Franck-Hertz Experiment

1 Aim

To verify existence of atomic energy levels through transfer of energy from electrons to atoms.

2 History

This experiment was performed by German physicists James Franck and Gustav Hertz in 1914. Bohr had proposed the atomic levels whereby energy levels with discrete values of energy were thought to exist inside the atom. The Franck-Hertz experiment provided support for the Bohr model of the atom. This experiment proved that the atomic levels indeed existed. The atomic levels found in this level are the same as those suggested by line spectra.

3 The Experiment

Franck and Hertz bombarded vapours of various elements with electrons of known energy. The circuit is given in Fig. 1. The accelerating potential is given by V. A small potential difference V_0 between the grid and the plate prevents electrons below a certain energy to pass through and contribute to the current at the plate. As V increases, more and more electrons arrive at the plate and the current I increases. The electrons collide with the atoms in the vapours. If V is low, the electrons do not have enough energy to excite the atoms they collide with and hence undergo elastic collision. Therefore they retain their initial kinetic energy in the process. The plate current increases with increasing voltage.

However after a certain critical energy is reached, the plate current drops. This suggests that an electron colliding with one of the atoms gives up some or all of its kinetic energy to excite the atom to an energy level above the ground state. Such a collision is inelastic and the kinetic energy is not conserved. On a further increase in the voltage,

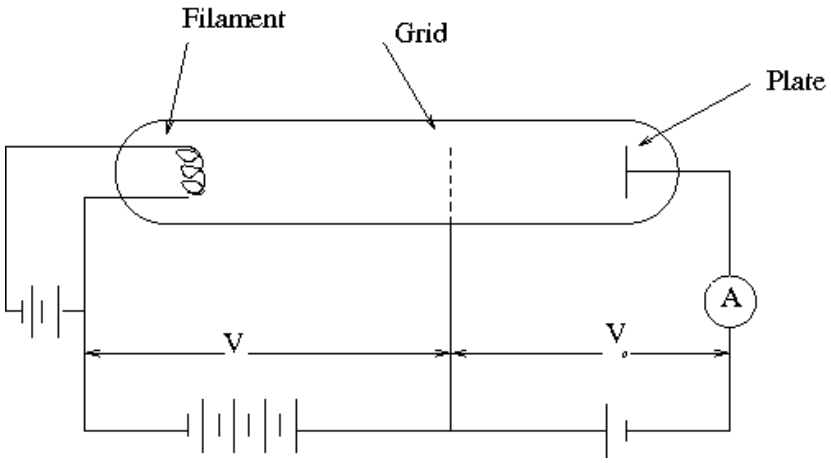

Figure 1: A schematic diagram for the Franck Hertz experiment

the current begins to increase again as the energy left is insufficient to reach the plate,0 after undergoing an inelastic collision. As soon as the energy is sufficient to raise the energy levels of atoms further, the current begins to drop again.

This process continues with increasing accelerating voltage, thus giving rise to repeated maxima and minima in the $I - V$ curve. The average distance between two successive peaks gives the excitation potential for the Ar atom (also see Fig. 2).

4 Apparatus in the Lab and Procedure

The Franck Hertz tube is a tetrode filled with Argon (Ar) gas (the original experiment was performed using mercury vapour). There are four active electrodes. It has an an additional grid called the 'control grid' (G_1) which is placed near the cathode (why?!). The second grid (G_2) is the screen grid and this is the grid mentioned in the above discussion.

1. Before switching the power ON, make sure that the control knobs are at their minimum positions and current multiplier knob is set at 10^{-7} position.
2. **Manual Mode**: Turn the manual-auto switch to Manual. Turn display selector to V_{G_1K} and adjust the V_{G_1K} knob, until the voltmeter reads $1.5V$.
3. Turn the voltage display selector to V_{G_2A}, until the voltmeter reads $7.5V$.
4. Rotate the V_{G_2K} knob and observe the variation of the plate current with an increase in the voltage.

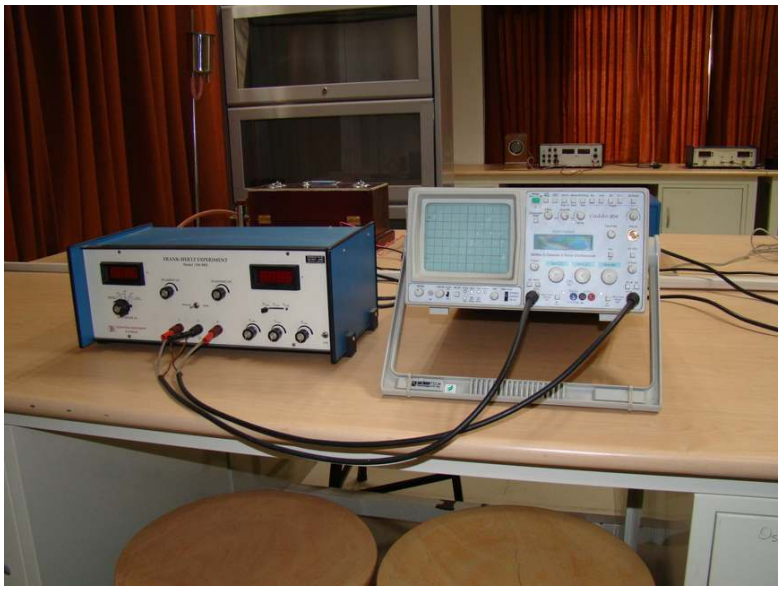

Figure 2: Apparatus in the laboratory.

5. Plot the output current versus the accelerating voltage V_{G_2K}. Calculate the average distance between two successive maxima. This gives the value of the first excitation potential for Ar.

6. **Scanning Mode**: Turn the manual-auto switch to Auto. Connect the instrument's X, Y, G sockets to the corresponding sockets of the CRO. Put the scanning range switch of CRO to X-Y mode/external X. Switch on the scanning knob of the instrument and observe the waveform. Adjust the Y-gain and X-gain of the CRO to make a clear wave-form and Y amplitude within the screen range. Rotate the scanning potentiometer clockwise till the end. Again measure the horizontal distance between the peaks.

5 Precautions

1. In the manual mode, at voltage over $60V$, if the ammeter current spikes (shoots up), then decrease the voltage immediately.

2. Whenever filament voltage is changes, allow 2-3 minutes for it to stabilize.

3. Before switching the power ON or OFF, make sure all voltage knobs are at their minimum position and the manual-auto switch is at the manual position.

6 References

1. Concepts of Modern Physics, Seventh Edition, Arthur Beiser, A. Mahajan and S. Rai Choudhury.