Radioactive Decay

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1 Abstract

The objective of this experiment is study of radioactive decay via to measure half life of the element. In our experiment, Radon gas used for calculating $t_{1/2}$

2 Theory

Radioactive decay is a stochastic process, which one cannot determine when a particular atom will decay. We can use the formula given below to understand the behaviour of radiation.

$$N(t) = N_0.e^{-\lambda t} \tag{1}$$

where λ is the decay constant and N_0 is the initial number of the unstable nuclei when t equals to zero. Rate of decay can be studied with observing ionization capacity. A circuit provided with a high voltage is an appropriate setting for this observation. Charged particle produces current and this will give us an opportunity to examine amount of decay as a function of time.

Wulf' s electroscope discharges after reaching full charged state.
$Q = I.S \ I = \frac{Q}{S} \ I \propto \frac{1}{S}$
S is the time elapsed
and

$$\frac{1}{s} = \frac{1}{s_i} e^{-\lambda T_i} \tag{2}$$

leads the formula

$$ln(s) = ln(s_i) + \lambda T \tag{3}$$

s_i is constant and T is the average time t

Radon gas using for this experiment ^{220}Rn with its theoretical lifetime of 55.6 seconds.

$$t_{1/2} = \frac{ln2}{\lambda} \tag{4}$$

3 Apparatus

- Wulf's Electroscope
- Thorium Salt (^{232}Th)
- Ionization Chamber
- Stopwatch
- HV Power Supply (0-5kV)

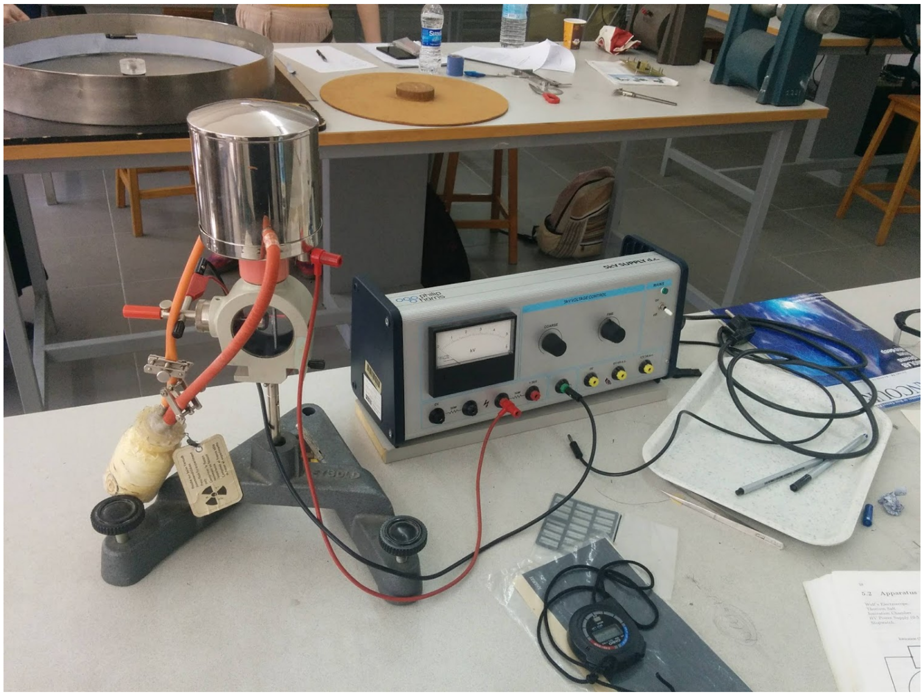

Figure 1: Laboratuary Setup: Apparatus

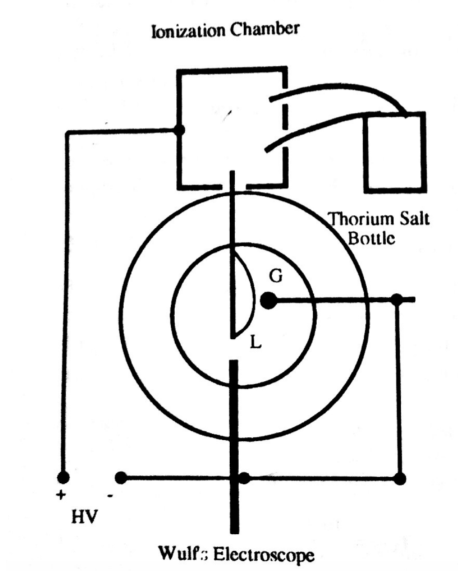

Figure 2: Diagram for Wulf's Electroscope

4 Procedure

We firstly waited for balanced condition. We freed small hose connection to provide Radon gas. We took 5 data sets from 2500 voltage to 4500 voltage. We pumped 5,10 and 15 times. We recorded times with stopwatch when electroscope discharges each time.

