

Frank – Hertz Experiment

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Abstract:- Frank-Hertz experiment was performed by James Frank and Hertz in 1914. James Frank and Gustav Hertz published the results of an experiment which provided strong evidence that Bohr's model of atoms with quantized energy levels was correct. When they were performing this experiment they weren't try to test Bohr's model; infact, they weren't even aware of Bohr's theory ! as Frank admitted Later

"It might interest you to know that when we made the experiment that we did not know Bohr's theory. We had neither read nor heard about it. But we made that experiment (and got the result that confirmed Bohr's theory) because we hoped that if we was found out where the border line between elastic and inelastic impact lies.....only one line might appear. But we did not know whether that would be so, and we did not know whether at all an emission of an atom is of such a type that one line alone can be emitted and all the energy can be used for that purpose. The experiment gave it to us, and we were surprised about it. But we were not surprised after we read Bohr's paper later, after our publication."

A nice ancient to win a Nobel Prize (1925) for an experiment that you didn't really understand at the time.

From quantum theory of Radiation given by Plank in 1901 and Photoelectric effect and Einstein photoelectric equation it was seen that electromagnetic radiation when interacts with matter acts like an assemblage of discrete quanta of energy rather than like a continuous wave. The idea of discontinuous emission and absorption of radiation was new in Physics hence there was a need to confirm it experimentally. In 1914, James Frank and Gustav hertz demons – trated experimentally that mechanical energy, like electromagnetic energy, is absorbed by atoms in descrete quanta.

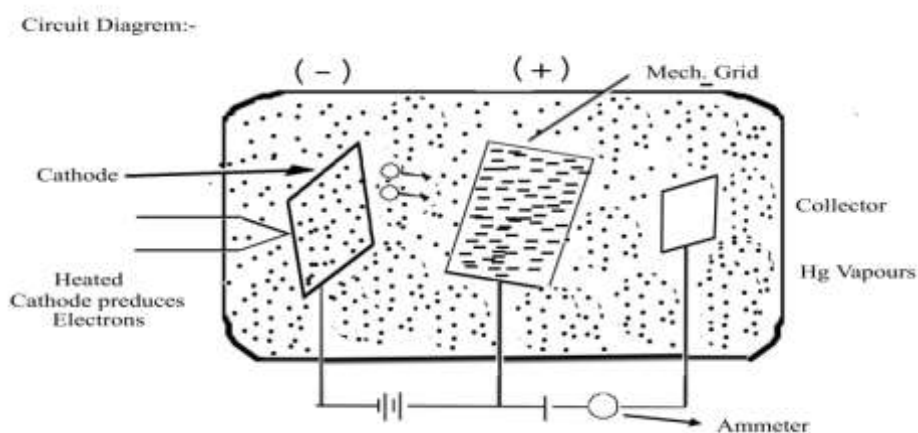


Fig-I

Circuit Diagram of Frank – Hertz Tube

In Frank-Hertz tube, we take vapours of mercury (Hg). You can also take vapours of Helium (He), Neon (Ne), Argon (Ar), Oxygen (O), Nitrogen (N) and Hydrogen (H). When we performed experiment using these gases, then the value of quantization energy level is different for each gas. When we use Hg gas vapours then the value for Hg is 4.9 eV and 19 eV for Ne gas. In Frank-Hertz tube we use three electrodes, accelerating voltage for accelerating the particles, retarding potential for control the value of current on the collector plate, where all the e^- s collect on the plate.

The whole working of the tube is shown below.

Working:- In Frank-Hertz tube, we take the vapours of mercury (Hg) and three electrodes

- Cathode
- Mesh Grid
- Collector

From Fig. 1, it is shown that the filament or cathode provide the accelerating voltage. Initially, the accelerated voltage is low and the motion of emitting electrons from the filament is very slow. When the V_{acc} is low then due to slow motion of the $C(-)S$, the collision between e^- s (electrons) and the Hg atoms is elastic. As the collision is elastic then they do not lose its kinetic energy and they accelerate towards the mesh grid (Or towards the positive potential). The main reason of elastic collision is that the Hg atoms are of Large mass and the motion of electrons is slow due to this, they collide with massive Hg atoms and electrons change its direction after collision with Hg atoms.

