Franck–Hertz experiment

Aim:

To determine the first excitation potential of gas (Argon) by Franck-Hertz experiment.

Apparatus:

Tetrode tube filled with experimental Argon gas, filament, power supply three variable voltage sources, nanoammeter.

Experimental Set-up:

The experimental set up involves a tube containing low pressure experimental gas fitted with four electrodes: an electron-emitting cathode (K), a mesh grid (G1) for minimizing space charge effects a mesh grid (G2) for acceleration, and an anode (A). The anode was held at a slightly negative electrical potential relative to the grid G2 (although positive compared to the cathode), so that electrons had to have at least a corresponding amount of kinetic energy to reach it after passing the grid and thereby making the dips in the plate current more prominent. Instruments were fitted to measure the current passing between the electrodes, and to adjust the potential difference (voltage) between the cathode (negative electrode) and the accelerating grids Fig (1).

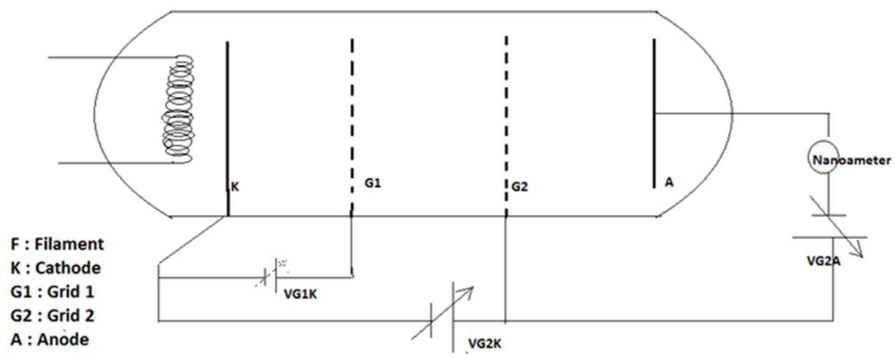


Figure 1

Formula Used:

If V_n is the potential corresponding to n^{th} peak and V_1 is the potential corresponding to 1^{st} peak then

Mean 1^{st} excitation potential = $\frac{V_n - V_1}{n-1}$

Where (n-1) is the number of dips between 1^{st} and n^{th} peak.

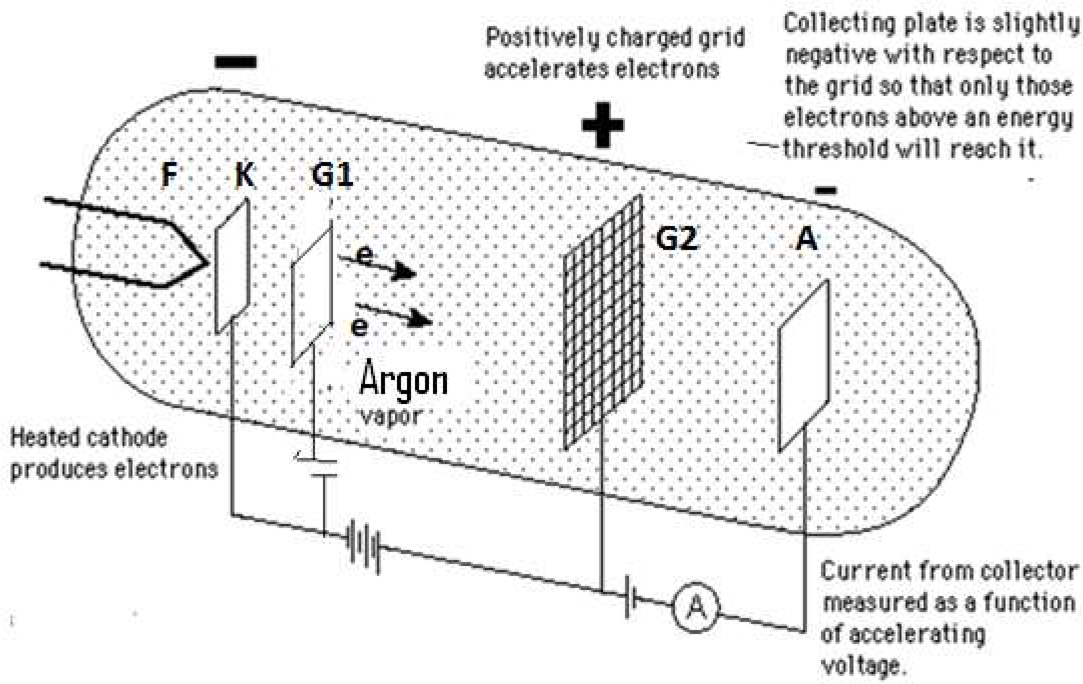
Introduction

From the early spectroscopic work it is clear that atoms emit radiation at discrete frequencies; from Bohr's model, the frequency of the radiation ν is related to the change of energy levels through $E = h\nu$. It is then to be expected that transfer of energy to atomic electrons by any mechanism should always be in discrete amounts. One such mechanism of energy transfer is through inelastic scattering of low- energy electrons.

