Franck-Hertz Lab 02

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Abstract

The purpose of the Franck-Hertz experiment is to demonstrate that Bohr's ideas of atoms having discrete quantized energy states is true. In this lab we fixed several voltages (V_f, V_{G1}, and V_P) and adjusted the electron accelerating voltage, V_{G2} to see how that affects the current. While cycling through voltages we get a plot with peaks and troughs in current. We recorded those corresponding voltage values to determine the first excitation energy of Argon. The results we obtained from this lab were $11.6 \pm 0.1V$. The accepted value is $11.62V$ which results in a discrepancy of $0.02V$. We also found an average value for Planck's constant, $h = (6.622 \pm 0.08) * 10^{-34}$ J*s which agrees with the accepted value of $6.626 * 10^{-34}$ J*s to a discrepancy of 0.00352 J*s. In our experiment the largest source of uncertainty was obtaining an accurate reading of peaks and troughs because the current would change independently of our adjustments.

1 Introduction

In order to prove that quantization also occurs within the atomic structure, not just a characteristic of light, we need to be able to probe an atom without light. To do this we use electrons to prove the quantized atomic states. We can probe an atom by 'shooting' electrons at the atoms instead of light. If one of these incident electrons collides with an electron bound in an atomic state of definite energy then by the theory of quanitized energies this bound electron can only transition to another definite energy state if the incident electron has energy equal to the difference of the two energy states. In this process the incident electron would give off all of its energy and we measure this energy loss corresponding to the specific energies to transition between energy states. To transition from the ground state the the first excited state an incident electron with the correct energy[1] can be obtained through an accelerated electric field giving the following equation:

$$\frac{1}{2}m_e v^2 \geq eV_1 = E_1 - E_0. \tag{1}$$

[1]Theoretically the incident electron must exactly equal the energy difference between the ground state and the first excited state but in the experimental instance accounting for any losses in energy likely due to not perfectly elastic collisions we will say the electron energy must be greater than or equal to.

m_e is the mass, v the speed, and e the charge all of the incident electron. E_1 is the energy of the first excited state whereas E_0 is the energy of the ground state. V_1 is the smallest voltage of an accelerating electric field needed to kick an electron from ground to excited state 1. Therefore eV_1 is called the first excitation potential energy.

The Franck-Hertz experimental apparatus has several adjustable voltage knobs (V_f, V_{G1}, V_{G2}, and V_P)[2]. By fixing all except V_{G2} which we adjust affects the energy of the incident electrons by accelerating them. By increasing this accelerating voltage to the incident electrons the current, I_p, will increase until the electron energy is greater than the first excitation potential, eV_1. Through the electron collision the incident electron's energy becomes less than eV_{G2} causing a reduction in current, I_p. This repeated continuous process is illustrated in figure 1. For the argon atoms used in this experiment the voltage difference between any successive peaks or troughs from figure 2 corresponds to the first excitation potential of the atom. This proves Bohr's idea of discrete energy levels in atoms.

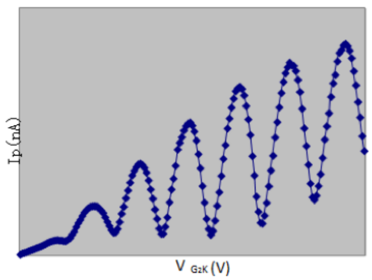

Figure 1: Lab Manual's sample current vs accelerating voltage V_{G2} curve.

When the excited argon electrons transition to lower energy states emission spectra lines will be given off corresponding to an energy of eV_1. To determine Planck's constant, h, we can use the following formula given the first excitation potential.

$$h = \frac{eV_1\lambda}{c} \tag{2}$$

where $e = 1.602 * 10^{-19}$ C, $\lambda = 106.7$ nm, and c is the speed of light.

2 Experimental Description

For this experiment we observed current changes from an increase in an accelerating voltage, V_{G2}. We begin by fixing the V_f, V_{G1}, and V_P adjust knobs. After fixing these parameters we set up an oscilloscope to the desired display with 1 Volt per division for channel 1 and 50 milivolts per division for channel 2. With everything set up we then began taking data; slowly increasing the V_{G2} knob and recording voltages corresponding with peaks and troughs as in figure 1. Given that the oscilloscope is plotting minimums and maximums we can get our reading for minimum (troughs) when we read the current to be at a local minimum and likewise for maximum (peaks). We adjusted the V_{G2} knob from 0 to 90 volts to obtain the plot similar to that in figure 1. We repeated this process four times.