5 Data & Data Analysis

$$S_i = t_{i+1} - t_i \tag{5}$$

$$T_i = \frac{t_{i+1} + t_i}{2} \tag{6}$$

$$ln(s) = ln(s_i) + \lambda T_i \tag{7}$$

Voltage	# of discharge	5	10	15
2500	1	10.7	5.62	2.92
	2	23.32	25.91	16.7
	3	38.46	49.27	33.12
	4	57.71	84.49	53.43
	5	82.82	144.68	79.79
3000	1	4.62	8.23	2.06
	2	18.04	28.72	16.82
	3	35.97	55.4	34.26
	4	58.9	94.44	56.17
	5	91.25	169	86.17
3500	1	2.79	10.14	1.22
	2	17.21	25.98	18.49
	3	33.98	45.4	39.5
	4	55.0	70.48	67.6
	5	83.55	106.92	109.85
4000	1	9.01	3.24	15.3
	2	44.11	17.55	34.64
	3	69.5	34.72	59.26
	4	104.31	55.55	95.62
	5	168.88	84.88	159.99
4500	1	3.21	2.0	8.11
	2	18.65	11.26	27.54
	3	36.73	23.28	53.02
	4	89.96	38.84	90.11
	5	139.65	59.78	160.48

t5-3000	s5-3000	ln(s)	σ
11.33	13.42	2.596746132	0.1053
27.005	17.93	2.886475288	0.0788
47.435	22.93	3.132446097	0.0616
75.075	32.35	3.476614021	0.0437

I calculated s, T and $\ln(s)$ values from using Excel. After that, I created a T vs $\ln(s)$ graph from these data for 3000 V with python.

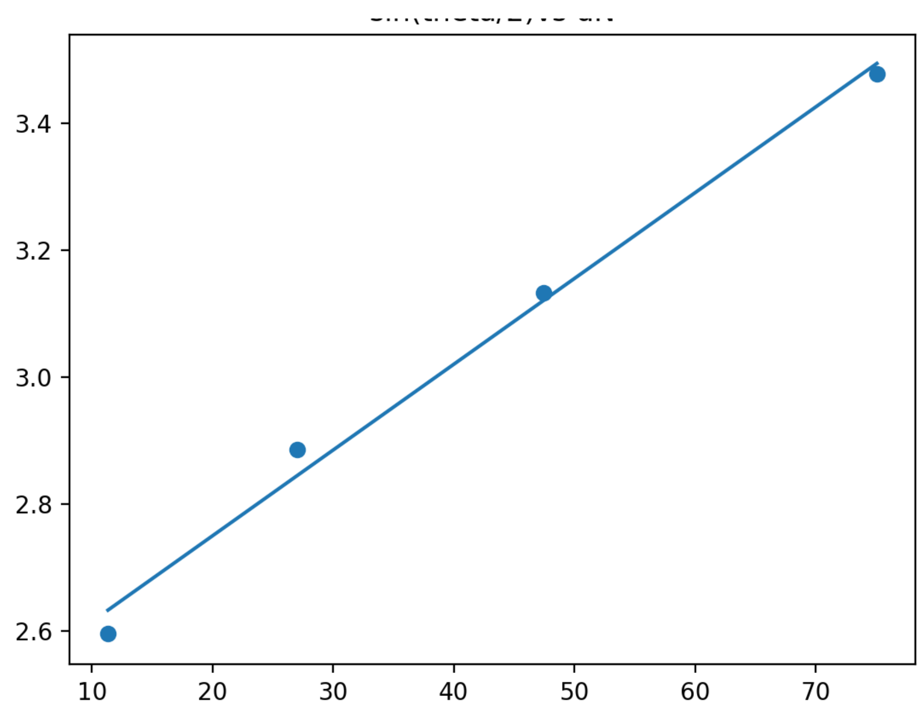

Figure 3: T vs $\ln(s)$ graph under 3000 V

Then, I found 15 decay constants to find λ value weighted average.

$$\lambda_{w.ave} = \frac{\sum_i \omega_i \lambda_i}{\sum_i \omega_i} \tag{8}$$

$$\omega_i = 1/\sigma_i^2 \tag{9}$$

Equation for half life value of element:

$$t_{1/2} = \frac{\ln 2}{\lambda_{w.ave}} \tag{10}$$

and its uncertainty can be calculated as;

$$\sigma_{t_{1/2}} = \frac{\ln 2 \times \sigma_{\lambda_{w.ave}}}{\lambda_{w.ave}^2} \tag{11}$$

$$\sigma_t^2 = \left\{ \frac{d(ln(2)/\lambda)}{d\lambda} \right\}^2 \sigma_\lambda^2$$

$$\sigma_t^2 = \left\{ \frac{-ln(2)}{\lambda^2} \right\}^2 \sigma_\lambda^2$$

6 Conclusion

As result of these calculations and measurements we found experimental value of λ with its uncertainty as;

$$\lambda_{w.ave} = 0.01179 s^{-1} \tag{12}$$

$$\sigma_{\lambda w.ave} = 1.84 \times 10^{-5} s^{-1} \tag{13}$$

Calculated half-life value is below:

$$t_{1/2_{ex}} = 58.77028 \pm 0.091 sec \tag{14}$$

$$t_{1/2_{theory}} = 55.6 sec \tag{15}$$

Error propagation is:

$Error = \frac{|58.77-55.6|}{0,091}$ = 34.84 unfortunately this number is so huge.

There can be lots of reasons for the errors. There is no bound with pumps and numbers. Stopwatch record time can be also manipulating because of human delay. This leads to numbers of sample data would be more useful in making good estimations.

7 References

- Gulmez, E. / 1999 Advanced Physics Experiments.
- $https://www.wikiwand.com/en/Radioactive\_decay$

Calculation codes are here:
https://github.com/samilokan/442/blob/master/rdecay.py