield similar peak alpha counts.



DATA AND ANALYSIS

- Measured gamma counts (6 hours) versus predicted gamma counts.
- Adjusted initial radon nuclei to yield similar initial number of gammas



POSSIBLE SOURCES OF ERROR

- “Approximated” relationships from differential equations
- Initial conditions of models (alpha and gamma counts)
- Residual radon / progenies in the Lucas cell
- Loss of radiation on coffee filter from basement to lab

CONCLUSION

- I've modeled the decay series of radon gas into four of its progenies.

- I attribute a large portion of the discrepancies to the approximate differential equations.
- I am happy with the results!

- "File:Pierre and Marie Curie at work in laboratory." *Wikimedia Commons*, 26 May 2018, commons.wikimedia.org/wiki/File:Pierre_and_Marie_Curie_at_work_in_laboratory_Wellcome_L0001761.jpg.