The Frank-Hertz Experiment

Adnan Basar (Partner: Kadir Simsek)*
2010205108
(Dated: May 3, 2013)

In this experiment, we are going to measure an important phenomena encountered in collisions between electrons and atoms: quantized excitation due to inelastic scattering.

1. INTRODUCTION

Franck and Hertz described the first observation of quantized excitation in 1914, one year after Bohr published his theory of the hydrogen atom with its concept of quantized energy states. They discovered that electrons moving through mercury vapor with an energy greater than or equal to a critical value near 4.9 eV can excite the 2536 $\mathring{A}$ line of the mercury spectrum. Electrons with less than the critical energy bounce elastically when they collide with mercury atoms and fail to excite any electromagnetic emission. The experiment provided crucial evidence in favor of the Bohr theory. This graph easily shows that excitation levels.

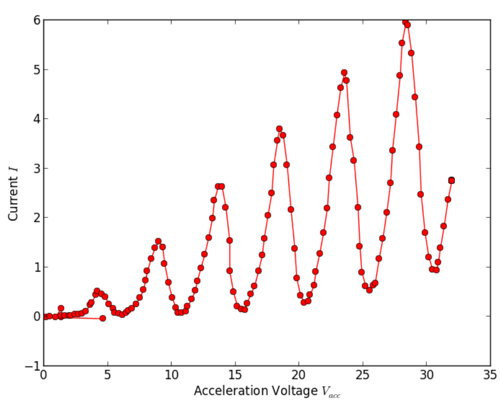

FIG. 1: Excitation levels of electrons through mercury vapor

1.1. Contact Potential

Consideration of contact potentials is also necessary. In simple terms, this means that the accelerating potential is not completely converted into kinetic energy of the electrons: some of it provides the work function of the cathode material, i.e. the amount of energy (measured in electron volts) necessary to free the electrons from the cathode. The cathode is coated with a material with a relatively low work function. The collector plate, since it is used merely as electron collector, has a somewhat higher work function. The contact potential is the difference between the work functions, since they are oppositely directed in the electric field, that is, the electric field has to work against the cathode potential but is helped in the case of the collector plate. Thus we should expect that the voltage to the first peak will be greater than the average peak to peak voltage, due to the contact potential. The contact potential can be calculated as the average peak to peak voltage subtracted from the first peak voltage.

2. EXPERIMENTAL SETUP

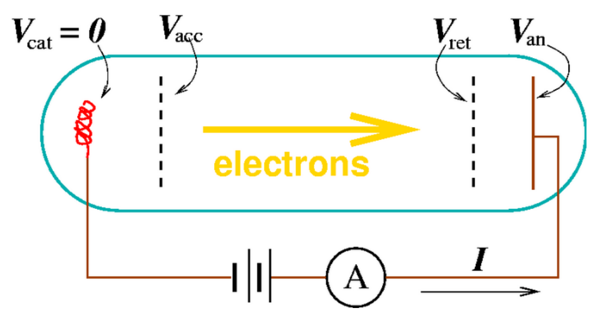

FIG. 2: Franck-Hertz Tube

In this experiment we used such items as:

- Franck-Hertz Tube
- DC Power Supply
- Current Amplifier
- AC filament Power Supply
- Temperature Probe with Display
- Electric Oven with The Special Copper Tube and The Power Supply

3. DATA AND ANALYSIS

We have data from five 5 different temperatures as in the tables:

*Electronic address: adnanbasarr@icloud.com

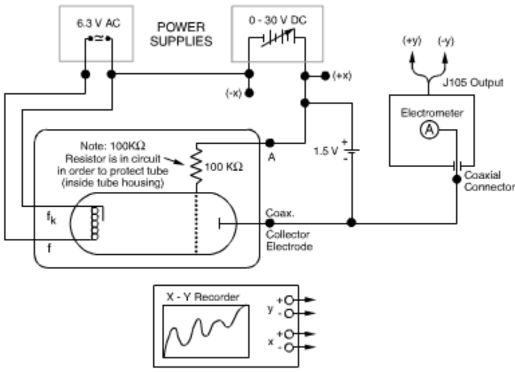

FIG. 3: Schematized Setup

Temperature (C)	$V_1(1.5\ V)$	$V_2(2.0\ V)$	$V_3(2.5\ V)$
	7.05 V	6.45 V	6.15 V
	12.15 V	11.70 V	11.25 V
155	17.25 V	16.95 V	16.65 V
	22.80 V	22.35 V	21.90 V
	28.20 V	27.75 V	27.15 V

