# Radioactive Decay

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A radioactive species is often characterized by its halflife $t_{\frac{1}{2}}$, which is defined as the time it takes for onehalf of the nuclei to decay. In this experiment, we are going to calculate half-life of Radon gas.

## 1. INTRODUCTION

The rate at which a particular radioactive material disintegrates in a given time interval is called the decay constant $\lambda$. The decay constant is characteristic of the particular nuclear species and is independent of all external physical and chemical conditions. Radioactive decay is a statistical process as one cannot predict when any individual nucleus will decay. The most that one can know is that the probability that a nucleus will decay in a small time interval $dt$ is $\lambda dt$.

When a large number of nuclei of a single species are studied, statistics can be used to make definite predictions aboutthe average number of decaysthat occurin a small time interval. Let $N(t)$ be the total number of undecayed nuclei at time $t$. If one studied many identically prepared samples, the average number of decays that occur every second $\frac{dN}{dt}$ is given by

$$\frac{dN}{dt} = -\lambda N(t)$$

This can be integrated to give the number of undecayed nuclei at time $t$

$$N(t) = N_0 e^{-\lambda t}$$

Here $N_0$ is the number of nuclei present at $t = 0$.

Using the equation for $N(t)$ we see that $t_{\frac{1}{2}}$ satisfies

$$\frac{N}{N_0} = \frac{1}{2} = e^{-\lambda t \frac{1}{2}} \Longrightarrow t_{\frac{1}{2}} = \frac{ln2}{\lambda}$$

## 2. EXPERIMENTAL SETUP

- Wulf's Electroscope
- Thorium Salt
- Ionization Chamber
- HV Power Supply (0-5 kV)
- Stopwatch

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## 3. DATA AND ANALYSIS

In data analysis part, we have $S_i$ and $T_i$ values by using discharge time $t_i$ where:

$$S_i = t_{i+1} - t_i$$

$$T_i = \frac{t_{i+1} + t_i}{2}$$

.

| Squeeze Number | $S_i$ | $T_i$ |
|---|---|---|
| 6 | 17.0 sec | 8.5 sec |
| 6 | 34.0 sec | 34.0 sec |
| 6 | 60.0 sec | 81.0 sec |
| 8 | 25.0 sec | 12.5 sec |
| 8 | 47.0 sec | 53.5 sec |
| 10 | 21.0 sec | 10.5 sec |
| 10 | 40.0 sec | 42.0 sec |
| 10 | 87.0 sec | 104.5 sec |
| 11 | 22.0 sec | 11.0 sec |
| 11 | 44.0 sec | 44.0 sec |
| 11 | 84.0 sec | 98.0 sec |

TABLE I: Values for Voltage 2500 V

| Squeeze Number | $S_i$ | $T_i$ |
|---|---|---|
| 6 | 10.0 sec | 5.0 sec |
| 6 | 37.0 sec | 18.5 sec |
| 6 | 69.0 sec | 81.5 sec |
| 8 | 20.0 sec | 10.0 sec |
| 8 | 53.0 sec | 46.5 sec |
| 8 | 170.0 sec | 158.0 sec |
| 10 | 13.0 sec | 6.5 sec |
| 10 | 84.0 sec | 55.0 sec |
| 10 | 177.0 sec | 185.5 sec |
| 11 | 11.0 sec | 5.5 sec |
| 11 | 41.0 sec | 31.5 sec |
| 11 | 153.0 sec | 128.5 sec |

TABLE II: Values for Voltage 3000 V

| Squeeze Number | $S_i$ | $T_i$ |
|---|---|---|
| 6 | 5.0 sec | 2.5 sec |
| 6 | 39.0 sec | 19.5 sec |
| 6 | 83.0 sec | 85.5 sec |
| 8 | 12.0 sec | 6.0 sec |
| 8 | 37.0 sec | 30.5 sec |
| 8 | 125.0 sec | 112.5 sec |
| 10 | 6.0 sec | 3.0 sec |
| 10 | 34.0 sec | 23.0 sec |
| 10 | 67.0 sec | 73.5 sec |
| 11 | 4.0 sec | 2.0 sec |
| 11 | 43.0 sec | 18.5 sec |
| 11 | 116.0 sec | 81.0 sec |

