

Franck-Hertz Experiment – Quantized Energy Levels in Atoms

Dr. Darrel Smith¹

Physics Department

Embry-Riddle Aeronautical University

(Dated: 8 February 2019)

The purpose of this experiment is to observe the discrete energy states in neon atoms. As electrons are accelerated through the rarified neon gas they move toward the anode, and sometimes collide with a neon atom. If the accelerated electron has sufficient kinetic energy, its collision with a neon atom causes the excitation of a 2s electron into the 3s or 3p state. This leaves the accelerated electron with *zero* kinetic energy; however, it is free to accelerate once again. Assuming the accelerated electron makes it to the anode, the recorded current will be proportional to the *velocity*, and thus the *kinetic energy* of the electron. A reduction in the expected current means that some of the electron's kinetic energy was used to “pump” neon atoms into excited states. The observation of discrete current peaks is the signature for verifying discrete energy states within the neon atom.

I. BACKGROUND

The following background information comes from the Leybold Physics Leaflet (P6.2.4.4) found on my [physicsx](#) website. In 1914, James Franck and Gustav Hertz discovered “an energy loss in discrete steps for electrons passing through mercury vapor.” An ultraviolet line ($\lambda = 254$ nm) was observed. Photons of this wavelength are invisible to the naked eye, so we will be using neon where photons are produced in the red-orange part of the spectrum where they can be observed. The most probable excitation through inelastic electron collision takes place from the ground state to the ten 3p states, which are between 18.4 eV and 19.0 eV above the ground state. The four lower 3s states in the range from 16.6 eV and 16.9 eV are excited with a lower probability. As electrons de-excite from the 3p state to the 3s state, they emit a quantum of energy hf with a frequency in the visible red-orange region.

II. THE EXPERIMENT

The experiment is described in Leybold Physics Leaflet (P6.2.4.4) labeled as “Experiment Description” on my website under the Franck-Hertz experiment. There is a power supply box providing voltage to the filament (i.e., source of electrons), as well as voltage difference need to operate the neon tube (see Fig. 1). The power supply box is connected to the neon tube, and to your computer where the voltages can be computer-controlled.

III. THE EQUIPMENT

The lab equipment for this experiment is shown in Fig. 2. The equipment should be connected in the manner described in the figure caption. The equipment is also shown on page 3 of the Leybold leaflet. Please read this to familiarize yourself with the equipment you will be using. One important thing to note is that there is no

Fig. 1: Schematic diagram of the Franck-Hertz tube, Ne

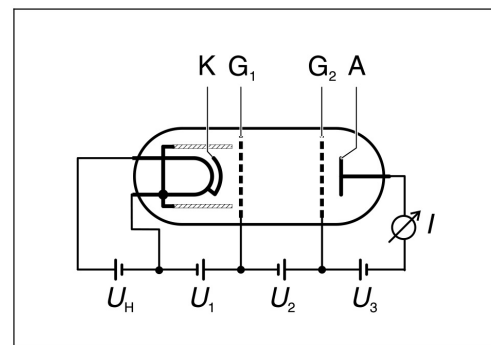


FIG. 1. Electrons are produced at the cathode (K) and are accelerated through grids G_1 and G_2 . The potential between G_1 and G_2 is varied between 0 and 80 volts. After passing the second grid (G_2), the electrons are “braked” by a constant voltage U_3 . *Figure is from the Leybold leaflet.*

able B in the equipment we are using. The computer should have the Cassy interface software (from Leybold) up-and-running in order to receive the voltage and current information from the Cassy interface box..

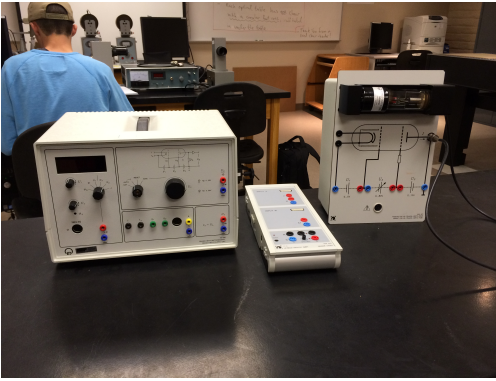


FIG. 2. The experimental apparatus is comprised of three pieces. The power supply (left) is connected to both the Cassy interface box (center) and the neon tube assembly (right). The Cassy interface box is then connected to the computer where the current is displayed as a function of voltage (U_2).

IV. PROCEDURE

The procedure is described starting on page 3 of the leaflet. Begin with “*Optimizing the Franck-Hertz curve*”. You will find two leaflets on my physics website describing the apparatus. There isn’t much in the way of equations. You will want to keep your attention fixed on the repeated voltage differences between the current peaks as shown in Fig. 3. Take note that Fig. 3 refers to mercury gas; however, you will be using neon gas. Therefore, the voltage difference between peaks will be different.

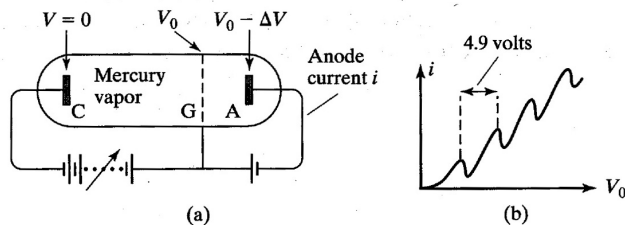


FIG. 3. This figure describes the Franck-Hertz experiment as shown from your textbook, *Taylor and Zafiratos*. The current collected on the anode A is shown in the figure to the right. Discrete jumps in the current are observed indicating that electrons are transitioning into excited states within the neon atoms.

V. IMPORTANT CONSIDERATIONS

- There is no need to touch the neon tube, so please keep your fingers off the tube.
- You will need to adjust the U_1 and U_3 voltages quite a few times to get a “feel” for the current plots you will be seeing while U_2 is varying from 0 to 80 volts.
- You should try to get a minimum of three peaks so you can measure at least two separations in ΔV .
- The goal is to report on the excitation energy ($e\Delta V$) between the ground-state and $3p$ states. This corresponds to the kinetic energy given up by the accelerated electron as it makes an *inelastic collision* with the neon atom.

VI. SOFTWARE

The software for this lab is the CASSY software. If the CASSY software already loaded on the campus PC’s does not work, you can find it at the bottom of the following URL page: <https://www.ld-didactic.de/en/service/software-download/cassy-s.html>. Go to the bottom of this web page and you will find a section titled: VERSION 1.77 (FREE UPDATE OF CASSY LAB 1). Download the English version and try running this.