TABLE I: For Temperature 155 C

Temperature (C)	$V_1(1.5\ V)$	$V_2(2.0\ V)$	$V_3(2.5\ V)$
	7.05 V	6.45 V	6.00 V
	11.85 V	11.40 V	10.95 V
165	16.95 V	16.65 V	15.90 V
	22.05 V	21.75 V	21.00 V
	27.45 V	26.85 V	26.40 V

TABLE II: For Temperature 165 C

Temperature (C)	$V_1(1.5\ V)$	$V_2(2.0\ V)$	$V_3(2.5\ V)$
	7.05 V	6.60 V	6.00 V
	11.85 V	11.25 V	11.10 V
175	16.95 V	16.50 V	16.05 V
	22.20 V	21.60 V	21.15 V
	27.45 V	27.15 V	26.40 V

TABLE III: For Temperature 175 C

Temperature (C)	$V_1(1.5\ V)$	$V_2(2.0\ V)$	$V_3(2.5\ V)$
	6.75 V	6.45 V	6.00 V
	11.55 V	11.25 V	10.95 V
185	16.65 V	16.05 V	15.90 V
	21.45 V	21.15 V	20.85 V
	26.70 V	26.25 V	25.80 V

TABLE IV: For Temperature 185 C

Temperature (C)	$V_1(1.5\ V)$	$V_2(2.0\ V)$	$V_3(2.5\ V)$
	7.05 V	6.60 V	6.30 V
	11.70 V	11.40 V	11.10 V
195	16.65 V	16.20 V	15.60 V
	21.45 V	21.15 V	20.85 V
	26.40 V	25.95 V	25.65 V

TABLE V: For Temperature 195 C

For each division of tables, we are going to calculate

- $\Delta V = V_{i+1} - V_i$
- Avarage: $(\Delta V)_{mean} = \frac{1}{N}\sum \Delta V_i$
- Standard Deviation-Squared: ${\sigma_{\Delta V}}^2 = \frac{1}{N-1}\sum \Delta V_i - {\Delta V_{mean}}^2$

For all values, we have following results in table.

Voltage (V)	Temp. (C)	ΔV_{mean} (V)	$\sigma^2_{\Delta V}$ (V^2)
1.5	155	5.28	0.050
2.0	155	5.32	0.007
2.5	155	5.25	0.014
1.5	165	5.1	0.059
2.0	165	5.1	0.014
2.5	165	5.1	0.044
1.5	175	5.1	0.044
2.0	175	5.13	0.140
2.5	175	5.1	0.014
1.5	185	4.98	0.050
2.0	185	4.95	0.029
2.5	185	4.85	0.044
1.5	195	4.83	~ 0
2.0	195	4.83	0.005
2.5	195	4.83	0.095

TABLE VI: Results of Mean and Standard Deviation Squared Calculations

$$V_{weighted} = \frac{\sum \frac{\Delta V_i}{\sigma^2_{\Delta V_i}}}{\sum \frac{1}{{\sigma \Delta V_i}^2}} = 5.05\ V$$

$$\sigma^2_{weighted} = \frac{1}{\sum \frac{1}{{\sigma \Delta V_i}^2}} = 0.001\ V^2$$

$\sigma_{instrumental}$ is given as 0.05 V.
$\sigma^2_{total} = \sigma^2_{weighted} + \sigma^2_{instrumental} = 0.0038\ V^2$
$\sigma_{total} = 0.061\ V$

4. RESULTS

In results part, the true value for the voltage difference is 4.9 eV. We have found as: 5.05 V and $\sigma_{total} = 0.061\ V$

$$\text{Error:} \frac{abs(4.9-5.05)}{0.61} = 2.56\ \sigma \text{ range.}$$

5. CONCLUSION

We obtained a value that is very close to true value, but actually with error calculation, it is not a good idea to make estimations by using our experiment. We could not take precise data from experiment since fluctuations of temperature does not allow. σ shows that this result in easy observation.

6. REFERENCES

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

Acknowledgments

I would like to thank my partner Kadir Simsek for his help to the experiment, and also to the teaching assistant Merve Tarman for her guidance during the experiment.