(MP3-3) Frank-Hertz Experiment

Aim of experiment

Measurement of the first exited state of Hg atom

Apparatus

A Mercury-Filled Franck-Hertz Tube Control Unit Enclosing an Oven, Power Supply, and a DC Current Amplifier.

Theory of experiment

The modified Bohr model of the atom, assumes the atom can exist only in certain bound energy states. In addition, quantum mechanics was introduced to predict for the existence of emission of electromagnetic waves of certain wavelengths adherent for each atom.

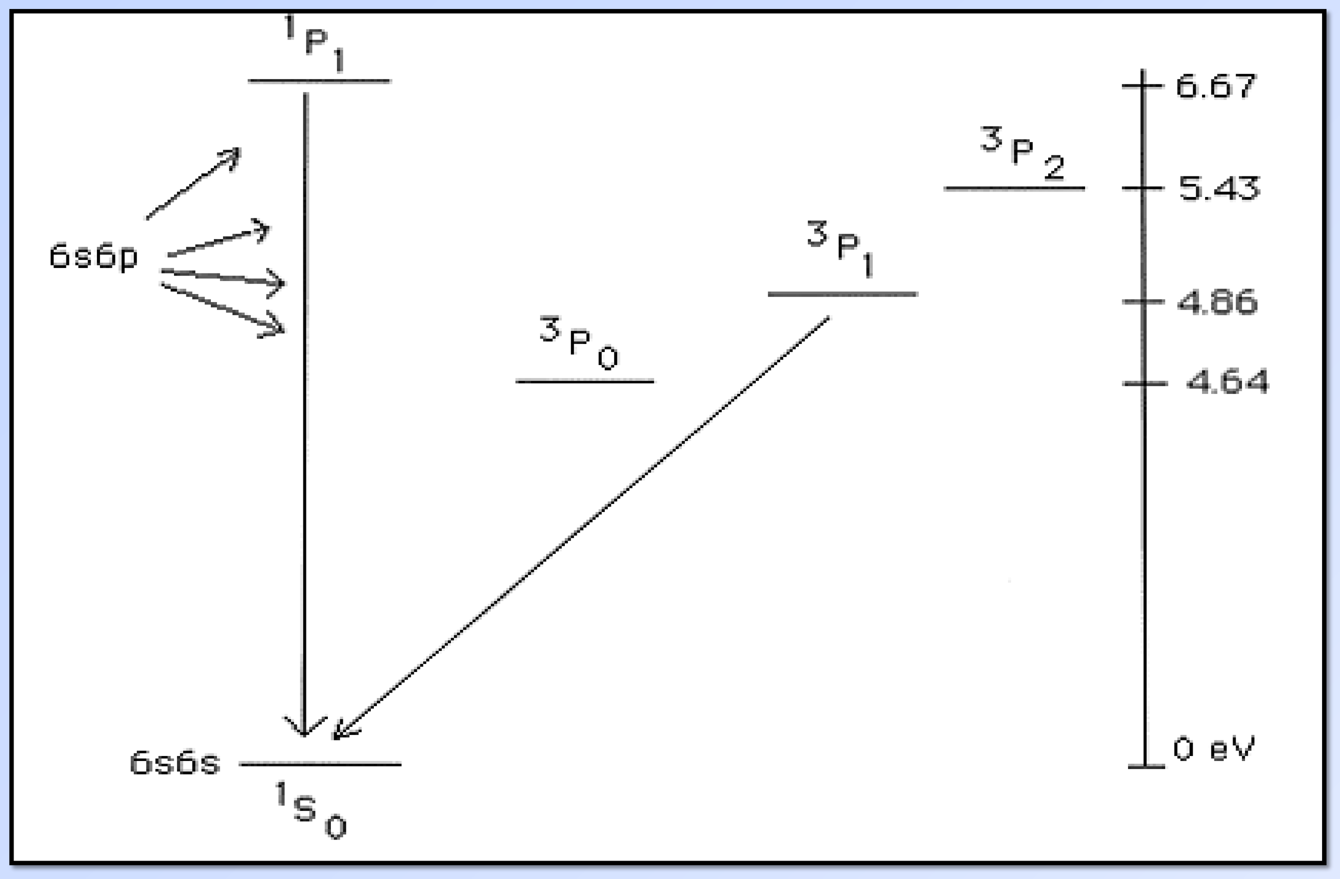

Figure 1. The lowest excited energy levels of Hg atom

According to the quantized energy levels model, mercury atom will normally be in its ground state, with two valence electrons occupying a state designated by $(6s)^2$; 2 electrons in n=6, *l*= 0 singlet particle state. The next level, *figure 1*, above the ground state is a triplet level according to the spectroscopic notation $^{2s+l}L_j$; *are* $^3P_0$, $^3P_1$, $^3P_2$.

The Franck-Hertz experiment is one of the classic demonstrations of the quantization of atomic energy levels. It provided support for the Bohr model of the atom. A sketch of Franck-Hertz apparatus is shown in *figure 2*.

