Optical Measurement of Nuclear Decay with a Cloud Chamber

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We intend to identify and characterize decay phenomena in radioisotopes using a cloud chamber and optical measurements. The cloud chamber uses an extreme temperature gradient to hold alcohol isopropyl alcohol Radioisotope source disintegrations emit charged particles which can cause localized ionizations in the vapor, the ionization and transfer of energy produces condensation phase transition with visible characteristic trails. We use ceramic heaters and PTC heating elements as well as dry ice to produce the desired temperature gradient in the chamber. We capture cloud chamber images using a single board computer, programmable LEDs, and a programmable camera. tungsten thoriated rods and americium sources are visible without optical assistance. RESULTS

I. BACKGROUND

Some of the most interesting aspects of the nuclear phenomenon are the most challenging barriers to teaching and presenting information to support a common understanding of the physical properties of atoms, matter, and energy. In building a nuclear science learning, understanding, and experience base perception barriers are at least worthily of note.

The historical context basis for the the energy of the atom is remarkable but is at least worthy of note as a bias to background for understanding.

Being invisible to the naked eye, odorless under normal conditions, and generally evasive to the other senses, the foundational knowledge base of atomic phenomena is transferred through recounting, analogy, and comparison. Students and the curious are told some things that behave like atoms, some larger scale phenomena that extend casual comparison to the atomic scale, or broad descriptions of key events in atomic cycles. The few and fortunate, may have the opportunity to have the best shot at a forensic view of the properties through indirect observation. Indirect observation, for being the least misleading, is then probably the best method for presenting the atomic phenomena.

To meet this challenge, cloud chambers serve as an exceptionally suitable method to observe the nuclear phenomena. This project applies a combination of engineering, modeling, programming, measurement design, and data analysis techniques. Additionally, the process of this experiment distills key knowledge concepts from a broad set of skills central to the Nuclear Science focused BS-Physics and BS-Chemistry programs in the areas of: Chemistry Thermal and Quantum Physics Analog and Digital Electronics Programming for Science and Engineering, and Nuclear Science Fundamentals, Measurements, and Applications

II. THEORY

A. Decay Phenomena Theory

1. Alpha Decay

The general formula for Alpha Decay (α) is listed:

$$ {}^{\mathrm{A}}_{\mathrm{Z}}\mathrm{X}_{\mathrm{N}} \rightarrow {}^{4}_{2}He^{2+} + {}^{A-4}_{Z-2}Y^{2-} $$

2. Beta Decay

The general formula for Beta Minus ($\beta-$) is listed:

$$ {}^{\mathrm{A}}_{\mathrm{Z}}\mathrm{X} \rightarrow {}^{A}_{Z+1} Y^{+} + {}_{-1}e^{-} + \bar{v} $$

In beta minus decay, a neutron is converted into a proton, an electron, and an anti-neutrino

$$ {}^{1}_{0}\mathrm{n} \rightarrow {}^{1}_{1}p + {}_{-1}e^{-} + \bar{v} $$

III. METHOD

For analysis we use 2% and 4% tungsten-thoriated rods as cloud chamber sources. In these sources tungsten content is most likely one most abundant and stable isotopes of so decay activity is not expected. The contained thorium, is likely the most naturally abundant isotope, thorium-232. Which decays Thorium

$$ {}^{232}_{90}\mathrm{Th}_{142} \rightarrow {}^{4}_{2}He^{2+} + {}^{228}_{88}Ra^{2-} $$

IV. MATERIALS

Our experiment and measurement uses the materials listed below:

- Cloud Chamber,

  5.5-gallon standard glass aquarium

  Steel Plate

  Foam Board Insulation 1-in sheet

  Source element holder (3D Printed)

- Radioisotope Samples
  - 2% Tungsten-Thoriated Rods
  - 4% Tungsten-Thoriated Rods
- 99% Isopropyl Alcohol
- Heating Element,
  - 50C/70C/110C PTC Heating Element
  - Stainless Steel Trays ($10.17 \times 15.18 \times 4.3$cm)
  - Meanwell 24v 25A Power Supply
  - Aluminum and 3D Printed Heater Stand
- Raspberry Pi Imaging Unit,
  - Raspberry Pi 4 Model B with peripherals
  - Standard Monitor
  - Power Supply Unit, USB-C, 5.1V, 3A
  - Camera Module 3 NoIR
- Lighting Unit,
  - Meanwell 5v 3.0A Power Supply
  - NeoPixel Fit0612
- High Voltage Generator Unit
  - Arc Pulse Generator and Step-up Voltage Transformer with Input DC 3.6V-12V/Output 3kV-11kV)
  - Meanwell 5v 3.0A Power Supply

V. PROCEDURE

Measuring Experimental Count Rate

Atomic disintegration are measured and evaluated as a proportional to source activity. Activity within the cloud chamber is measured based proportionality of observed ionization. Ionizations (n) within the active area are counted for a sample time period (t). For each sampling, The ratio of ionizations per time provides the experimentally measured rate for the sample period:[1]

$$R_s = \frac{n}{t_s} \tag{1}$$

Expected Count Rate

The average mass of the 2% W-Th source is 14.660g, the average mass of Th-232 in the source is approximately 0.293g. Since Thorium has a molar mass of 232.038 g/mol, there are 0.001264 mols, or approximately 7.609×10^{20} atoms. A radiated alpha particle decay energy has a range of 2.2 μm in the material due to the density of Tungsten. Only 0.366% of radiated alphas could be detected externally, and the source then has an effective n of 2.788×10^{18} For a source with a half life of 1.41×10^{10} years, the decay constant is 1.562×10^{-18} Th-232 has an activity of 2.6×10^{24} disintegrations per minute per kg, based on the effective n we could expect 512 disintegrations per minute

FIG. 1: Possible sources for future analysis

VI. DATA ANALYSIS

VII. CONCLUSION

Future Research

VIII. ACKNOWLEDGMENTS

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IX. APPENDIX

A. Thorium Source Data

TABLE I: Tungsten-Thoriated(2%) Rods

Dimension	Measurement
Length	17.78cm
Diameter	0.24cm
Mass	14.66g

TABLE II: Tungsten-Thoriated(4%) Rods

Dimension	Measurement
Length	17.78cm
Diameter	0.1cm
Mass	14.66g

B. Americium Source Data

Dimension	Measurement
Length	17.78cm
Diameter	0.1cm
Activity	1.0 μCi or 37 kbq

REFERENCES

[1] B. Allison, Particle physics -cloud chambers activities for schools (2012), https://www.birmingham.ac.uk.