Franck-Hertz Proposal

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I. Outline

The Franck-Hertz experiment is a test of the Bohr atom, and specifically tests the hypothesis of the discrete energy levels of electrons in atoms. This experiment will use an electron tube filled with mercury gas, between an anode and a cathode. A power source is required to move electrons through the tube and a heating source is required to keep the mercury in a vaporized state. An oscilloscope will be used to measure the voltage in the electron tube. In the experiment, we will gradually vary the energy level of electrons in the tube and look for collisions between the electrons and mercury atoms, which will cause drops in voltage in the electron tube as electrons transfer their energy into the mercury. The Bohr hypothesis predicts atoms can only absorb energy at discrete levels. This implies that electrons can only transfer their energy to the mercury atoms if they are at a distinct energy level. Thus if we only see voltage drops at certain energy levels, we can verify the validity of discrete energy levels in atoms.

II. Background

The Bohr atom is a vital step in our understanding of modern physics, as it is the first model of the atom derived from quantum mechanic principles. The Bohr model of the atom puts electrons in certain orbits each with its own binding energy level. This implies that for an electron to move between orbits, it needs to absorb or emit the exact amount of energy as the difference between the two orbitals. This model predicts the structure of atoms, as well as how photons are produced and absorbed by atoms. By testing the Bohr model, we will be able to confirm or adjust the proposed structure of the atom and orbits of electrons, while also testing the validity of quantum mechanics. As the atom is the fundamental building block of matter, it is vital to have a comprehensive understanding of it, to further our research into physics, chemistry, material science, semiconductors, and many other sciences.

III. Procedure

For the experiment we will be using a vacuum tube filled with mercury (Hg) gas. This tube will have three electrically biased plates; a cathode, grid anode, and collector. A schematic of the vacuum tube can be seen in figure 1.

We can apply a bias voltage on the filament by using the voltage source U_F at around 6V to 7V. This bias will heat up the filament allowing electrons to boil off. Next a potential difference can be applied between the cathode (filament) and the anode using U. The boiled off electrons will then be accelerated between the cathode and the anode. The anode will be a mesh grid so that electrons may pass through the gaps and hit the collector where we can measure the current. However, this collector will have a small bias ($U_{GA} \approx 2V$) to prevent low energy electrons from being measured.

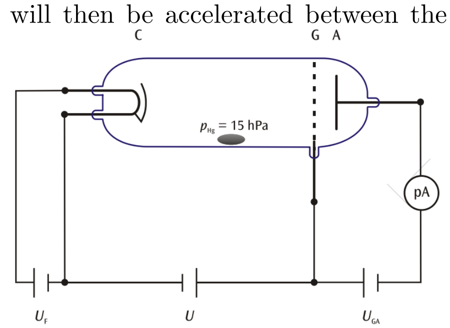

FIG. 1. Schematic of the Franck-Hertz Vacuum Tube.

With this setup, we can use voltage source U to vary the filament and grid anode bias between 0V and 80V. With this variable bias we should see the behaviors outlined above.

IV. Analysis

The data will be recorded in two different stages. In the first stage, we will use the built-in 50Hz sawtooth wave to quickly cycle between 0V and 80V and plot it on the oscilloscope. This will allow us to visualize the maxima/minima and change the U_F and U_{GA} to get a clean trace. After this we will begin the second stage, manually recorded data points. With these data points we will be able to better visualize and analyze the data using software tools such as MatLab or Python3 with SciPy. Using these tools we will be able to fit Gaussians and background to each maxima/minima. With these Gaussians we will be able to see where each peak is and if it lines up with the theoretical multiples of 4.9eV.

V. Conclusion

James Franck and Gustav Hertz won the 1925 Nobel Prize in Physics for successfully carrying out the experiment outlined in this proposal. Our goal is to replicate their experiment using modern equipment. By accelerating electrons through a mercury filled tube, we hope to see the same oscillatory pattern corresponding to inelastic collision between the electrons and mercury where the electron gives enough energy to atom to ionize it. Using software tools, we can then find the exact positions and errors associated with the peaks and troughs.