TABLE III: Values for Voltage 3500 V

| Squeeze Number | $S_i$ | $T_i$ |
|---|---|---|
| 6 | 31.0 sec | 16.5 sec |
| 6 | 61.0 sec | 61.5 sec |
| 8 | 19.0 sec | 8.5 sec |
| 8 | 44.0 sec | 41.0 sec |
| 8 | 106.0 sec | 116.0 sec |
| 10 | 24.0 sec | 12.0sec |
| 10 | 45.0 sec | 46.5 sec |
| 10 | 106.0 sec | 122.0 sec |
| 11 | 15.0 sec | 7.5 sec |
| 11 | 32.0 sec | 31.0 sec |
| 11 | 54.0 sec | 74.0 sec |

TABLE IV: Values for Voltage 4000 V

And bu using linear fitting for specific voltage and squeeze number, we will have 20 $\lambda$ and $\sigma_\lambda$. Fitting to

$$lnS = lnS_0 + \lambda T$$

where $y = lnS$ and error propagation for $\sigma_{lnS}$

$$\sigma_y{}^2 = \sigma_{lnS}{}^2 = \left(\frac{d}{dS}\left(lnS\right)\right)^2 \sigma_S{}^2 = \frac{2}{s^2}$$

where $\sigma_S = \sqrt{2}$.

After fitting, we have 20 $\lambda$ and 20 $\sigma_\lambda$. By using these values, weighed values and errors can be calculated as:

$$\lambda_w = \frac{\sum_{i=1}^{20} \frac{\lambda_i}{\sigma_i{}^2}}{\sum_{i=1}^{20} \frac{1}{\sigma_i{}^2}}$$

| Squeeze Number | $S_i$ | $T_i$ |
|---|---|---|
| 6 | 10.0 sec | 5.0 sec |
| 6 | 37.0 sec | 18.5 sec |
| 6 | 117.0 sec | 82.0 sec |
| 8 | 15.0 sec | 7.5 sec |
| 8 | 37.0 sec | 36.5 sec |
| 8 | 97.0 sec | 106.5 sec |
| 10 | 8.0 sec | 4.0 sec |
| 10 | 32.0 sec | 24.0 sec |
| 10 | 52.0 sec | 66.0 sec |
| 10 | 192.0 sec | 188.0 sec |
| 11 | 12.0 sec | 6.0 sec |
| 11 | 34.0 sec | 29.0 sec |
| 11 | 67.0 sec | 79.5 sec |

TABLE V: Values for Voltage 4500 V

| Voltage | Squeeze Number | $\lambda$ | $\sigma_\lambda$ |
|---|---|---|---|
| 2500 V | 6 | 0.014 | 0.00082 |
| 3000 V | 6 | 0.011 | 0.00066 |
| 3500 V | 6 | 0.012 | 0.0006 |
| 4000 V | 6 | 0.015 | 0.00114 |
| 4500 V | 6 | 0.019 | 0.0006 |
| 2500 V | 8 | 0.015 | 0.00156 |
| 3000 V | 8 | 0.011 | 0.00023 |
| 3500 V | 8 | 0.012 | 0.00034 |
| 4000 V | 8 | 0.013 | 0.0004 |
| 4500 V | 8 | 0.015 | 0.00051 |
| 2500 V | 10 | 0.014 | 0.0005 |
| 3000 V | 10 | 0.006 | 0.00014 |
| 3500 V | 10 | 0.015 | 0.0009 |
| 4000 V | 10 | 0.012 | 0.00036 |
| 4500 V | 10 | 0.011 | 0.00018 |
| 2500 V | 11 | 0.013 | 0.00053 |
| 3000 V | 11 | 0.016 | 0.00035 |
| 3500 V | 11 | 0.014 | 0.00056 |
| 4000 V | 11 | 0.015 | 0.00099 |
| 4500 V | 11 | 0.016 | 0.00083 |