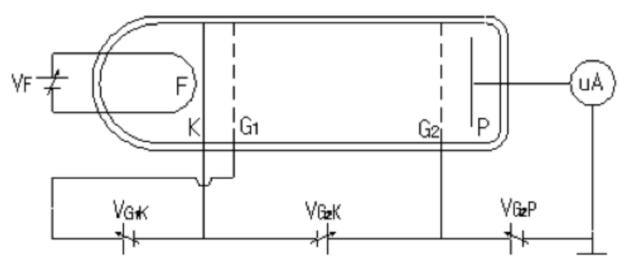

Figure 2: Franck-Hertz apparatus schematic

[2]See figure 2

3 Experimental Results

From the experiment procedure we obtained four sets of Voltage data points corresponding to minima and maxima in the voltage current plot. From equation (1), calculating the difference in any to adjacent peaks or troughs we collected a set of first excitation potentials in which we took an average value. The average first excitation energy for argon we determined was $11.6 \pm .01V$ with a discrepancy of $0.02V$.

With this average excitation energy we can determine an average value for Planck's constant, h. From equation (2) we calculated $h = (6.622 \pm 0.08) * 10^{-34}$ J*s to a discrepancy of 0.00352 J*s.

3.1 Note to the Uncertainty

In calculated an average value we found a standard deviation for both the first excitation energy of argon, eV_1, and for Planck's constant, h. Our standard deviation of the first excitation energy was $\sigma eV_1 = 0.924V$ and our standard deviation for Planck's constant was $\sigma h = 5.266 * 10^{-35}$ J*s.

4 Sources of Uncertainty

To help analyze with errors and uncertainties from this experiment we created a histogram plot (see figure 3). This histogram plots shows us number of times a first excitation energy was measured with the blue curve giving a probability distribution of getting an excitation energy. From the plot we can deduce that the fourth bin is an outlier in that we would expect more measurements in this bin but see significantly less than expected. From the fifth bin we obtained measurements here much more more often than expected. This implies some ambiguity in on of our peak to peak or trough to trough measurements like to due with an improper reading.

To know the minimum or maximum currents at which we write the corresponding voltage we have to go passed the local extrema which means we have to change the voltage that we are taking measurements of. In doing this we go past our exact voltage reading that we desire and have to 'back track' i.e. turn the voltage knob backwards to get back to the extrema. Often this may affect our voltage data points but most like only to the hundredth's decimal place creating minimal changes in our desired average value.

5 Conclusion

In conclusion we determined the first excitation energy of argon to be $11.6 \pm 0.1V$. Our results agree with the accepted value of $11.62V$ which results in a discrepancy of $0.02V$. We also found an average value for Planck's constant, $h = (6.622 \pm 0.08) * 10^{-34}$ J*s which agrees with the accepted value of $6.626 * 10^{-34}$

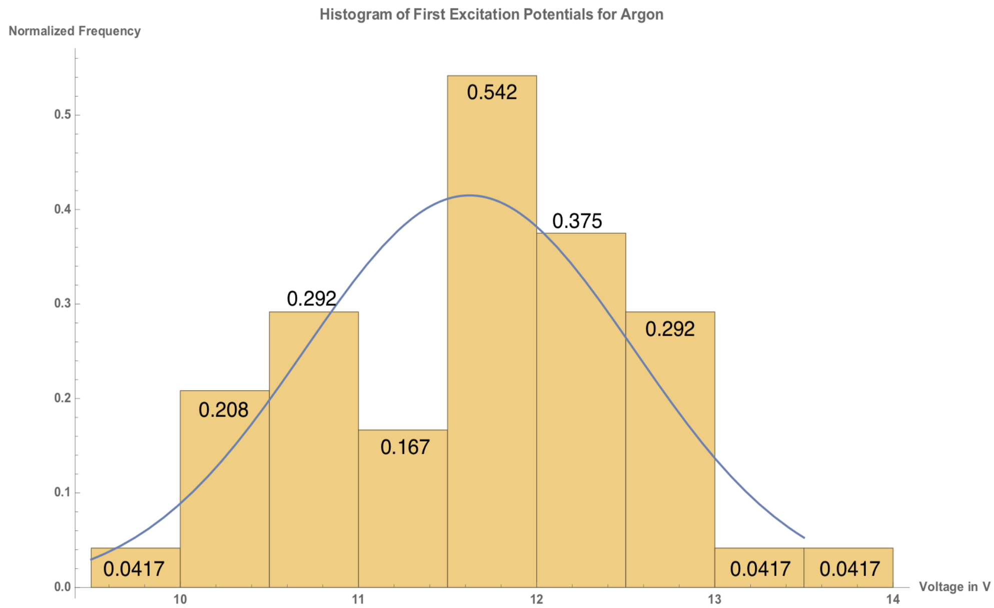

Figure 3: Histogram of first excitation energies of argon with probability curve.

J*s to a discrepancy of 0.00352 J*s. In our experiment the largest source of uncertainty was obtaining an accurate reading of peaks and troughs because the current would change independently of our adjustments.