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PHYS307 Applied Modern Physics

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Exp. MP-AS Franck-Hertz Experiment*

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Table 1: Data for different filament and collector voltages at instant oven temperature

	Filament Voltage: 6.0 V Collector Voltage: 2.0 V Oven Temperature: 160°C		Filament Voltage: 6.0 V Collector Voltage: 2.0 V Oven Temperature: 160°C	
Voltage at first minimum/maximum [V]	0	2.2	0	2.2
Voltage at second minimum/maximum [V]	4.6	5.2	4.3	7.2
Voltage at third minimum/maximum [V]	9.6	12.4	-	-
Voltage difference between first and second minima/maxima [V]	4.6	3.0	4.3	5.0
Voltage difference between second and third minima/maxima [V]	5.0	7.2	-	-
Mean of Voltage difference between the minima/maxima [V]	4.8	5.1	4.3	5.0

Data & Results

Mean and the standard deviation of the first excited energy level: **4.8±0.2 eV**
Calculation of standard deviation σ as follows:

$$(4.6 - 4.8)^2 = -0.2^2 = 0.04 \tag{1}$$

$$(5.0 - 4.8)^2 = 0.2^2 = 0.04 \tag{2}$$

$$\frac{0.04 + 0.04}{2} = 0.04 \tag{3}$$

Therefore standard deviation σ in this case

$$\sigma = \sqrt{0.04} = 0.2 \tag{4}$$

*Nobel Prize in Physics, 1925

Accepted value of the first excited energy level: **4.9 eV**
Contact Potential difference between the anode and the cathode: **4.0 V** and **6.0 V**

1. What are the advantages and disadvantages of the method used in this experiment by comparing with the optical methods?

Optical methods of determining the excitation states suggested by Niels Henrik David Bohr. One important postulates of Bohr's is that radiation is only emitted when an atom makes transitions between stationary states:

$$E_{ph} = E_m - E_n \tag{5}$$

Main disadvantage of optical method is that atoms do not absorb at all the same wavelengths that it emits. Isolated atoms are normally found in the ground state - excited states live for very short time periods (≈ 1 ns) before decaying to the ground state. The absorption spectrum therefore contains only transitions from the ground state ($n = 1$). To observe transitions from the first excited state ($n = 2$) would require a significant number of atoms to occupy this state initially. Another disadvantage when try to determine excited states of atoms we need to use their thermal energies this states that to excite an atom to the first excited state from the ground state requires temperature that satisfies [1]

$$k_B T = E_2 - E1 = 10.2eV \tag{6}$$

which gives a temperature

$$T = \frac{(10.2eV)(1.6 \times 10^{-19} J/eV)}{1.38 \times 10^{-23} J/K} \approx 1.2 \times 10^5 K \tag{7}$$

which much larger than the room temperature (surface of the sun has temperature of 6.3×10^3 K.). If we need to provide a disadvantage of Franck-Hertz experiment that may be the experiment only must be performed by monoatomic gas like mercury (Hg), neon (Ne) and argon (Ar).

Discussion and Conclusion

In this we carried out a crucial experiment in Physics which is done by James Franck and Gustav Hertz in 1914. This experiment is proof of Bohr's Model. However, J. Franck and G. Hertz were not trying to test Bohr's model. As J. Franck admitted later, in fact, they were not even aware of Bohr's theory. They won their Nobel Prize 11 years later in 1925 because when they publish their paper *Collision between Electrons and Mercury Vapor Molecules and the Ionization Potential of Such Molecules* there were some mistakes [2]. In the summary part of the paper, the fourth result claim that *ionization potential of mercury is 4.9 volts.* However, this result is not quite correct because The mercury atoms are not being ionized by their collisions with electrons; they are simply being bumped upwards into an excited state [3]. Although J. Franck and G. Hertz made some mistakes in their work, Franck-Hertz Experiment can prove the Bohr's model. The deficiencies of Bohr model are as follows:

•Cannot be applied to multi-electron atoms.
•Does not predict fine structure of atomic spectral lines.
•Does not provide a method to calculate relative intensities of spectral lines.
•Predicts the wrong value of angular momentum for the electron in the atom.
•Violates the Heisenberg uncertainty principle (although Bohr's model preceded this by more than a decade)

In summary, in this experiment we studied the excitation state of mercury atom. We realized there are two different way to find excitation state of an atom: optical method and this experiment. While doing experiment, we had to set temperature at $\approx 160^\circ$ C but we could not do that. That is why our results are not quite correct. Normally we can determine $n = 5$ state but we reached to $n = 3$ state. Therefore we can say that our experiment is nearly incomplete. Figure 1 shows this result.

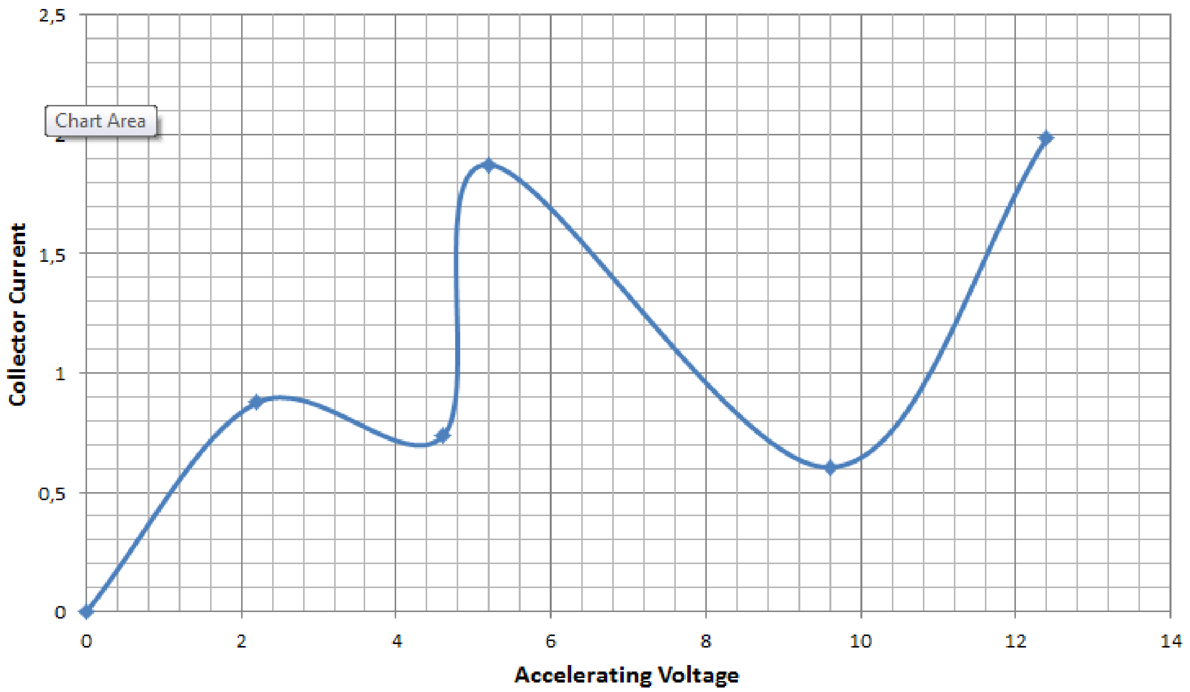

Figure 1: Collector Current I_c versus Accelerating Voltage V_a

References

[1] A. Melissinos, *Experiments in Modern Physics* (Academic Press Inc., 1966) p.14.
[2] J. Franck & G. Hertz, *Verhand. Deut. Physik, Ges.,* 16 (1914), 457-467.
[3] Mott and Massey, *The theory of atomic collisions*, (Oxford University Press, 1971) p.185, 3rd ed.