TABLE VI: Fitted $\lambda$ values where $\sigma_\lambda = \sigma_{a_1}$

and

$$\sigma_{\lambda_w}{}^2 = \frac{1}{\sum_{i=1}^{20} \frac{1}{\sigma_i{}^2}}$$

From weighted values of $\lambda$, we can measure $t_{\frac{1}{2}}$:

$$t_{\frac{1}{2}} \longrightarrow t_{\frac{1}{2}} = \frac{ln2}{\lambda_w}$$

and error of $t_{\frac{1}{2}}$:

$$\sigma_{t_{\frac{1}{2}}}{}^2 = \left(\frac{d}{d\lambda}\left(t_{\frac{1}{2}}\right)\right)^2 \sigma_{\lambda_w}{}^2$$

## 4. RESULTS

$$\lambda_w = 0.0104$$
$$\sigma_{\lambda_w} = 0.0088$$
$$t_{\frac{1}{2}} = 66.12 \text{ sec}$$
$$\sigma_{t_{\frac{1}{2}}}{}^2 = 0.24 \text{ sec}$$

Error of $t_{\frac{1}{2}}$:

$$Error = \frac{|66.12-55.6|}{0.48} = 21.47 \gg 1\sigma.$$

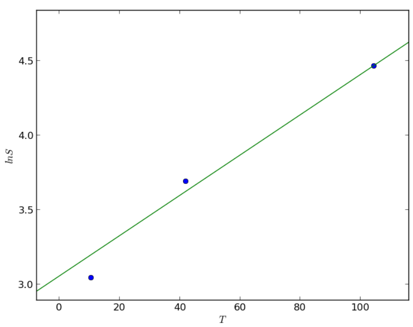


FIG. 1: LSF to straight line

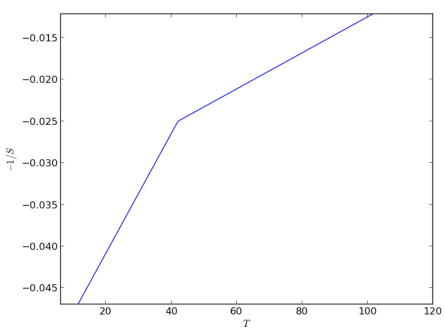


FIG. 2: $\frac{-1}{S}$ versus $T$

## 5. CONCLUSIONS

This experiment did not tell much things about radioactive decay since there would be a lot of causes of errors. For example, there were very few sample data to make good estimation and there were an irrelavence between them. My error shows this error explicitly. There is also no bound between numbers of squeezes, voltage value and $\lambda$. This experiment showed us sometimes number of sample would be more helpful in making good estimations.

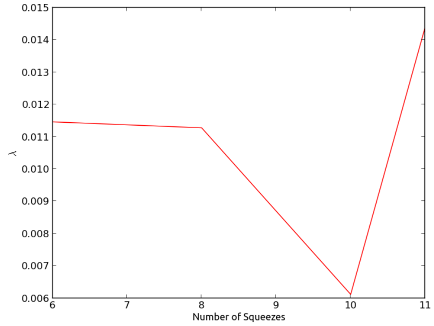


FIG. 3: $\lambda$ versus number of squeezes at voltage 3000V.

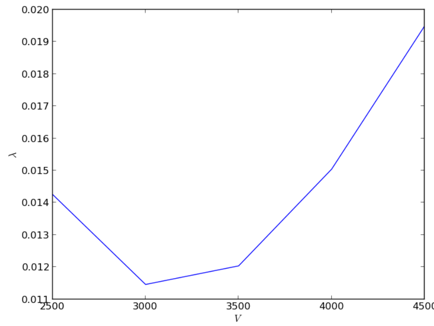


FIG. 4: $\lambda$ versus $V$ in 6 squeezes.

## 6. REFERENCES


- E. Gulmez, Advanced Physics Experiment, Istanbul, Bogazici University Publication, 1999
- http://web.mit.edu/8.13/www/experiments.shtml



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