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Franck-Hertz Experiment and Identification Materials

B.Baghbanzadeh

Department of Physics, Dezful Branch , Islamic Azad University, DEZFUL, IRAN

Abstract

The Bohr theory was verified experimentally by Franck and Hertz in 1914 ,by passing a beam of electrons accelerated by an electric field through gases. At first, the electron beam was passed through mercury vapor .The electrons collide with the mercury atoms. These collisions may be of any one of two kinds. One kind in elastic collisions which do not change the velocity or energy of the electrons, and only change the direction of their velocities. The other kind is inelastic collisions in which the electrons transfer some of their energy to the mercury vapor. A similar effect is observed with neon gas. The process of absorbing energy from electron collisions produces visible evidence. When the accelerated electrons excite the electrons in neon to upper states, they de-excite in such a way as to produce a visible glow in the gas region in which the excitation is taking place. By extension, conducting this experiment on different materials allows the energy level of the electrons in a material to be discovered. Materials might be identified in this way. A sample could be experimented on and the energy level of the material discovered and compared to know materials thus revealing its identity.

Keywords: Franck-Hertz experiment, Mercury, Collision, Electron

I. INTRODUCTION

The experimental set-up is shown in figure 1 .in this set-up arranged inside a glass envelope which also held an amount of mercury to produce mercury vapor under a pressure of about 0.1 mm Hg. The cathode was raised to incandescence and emitted electrons, and the anode was connected to a galvanometer .The difference of potential between the cathode and the grid set up an electric field which accelerated the electrons to an energy eV_1 where V_1 is the difference of potential between the cathode and the grid ,and e is the electronic charge . The electric field between the grid and the anode was a weak retarding one, due to a potential difference, V_2 of not more than 0.5 V. Anode is charged negatively in comparison with grid .Therefore only electrons with energy larger than eV_2 can reach the anode and cause a current signal. If $V_2=0$, all electrons would reach the anode and no modulation of the current signal could be measured.

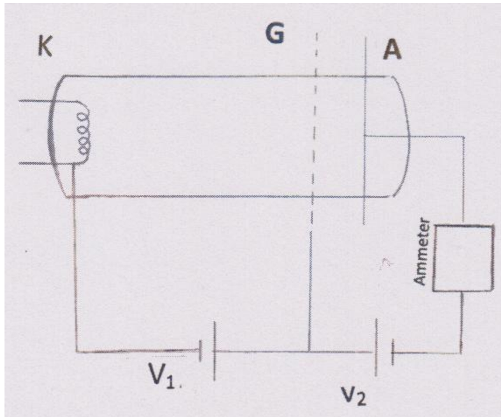

Fig.1 The Franck-Hertz tube and electrical connections. K is the cathode , G is the grid and A is anode

On passing through mercury vapor, the electrons collide with the mercury atoms. These collisions may be of any one of two kinds. One kind is elastic collisions which do not change the velocity or energy of the electrons and only change the direction of their velocities. The other kind is inelastic collisions in which the electrons transfer some of their energy to the mercury vapor .Since the electron mass is much lower than the mass of a mercury atom electrons hardly lose energy in elastic collisions, $\Delta E \propto \frac{4m_e}{m_{Hg}}$ but only change their direction. Therefore the processes we are interested in must be caused by inelastic collisions, in which a fraction of the electron energy is converted into internal, in our case excitational energy of the atom.

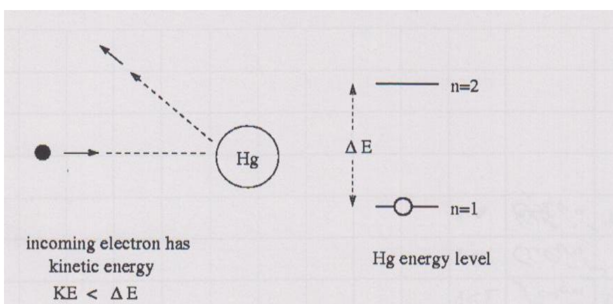

Fig.2 If the incoming electron has a kinetic energy which is less than the difference delta E between mercury s n =1 and n =2 energy levels , then it simply bounces off elastically , keeping all its original kinetic energy

Elastic collisions between the electrons and the mercury atoms cannot prevent the electrons from reaching the anode. Therefore, they cannot affect the value of anode current through the mercury – vapor tube, which is solely controlled by the accelerating field or, rather, by the potential difference between the cathode and the grid. In constant, during inelastic collisions the electrons may lose so much of their energy that they will not be able to overcome the weak retarding field between the grid and the anode, and anode current may drop to practically zero. According to

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Bohrs first postulate, the amount of energy that a mercury atom can receive from a colliding electron is just sufficient for the atom to undergo a transition to one of excited states. The excited state nearest to the ground or normal state for a mercury atom is separated by an energy gap of 4.88 ev.