Collision of Hg atom with e^-

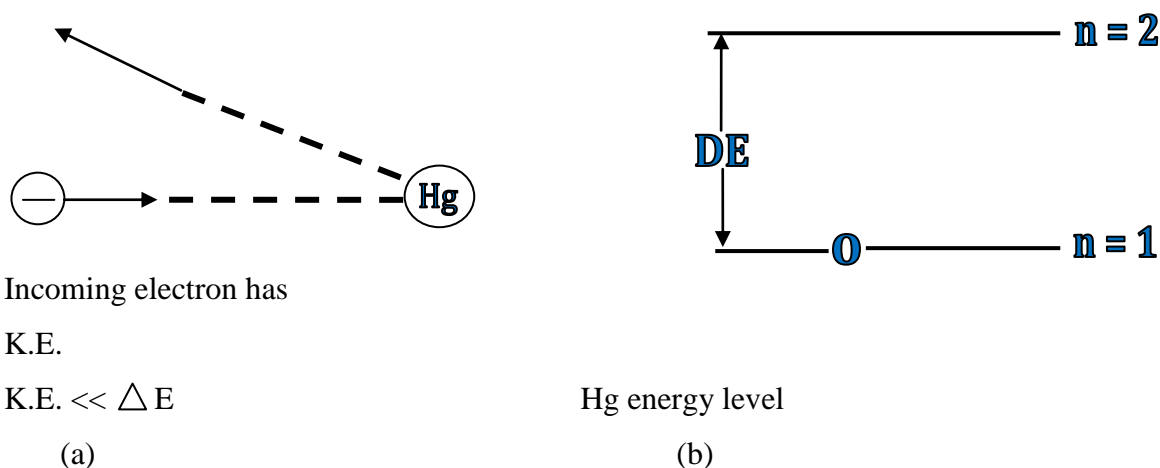
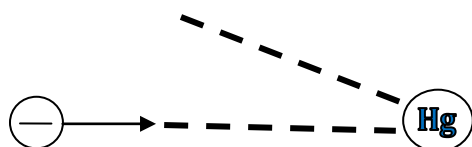


Fig. 2

When we increase the accelerating voltage slowly, the motion of electrons increases with increase of accelerating voltage. The collision between the electron and the Hg atoms is elastic due to less K.E. than DE . And the more number of electrons are attracted by the mesh grid which has positive potential. As we increase the V_{acc} , the number of electrons reaching at the mesh grid's more. After

reaching the collector plate only those electrons reach at the collector plate because at collector we gave retarding potential which deflects the electrons can reach the collector which has sufficient energy to break the retarding field.

Collision of Hg atom with electron



Incoming electron has K.E.

$$\text{K.E.} < \Delta E$$

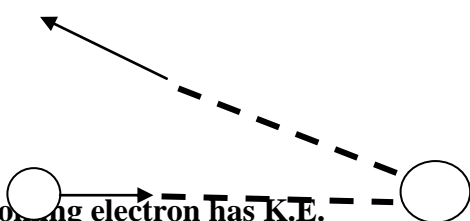
Fig – 3 (a)

Hg energy levels

Fig – 3 (b)

Fig. 3

When number of electrons reach at collector plate, we note the current by connecting ammeter with collector and at this stage the value of current is more and as we increase the accelerating voltage, the number of electrons an collector will be large and value of current will be more and at a particular accelerating voltage (at 4.9 ev for Hg) the potential is so much high of electrons and the collision between electrons and Hg atoms is inelastic collision and they transfer the energy to Hg atoms and electrons loose its kinetic energy and Hg atoms has enough energy for transition the electron of the Hg atom at this voltage (at 4.9 ev) the nos. Of electrons is very less at collector plate and the current is very small at 4.9 accelerating voltage.



Incoming electron has K.E.

$$\text{K.E.} = \Delta E \text{ or } \text{K.E.} > \Delta E$$

Fig – 4 (a)

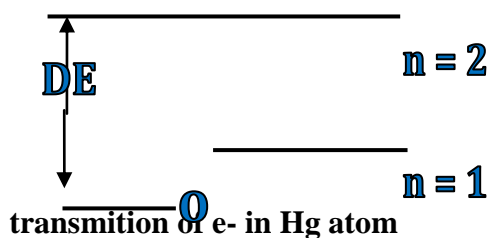


Fig – 4 (b)

Fig. 4

On further increasing the accelerating voltage the collector current increases after 4.9 ev and continuously processing of increasing accelerating voltage again at multiple of 4.9 vac the current is minimum at the collector due to inelastic collision between electron and Hg atoms. From this experiment, it can be concluded that the mercury atoms absorb mechanical energy in quanta of 4.9 ev. Similarly, we also define the quanta of neon. He O, H, Ar gas but for each gas the quanta-ization value is different for different gases. For Ne, the quantization value is 19 ev.

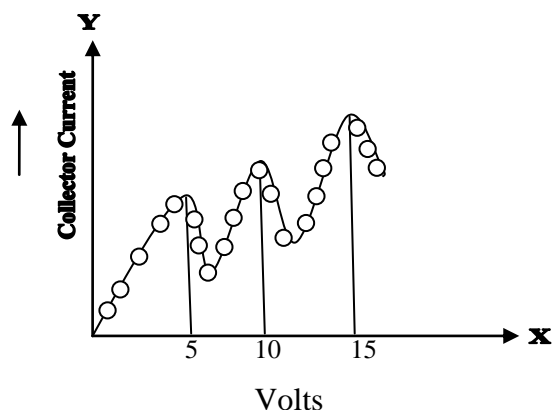


Figure - 5

Graph between accelerating voltage vs collector current in Frank-Hertz experience in Figure-5, it is clear the values of current is increases due to increase in accelerating voltage and at a fined value at 4.9 ev the current is minimum due to inelastic collision and after that current accelerating voltage and at a value 9.8 ev the current will be again minimum. So, 4.9 ev is the quantized value for Hg similarly, for the Ne gas which quantized value is 19 ev.

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