Franck and Hertz in 1914 set out to verify these considerations.

(a) It is possible to excite atoms by low energy electron bombardment.
(b) The energy transferred from electrons to the atoms always had discrete values.
(c) The values so obtained for the energy levels were in agreement with spectroscopic results.

The Franck–Hertz experiment elegantly supports Niels Bohr's model of the atom, with electrons orbiting the nucleus with specific, discrete energies. Franck and Hertz were awarded the Nobel Prize in Physics in 1925 for this work.



Operating Principle:

The Frank-hertz tube in this instrument is a tetrode filled with the vapour of the experimental substance Fig.1 indicates the basic scheme of experiment.

The electrons emitted by filament can be accelerated by the potential V_{G2K} between the cathode and the grid G_2. The grid G_1 helps in minimizing space charge effects. The grids are wire mesh and allow the electrons to pass through. The plate (A) is maintained at a potential slightly negative with respect to the grid G_2. This helps in making the dips in the plate current more prominent. In this experiment, the electron current is measured as a function of the voltage V_{G2K}. As Voltage increases, the electron energy goes up and so the electron can overcome the retarding potential V_{G2A} to reach the plate (A). This gives rise to a current in the ammeter, which initially increases. As the voltage further increases, the electron energy reaches the threshold value to excite the atom in its first allowed excited state. In doing so, the electrons lose energy and therefore the number of decreases. This decrease is proportional to the number of inelastic collisions that have occurred. When the V_{G2K} is increased further and reaches a value twice that of the first excitation potential, it is possible for an electron to excite an atom halfway between the grids, loose all its energy, and then gain a new enough energy to excite another atoms resulting in a second dip in the current. The advantage of this type of configuration of the potential is that the current dips are much more pronounced, and it is easy to obtain five fold or even larger multiplicity in the excitation of the first level i.e. one can get 5 peaks (dips) or more.

The Franck–Hertz experiment elegantly supports Niels Bohr's model of the atom, with electrons orbiting the nucleus with specific, discrete energies. Franck and Hertz were awarded the Nobel Prize in Physics in 1925 for this work.

Franck-Hertz Experiment Set-up, Model : FH-2558, consists of the following:

→ Argon filled tetrode
→ Filament Power Supply : 2.6 -3.3V continuously variable
→ Power Supply For V_{G1K} : 1.3 – 5V continuously variable
→ Power Supply For V_{G2A} : 1.3 – 15V continuously variable
→ Power Supply For V_{G2K} : 0 – 80V continuously variable
→ Multirange Analogue Voltmeter
Range : *0-5V, 0-15V & 0-100V*
→ Multirange Analogue Voltmeter
Range : *0-1 (50 divisions)*
Range Multiplier : 10^{-6}, 10^{-7}, 10^{-8} & 10^{-9}

The instrument can lead to a plot of the amplitude spectrum curve by means of point by point measurement.

Procedure:

1. Before the power is switched 'ON' make sure all the control knobs are at their minimum position and Current Multiplier knob at 10^{-7} or 10^{-8} or 10^{-9} (whichever suitable) position.

2. Switch 'ON' the power.

3. Turn the manual- Auto Switch to manual and check that the Scanning Voltage Knob is at its minimum position.

4. Turn Voltage Display Selector to V_{G1K} and adjust the V_{G1K} knob until voltmeter reads 1.5V.
5. Turn Voltage display selector to V_{G2A} and adjust the V_{G2A} knob until the voltmeter reads 7.5V.

When you have finished step 1-5, you are ready to do the experiment.
Rotate V_{G2K} knob and observe the variation of plate current I_p with the increase of V_{G2K}. The current reading would show maxima and minima periodically. The magnitude of maxima could be adjusted suitably by adjusting the filament voltage and the value of Current Multiplier. Now take the systematic readings, V_{G2K} vs. Plate current (I_p). For better resolution, the reading may be taken at an interval of 1V (1/2 division). Plot the graph with output current I_p on Y-axis and accelerating voltage V_{G2K} at X-axis.

