Franck - Hertz Experiment

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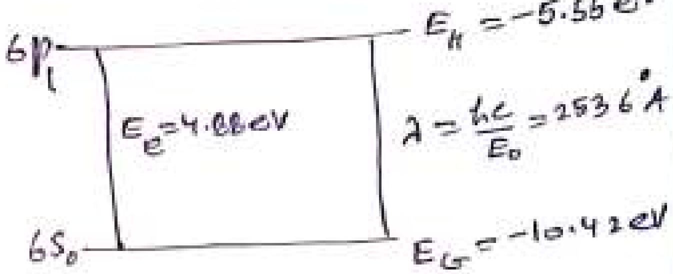
Franck-Hertz Experiment :-

Bohr's ideas of energy levels in atoms were confirmed in a famous experiment due to Franck and Hertz in 1914.

Franck and Hertz performed this kind of experiment by passing electrons with carefully controlled energies through mercury vapour.

In a heavy atom such as mercury $^{202}_{80}Hg$, the electrons in the innermost shells of the atom are difficult to be removed due to strong electrostatic attraction of the nucleus. Their binding energies are typically in the range of few KeV. The outermost valence electrons are somewhat shielded from the nucleus by the screening effect of electrons in the inner shells. Hence the binding energy of these electrons is only a few eV. In the experiment, only the outer valence electrons are involved, and the corresponding energy-level for this electron is shown as

These energy levels are generally termed as optical levels because any transitions among these levels involve photons with wavelengths in the visible or near visible region of the spectrum.



Optical energy levels for the Valence electron of $^{202}_{80}Hg$

The energy of the valence electron in the ground state (G) is $E_G = -10.42 eV$. The other levels H, I etc. are excited states, the first excited state (H) is having an energy $E_H = -5.55 eV$.

The energy needed for raising the electron from the ground state to the first excited state is

$$E_e = E_H - E_G = (-5.44 + 10.42) eV = 4.88 eV.$$

E_e is called the first excitation potential when the electron returns from the state H to the state G (in a very short time 10^{-8} sec) a photon of energy 4.88 eV and wavelength $\lambda = \frac{hc}{E_e} = 2536 Å$ is emitted.

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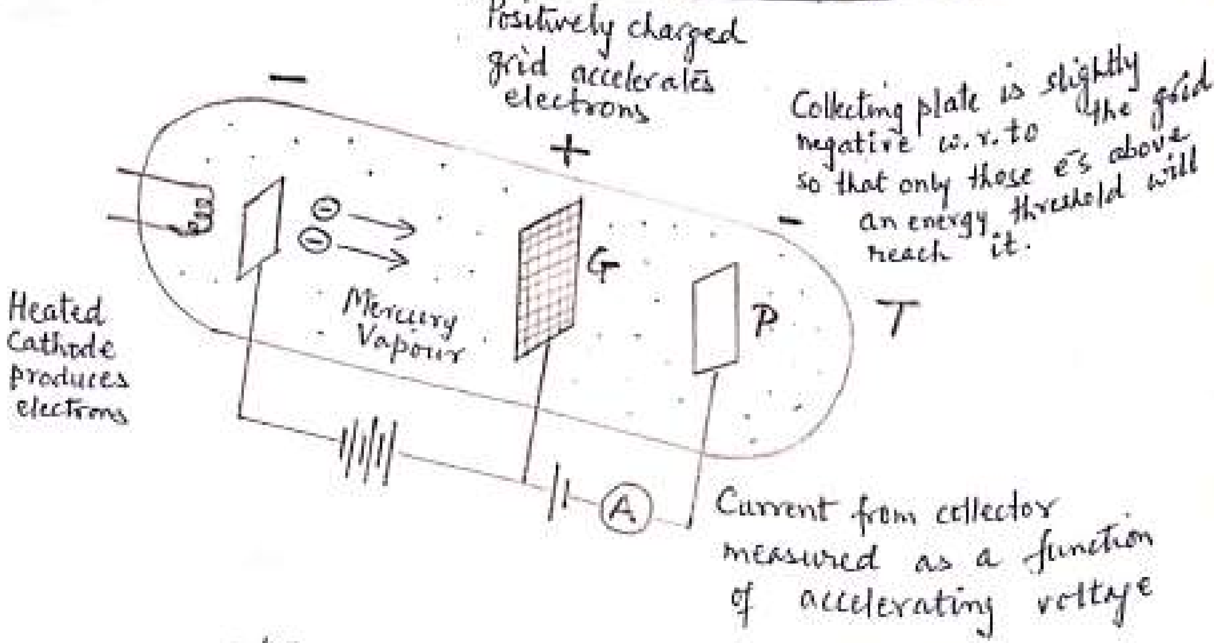
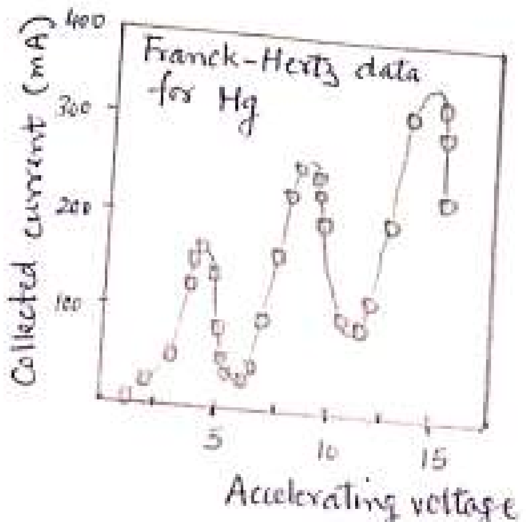
Experimental set-up for the Franck-Hertz experiment





Results of Franck-Hertz experiment with mercury Vapour

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Tube contains mercury vapour at low pressure and is maintained at a temperature of about 150°C.
The tube 'T' contains a filament, supplied by a battery a grid 'G' and a plate P. Between the filament and the grid, there is an accelerating potential V_a which varies between 0 and 60V. Between the plate and the grid, there is a small retarding potential V_r ($\equiv 0.5V$). Finally, there is a very sensitive electrometer in series with the plate which can measure the plate current of about 10^{-9}A.
When the accelerating potential V_a gets increased, the plate current also gets increased, except that a significant dip in the plate current occurs each time the accelerating potential gets increased by approximately 5V. Some of those electrons which have energies slightly greater than 4.88eV will undergo inelastic collisions and will be left with such small energy that they will not be able to reach the plate (due to presence of retarding voltage). When V_a is increased by an additional 5V, a second dip is observed (greater than the first dip). This second dip corresponds to those electrons that have experienced two inelastic collisions, the third dip will correspond to three inelastic collisions and so on each time the mercury atom will get excited and then return to the ground state by the emission of photons.
By using spectroscopic techniques, the wavelength of the radiation coming out was found to be 2536°A corresponding to transitions from the first excited state to the ground state. This result, together with the fact that energy difference two consecutive dips is about 4.9V confirms the existence of discrete energy levels in the mercury atom.
The Nobel Prize in Physics 1925 was awarded jointly for their discovery of the laws governing the impact of an electron upon an atom.

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