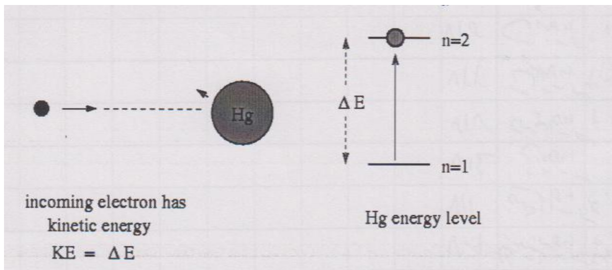

Fig.3 If the electron has kinetic energy equal to delta E , then it transfers most of its kinetic energy to the mercury atom , boosting the atom to the n=2 state . That levels the electron with very little kinetic energy

Until the electrons accelerated by the field acquire an energy of ev_1 = 4.86e, they experience only elastic collisions in which they lose no energy and reach the anode so that anode current is rising. As soon as an electron gains an energy of 4.86 ev an inelastic collision may take place, the electron may transfer all of its energy to a mercury atom, and this may jump from the ground into the excited state . Obviously, the electron cannot now overcome the weak retarding field between t grid and the anode and will fail to reach the anode. Thus at a potential difference of 4.86 V between the cathode and the grid , anode current should show a sudden decrease . Similar events should happen when the potential difference is 2×4.86V, 3x4.86v, etc. that is, when electrons may experience two , three or more inelastic collisions. This relation between anode current and the difference in potential, V_1, between cathode and grid in the Franck-hertz experiment is shown in the plot of fig .2 . As is seen , anode current suddenly decreases at V_1 equal to 4.86 V , 9.72 V and 14.58 V , in accordance with Bohr s first postulate .[1]
The Franck –Hertz experiments came as a proof of Bohr s third postulate in the following way. The mercury vapor in the tube was noted to emit ultraviolet light at a wavelength of 2537 A. This emission is explained by the fact that the mercury atoms excited by their collisions with electrons can reside in an excited state for a very short time interval, about 10^{-8s} ,and then jump back to their ground or normal state . According to Bohr S Third postulate, each transition of an atom to its ground state is accompanied by the emission of a quantum of radiant energy , or a photon of magnitude $\Delta E = h\vartheta$.
From $\Delta E = 4.86eV$,where e=1.6×10^{-19}c is the electronic charge , the wavelength of emitted light is found to be $\lambda = \frac{c}{\vartheta} = \frac{hc}{\Delta E} = 2537A°$

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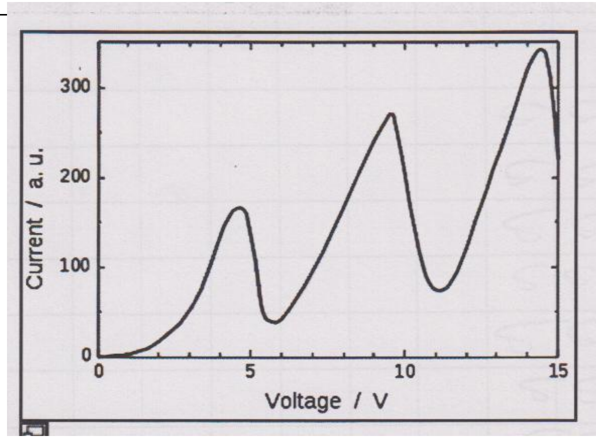

Fig.4 Accelerating voltage versus anode current

This result fully checks with experiment, for mercury vapor emits primarily this wavelength. Bohr s theory contributed immensely to the establishment of atomic physics. While it was in the making between 1913 and 1925, very important discoveries were made. These discoveries added to the wealth of present –day physics. Bohr s theory was especially stimulating to the advances of atomic and, partly, molecular spectroscopy. On the basis of Bohr s theory, a huge accumulation of experimental data on the spectra of atoms and molecules was presented in a systematic way and reduced to semi-empirical relations. Yet, Bohr theory showed some drawbacks from the outset .The most important among them was its inherent inconsistency because it was an attempt to reconcile classical physics and quantum – theoretical postulates. The gravest failure of Bohr theory was its inadequacy as regards helium and generally any system with a nucleus and more than one electron. Further developments showed that, successful in explaining some facts and incapable of interpreting others, Bohr s theory was a stepping stone to a consistent theory of atomic and nuclear phenomena, quantum mechanics [2].

II. MATERIAL AND METHOD

In the beginning we adjust voltage furnace at 120 V and when the temperature of furnace reached to 120 C then adjust voltage furnace on 75 V until changes of temperature is slower and slow to arrive 155 C. After the furnace reached to 155 C ,voltage disconnected until temperature in this point remain fix. If the temperature is reduced the furnace is connecting voltage again. This cut off and connect voltage will continue until temperature does not change. Begin the test, after 20 minute the tube was placed in the position. We recorded changes of current by changes of voltage.

TABLE1.CURRENT BY VOLTAGE

Voltage (V)	**Current (x0.05μA)**
5	**5**
6	**6**
7	**7**
8	**8**
9	**9**
10	**7**
11	**8**

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12	**9**
13	**10**
14	**11**
15	**9**
16	**10**
17	**11**
18	**12**
19	**13**
20	**10**
21	**11**
22	**12**
23	**13**
24	**14**
25	**11**
26	**12**
27	**13**
28	**14**
29	**15**
30	**13**

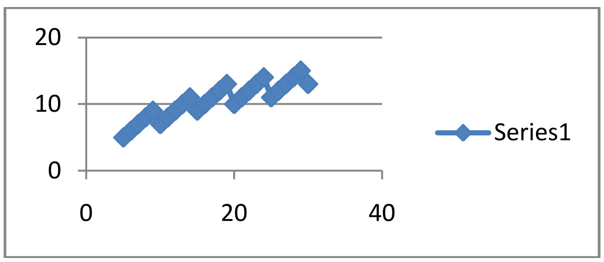

Fig.5 Anode current curve

III. RESULTS

The Franck-Hertz experiment is one of the basic experiments of atomic physics. The results of experiment provided strong evidence that Bohr s model of atoms with quantized energy levels was correct. Electrons emitted from a heated cathode are accelerated by a potential difference as they pass through a mercury vapor. When they have gained sufficient energy, the electrons collide in elastically with mercury atoms exciting them from the ground state. Electrons are collected at the anode, and the anode current shows minima and maxima at potential differences related to the energy difference between the ground state and the lowest lying excited states of the mercury atom [3].

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