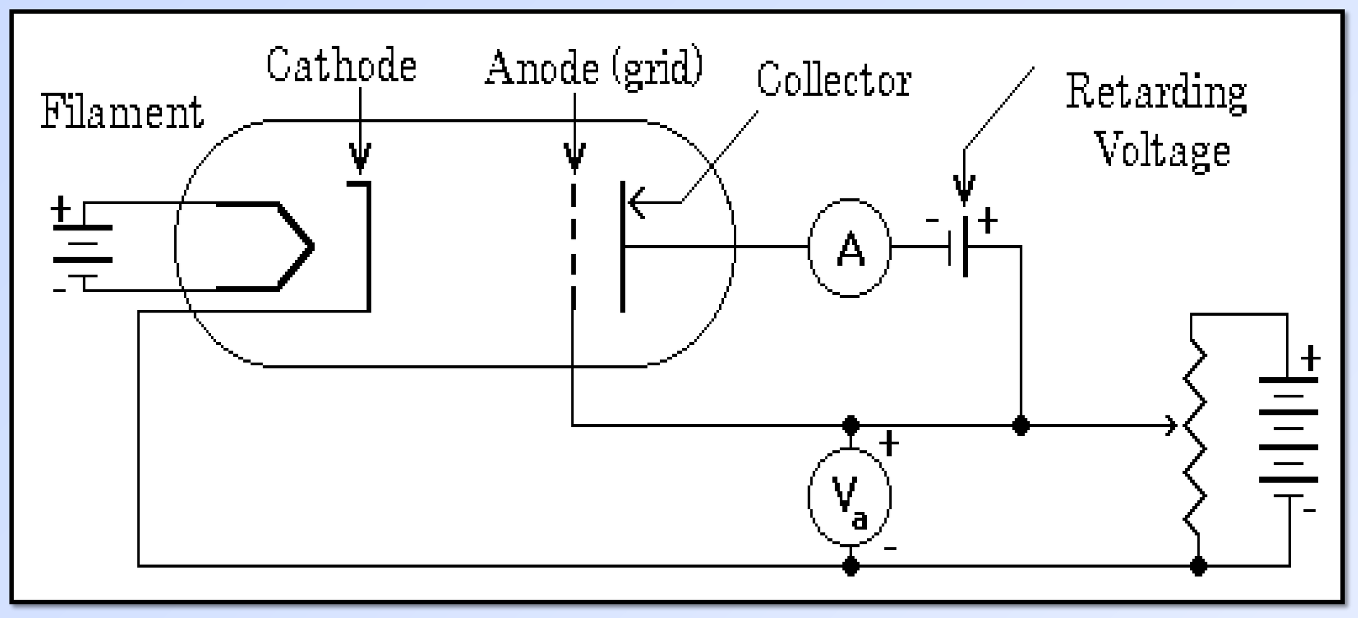

Figure 2. Sketch of Frank-Hertz Apparatus

In the Frank-Hertz experiment the electron beam may excite a vapor mercury atoms into the $^3P_0$ or $^3P_2$ state, but then stuck there (for a millisecond) and unable to absorb more energy. On the other hand, if the $^3P_1$ state is excited, it quickly de-excites (in 0.01 ms) and the atom is again available to absorb energy from the electron beam. The $^1P_1$ state is not observed since it acquires beam energy of 6.67 eV, which is not available after the excitation of $^3p_1$ states with energy 4.86 eV.

Frank -Hertz apparatus is a vacuum tube with a small amount of mercury enclosed. The tube was heated in an oven in order to vaporize the mercury, and then a series of voltages was applied to the tube. A small voltage was used to heat a filament for use as an electron source. Three more voltages were used to establish electric fields inside the tube.

The first field is a small field; it used in order to sweep the electrons away from the filament. It is observed that when filaments eject electrons they become slightly positive, and the region around the filament becomes slightly negative due to the cloud of electrons. If a small field isn't put in place to draw the electrons away from the filament, it becomes hard to draw out more electrons. The second field is an accelerating field; this is what gives the electrons the bulk of their kinetic energy. This is usually called the grid voltage because it is established by a grid that the electrons can penetrate. Once the electrons go through the grid there is a reverse field that acts to retard electrons from the counter. If there is only vacuum in the tube then the grid voltage will accelerate electrons to the counter, and if the retarding voltage is less than the grid voltage a current will be detected.

Electrons emitted by the filament are accelerated through mercury vapor. When the accelerating voltage reaches V_1, the electrons have just enough energy to excite the mercury atoms from the ground state to the lowest excited state. Thus, many of the electrons lose their energy and cannot reach the collector; this is signaled by an abrupt drop in collector current as the accelerating voltage is increased past V_1.

