FRANCK-HERTZ EXPERIMENT FOR MERCURY

EXPERIMENT PROCEDURE

- **Measure target current *I* as a function of the voltage *U* between cathode and grid.**
- **Determining the separation ΔU of current maxima or minima.**
- **Compare the voltage intervals with the excitation energies of mercury atoms.**

OBJECTIVE

Record and evaluate the Franck-Hertz curve for mercury.

SUMMARY

The Franck-Hertz experiment for mercury involves observing how energy is transferred from electrons as a result of inelastic collision while passing through mercury vapour. The transfer of energy occurs in discrete steps corresponding to the excitement by such collision of distinct energy level transitions in the mercury atoms. The experiment thus provides confirmation of the Bohr model of the atom and the discrete energy levels described by that model.

REQUIRED APPARATUS

Quantity	Product	Number
1	Franck-Hertz Tube with Mercury Filling and Heating Chamber (230 V, 50/60 Hz)	1006795 or
	Franck-Hertz Tube with Mercury Filling and Heating Chamber (115 V, 50/60 Hz)	1006794
1	Power Supply Unit for Franck-Hertz Experiment (230 V, 50/60 Hz)	1012819 or
	Power Supply Unit for Franck-Hertz Experiment (115 V, 50/60 Hz)	1012818
1	Analogue Oscilloscope, 2x30 MHz	1002727
1	Digital Multimeter P3340	1002785
1	HF Patch Cord	1002746
2	HF Patch Cord, BNC/4 mm Plug	1002748
1	Set of 15 Safety Experiment Leads, 75 cm	1002843

EXPERIMENT PROCEDURE

***James Franck* and *Gustav Hertz* reported in 1914 that electrons passing through mercury vapour transferred energy in discrete steps and that this is associated with observing the emission of mercury's ultra-violet spectral line (λ = 254 nm). *Niels Bohr* realised several months later that this was a confirmation of the atomic model he had developed. The Franck-Hertz experiment with mercury has thus become a classic experiment for the confirmation of quantum theory.**

An evacuated glass tube contains a heated cathode C, a grid G and a target electrode A placed in that sequence (see Fig. 1). Electrons are emitted from the cathode and are accelerated by a voltage U towards the grid. Having passed through the grid they reach the target and thus contribute to a target current I if their kinetic energy is sufficient to overcome a decelerating voltage U_{GA} between the grid and the target. In addition a glass tube with a droplet of mercury is included and this is heated to generate a vapour pressure of approximately 15 hPa.

As the voltage U increases the target current I initially increases since more and more atoms are attracted out of the space charge field around the cathode by the electric field.
At a certain value $U = U_1$ some atoms attain sufficient kinetic energy just in front of the grid so that they are able to provide sufficient energy to excite the mercury atoms by inelastic collision. The target current then drops to near zero since after such a collision, the electrons no longer have the energy to overcome the decelerating voltage.

As the voltage increases more, the electrons acquire enough energy to excite the mercury atoms further away from the grid. After such collisions they are accelerated again and can once again acquire enough energy to reach the target so the target current rises again.
At a still higher voltage $U = U_2$ the electrons can acquire so much energy after the first collision that they are able to excite another mercury atom. The target current once again drops drastically but rises once more as the voltage further increases. This continues for a third time at a still higher voltage and again the target current drops dramatically.

NOTE

The first minimum is not at 4.9 V itself but is shifted by an amount corresponding to the so-called contact voltage between the cathode and grid.

EVALUATION

The voltages U_1, U_2, U_3, …, at which the current dramatically drops in the recorded $I(U)$-characteristics all appear at a constant interval ΔU = 4.9 V. This interval corresponds to the excitation energy E_{Hg} = 4.9 eV (λ = 254 nm) at which mercury atoms are raised from the base state $^1S_0$ to the first $^3P_1$-state. The following equation applies:

$$E_{Hg} = e \cdot \Delta U \quad (1)$$

e: Elementary electron charge

The results can thus be traced to discrete energy absorption by mercury atoms due to inelastic collision and the associated transfer of a fixed amount of energy from the electrons.

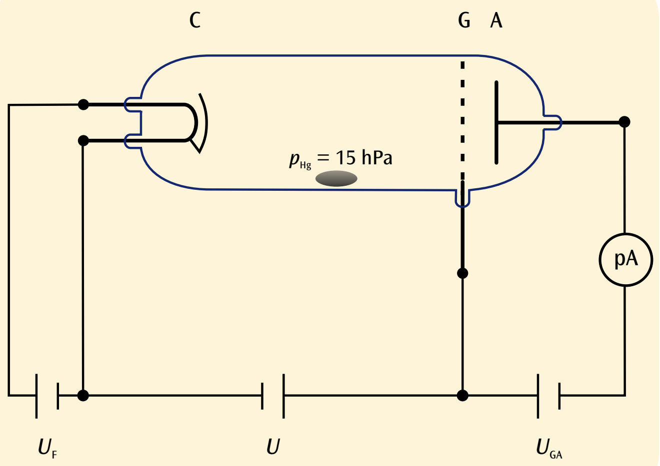

Fig. 1: Schematic of set up for measuring the Franck-Hertz curve for mercury.

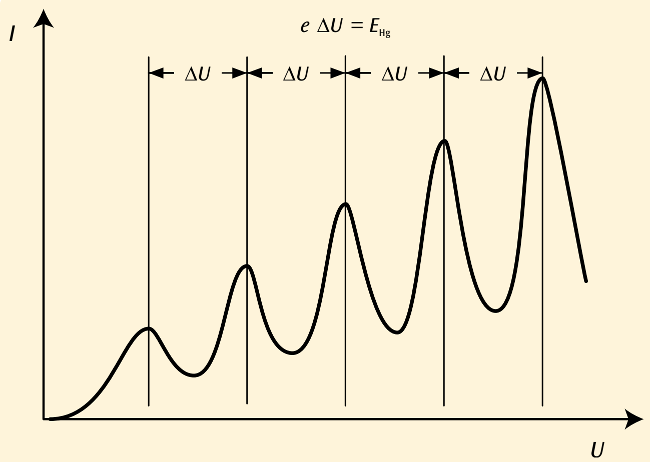

Fig. 2: Target current I as a function of the accelerating voltage U.