



### EXPERIMENT PROCEDURE:

- Measure target current  $I$  as a function of the voltage  $U$  between cathode and grid.
- Determining the separation  $\Delta U$  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 excitation 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	Description	Number
1	Franck-Hertz tube with Hg filling and heater, for 230 V AC	U8482150-230 or
1	Franck-Hertz tube with Hg filling and heater, for 115 V AC	U8482150-115
1	Power supply unit for Franck-Hertz experiment, for 230 V AC	U8482130-230 or
	Power supply unit for Franck-Hertz experiment, for 115 V AC	U8482130-115
1	Digital thermometer, 1 channel	U11817
1	K-type NiCr-Ni immersion sensor, - 65° C to 550° C	U11854
1	Analog oscilloscope, 2 x 35 MHz	U11175
1	Digital multimeter	U11809
1	High-frequency patch cord, 1 m	U11255
2	High-frequency patch cords, BNC / 4-mm-plug	U11257
1	Set of 15 safety patch cords, 75 cm	U13802

# Franck-Hertz Experiment for Mercury

UE502030

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

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

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.

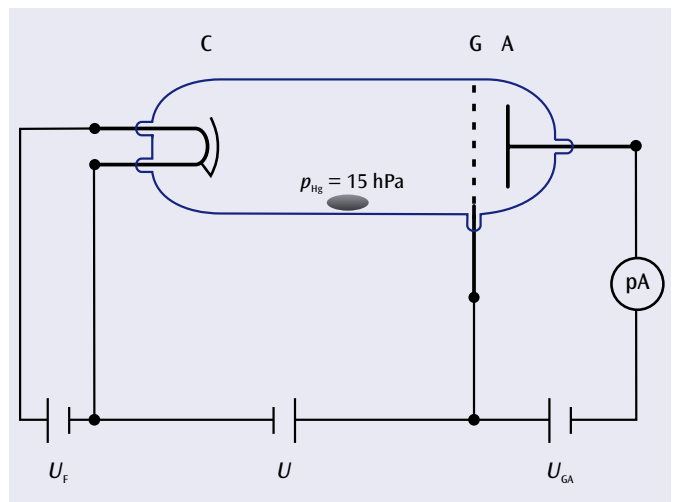


Fig. 1: Schematic of set up for measuring the Franck-Hertz curve for mercury

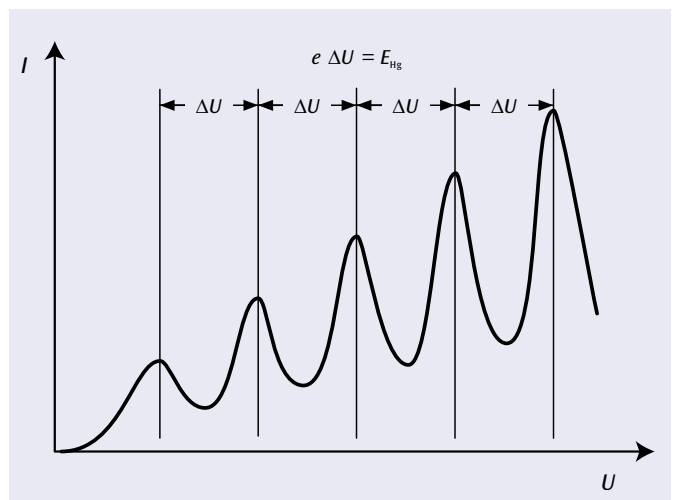


Fig. 2: Target current  $I$  as a function of the accelerating voltage  $U$