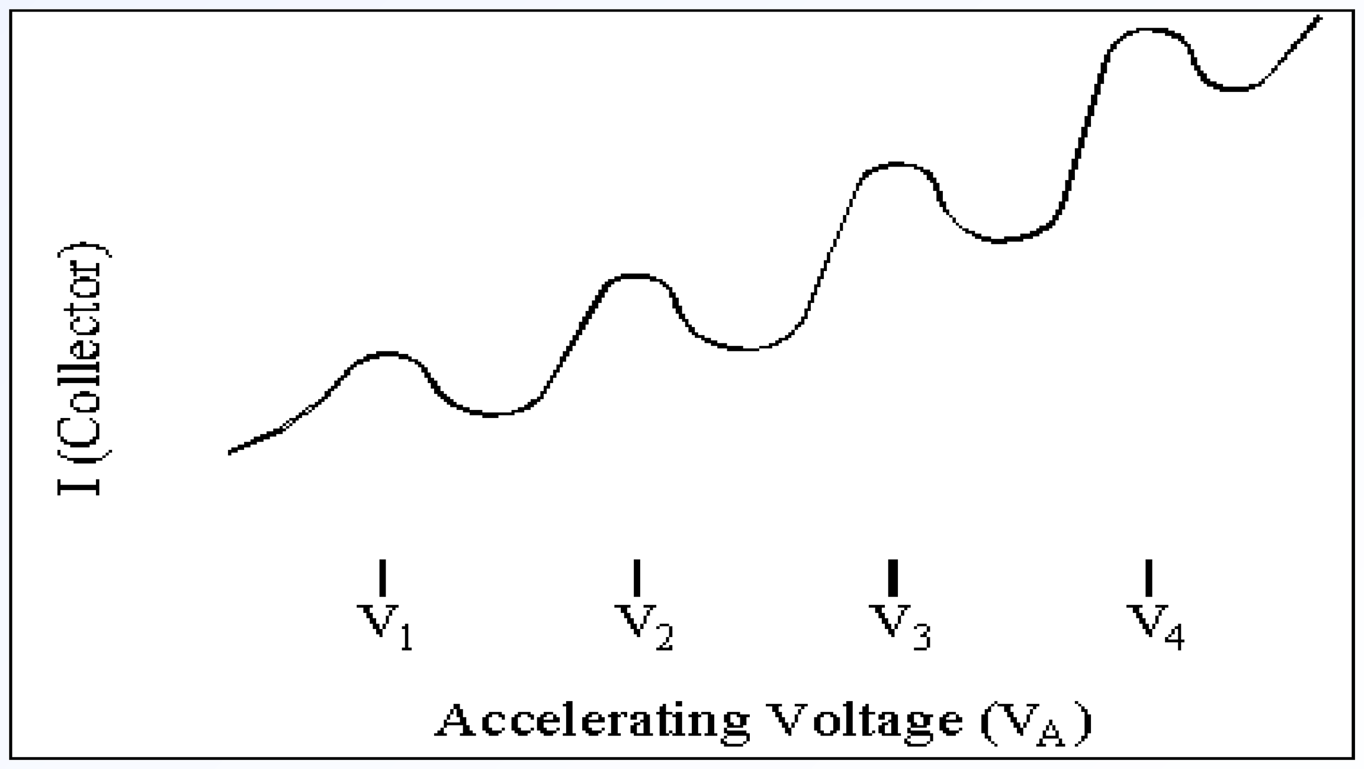

Figure 3. Qualitative trend of collector current vs. accelerating voltage.

Edusoft
Innovate to educate

(MP3-3) Frank-Hertz Experiment

As the accelerating voltage is increased beyond V_1, electrons which have been brought to rest as a result of exciting mercury atoms are again accelerated until they can produce another excitation. Thus, a second peak occurs at V_2, where ideally one expects $V_2 - V_1 = V$. However, contact potentials in the system displace the first peak at V_1 from its expected value, and V_1 itself is not a good measure of the excitation potential. The sequence of electron acceleration and atomic excitation may continue as the accelerating voltage is further increased so that a series of peaks may be observed.

Breakdown of the gas in the tube will occur when the accelerating voltage becomes too high. Onset of breakdown may be delayed by increase in vapor pressure (higher oven temperature) or decrease in number of electrons (lower filament current).

Procedure

1. Connect the various devices as shown in *figure 1*.
2. The values for a retarding potential, heater voltage, and gain were set
3. Adjust the temperature of the tube at 180 ºC in the case of mercury.
4. Increase the acceleration potential slowly, and record the corresponding current.
5. At first, current increases as the accelerating voltage increases up to critical voltage then current drop sharply to a minimum value.
6. Continue increasing the accelerating voltage, to obtain at least 3 successive minima.
7. Plot a graph between the accelerating voltage and current.
8. From the graph, determine the voltage at the minima, V_2, V_3, V_4 and calculate $V_3 - V_2$ and $V_4 - V_3$
9. Calculate the energy of the first exited state of mercury atom.

Results

V_a (V)	I (nA)

$V_1=$ $V_2=$ $V_3=$

$\Delta V_1=V_2-V_1=$ V

$\Delta V_2= V_3 - V_2=$ V

$^1P_1$ *energy level energy=* *eV*

Edusoft

Innovate to educate