Observation Table :

V_{G1K} : 1.5V
V_{G2A} : 7.5V

S No.	Aceeleration Potential V_{G2K} (Volts)	Plate Current I_p (nano Amperes)
1.		

2.		
3.		
..		
..		
..		

Results:

1. Graph with output current on Y-axis and accelerating voltage V_{G2K} at X-axis is plotted which shows series of dips in current at approximately 12.1 volt **(say)** increments (fig 2).

2. At low potential differences—up to 12.1 volts when the tube contained argon vapour—the current through the tube increased steadily with increasing potential difference. The higher voltage increased the electric field in the tube and electrons were drawn more forcefully towards and through the accelerating grid.

3. At 12.1 volts the current drops sharply, almost back to zero.

4. The current increases steadily once again if the voltage is increased further, until 24.2 volts is reached (exactly 12.1+12.1 volts.

5. At 24.2 volts a similar sharp drop is observed.

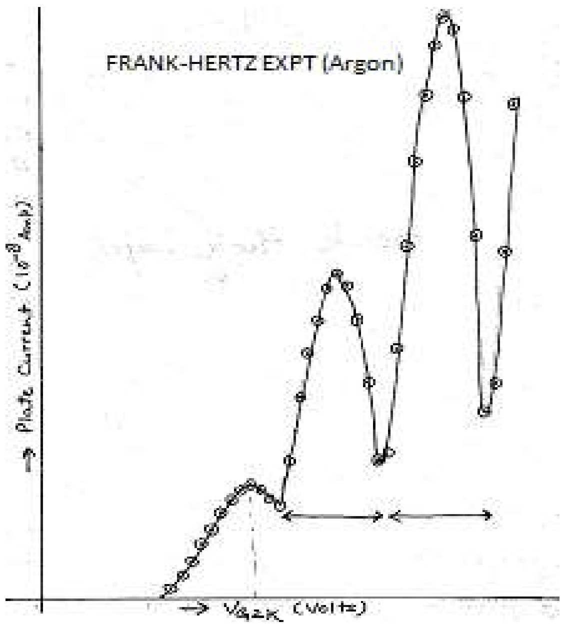
Precautions:

1. During the experiment (manual), when the voltage is over 60V, please pay attention to the output current indicator, if the ammeter reading increase suddenly, decrease the voltage at once to avoid the damage of the tube.
2. If you want to change the value of V_{G1K}, V_{G2A} and Filament Voltage during experiment, please first adjust the value of V_{G2K} to 'Zero'.

3. Whenever the filament voltage is changed, please allow 2-3 minutes for its stabilisation .

4. When the Frank-Hertz Tube is already in the socket, please make sure the following before the power is switched 'ON' or 'OFF', to avoid damage to the tube.

5. Manual – Auto switch is on Manual and Scanning and Filament Voltage knob at its minimum position (rotate it anticlockwise) and current multiplier knob at 10^{-7}.


FRANK-HERTZ EXPT (Argon)
→ Plate Current (10⁻⁸ Amp)
→ V_{G2K} (Volts)

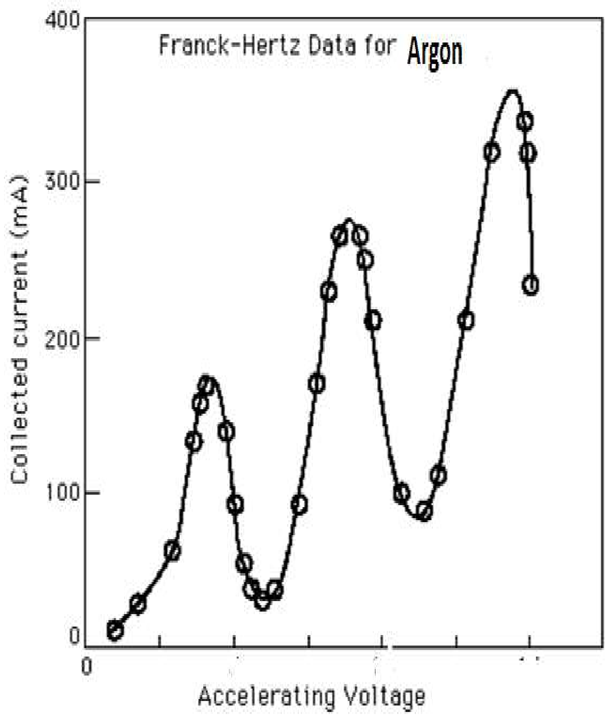

Franck-Hertz Data for Argon
Collected current (mA)
Accelerating Voltage
400
300
200
100
0
0

Figure 2