Atomic and nuclear physics

Atomic shell

Franck-Hertz experiment

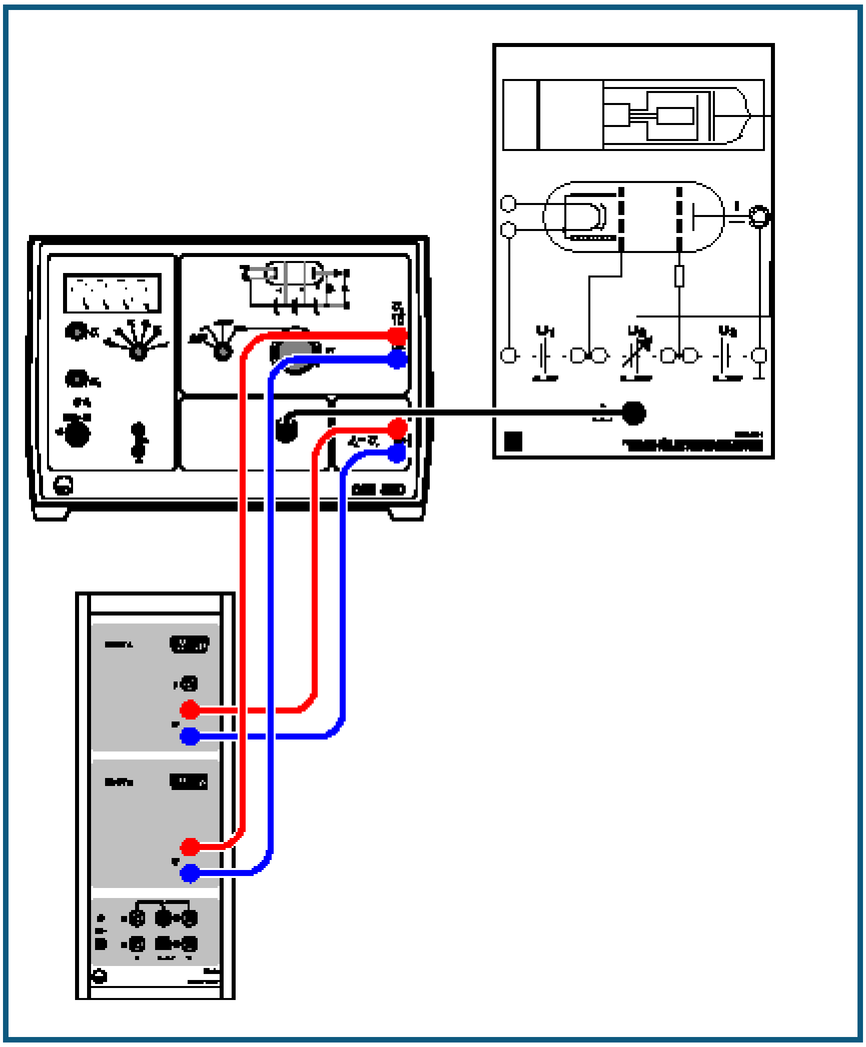
Franck-Hertz experiment with neon - Recording and evaluation with CASSY

Description from CASSY Lab 2

For loading examples and settings, please use the CASSY Lab 2 help.

CASSY Lab 2 (2013-06-07)

Franck-Hertz experiment with neon

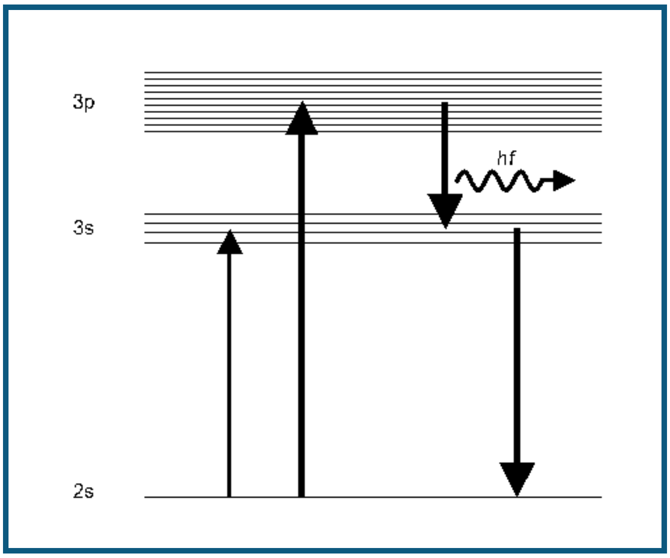


can also be carried out with Pocket-CASSY

Experiment description

In 1914, James Franck and Gustav Hertz reported an energy loss occurring in distinct "steps" for electrons passing through mercury vapour, and a corresponding emission at the ultraviolet line (λ = 254 nm) of mercury. Just a few months later, Niels Bohr recognized this as evidence confirming his model of the atom. The Franck-Hertz experiment is thus a classic experiment for confirming quantum theory.

In this experiment, the energy loss of free electrons through inelastic scattering (excitation through impact) from neon atoms is investigated. Most probably the excitation occurs from the ground state to the ten 3p states, which are 18.4 eV and 19.0 eV above the ground state. The four slightly lower 3s states at 16.6 eV to 16.9 eV are less likely to be excited. The de-excitation of the 3p states to the ground state by emission of photons is only possible with a detour via the 3s states. The light emitted during this process within the visible range between red and green and can therefore be observed without any equipment.



An evacuated glass tube is filled with neon at room temperature to a gas pressure of about 10 hPa. The glass tube contains a system of four electrodes. Electrons are emitted by the hot cathode and form a charge cloud. These electrons are attracted by the driving potential U_1 between the cathode and the grid-shaped control electrode G_1 and then accelerated by the acceleration voltage U_2 in the direction of grid G_2. Between G_2 and the collector electrode, a braking voltage U_3 is applied. Only electrons with sufficient kinetic energy can reach the collector and contribute to the collector current.

In this experiment, the acceleration voltage U_2 is increased from 0 to 80 V while the driving potential U_1 and the braking voltage U_3 are held constant, and the corresponding collector current I_A is measured. This current initially increases, much as in a conventional tetrode, but reaches a maximum when the kinetic energy of the electrons closely in front of grid G_2 is just sufficient to transfer the energy required to excite the neon atoms through collisions. The collector current drops off dramatically, as after collision the electrons can no longer overcome the braking voltage U_3.

As the acceleration voltage U_2 increases, the electrons attain the energy level required for exciting the neon atoms at ever greater distances from grid G_2. After collision, they are accelerated once more and, when the acceleration voltage is sufficient, again absorb so much energy from the electrical field that they can excite a neon atom. The result is a second maximum, and at greater voltages U_2 further maxima of the collector current I_A.

Equipment list

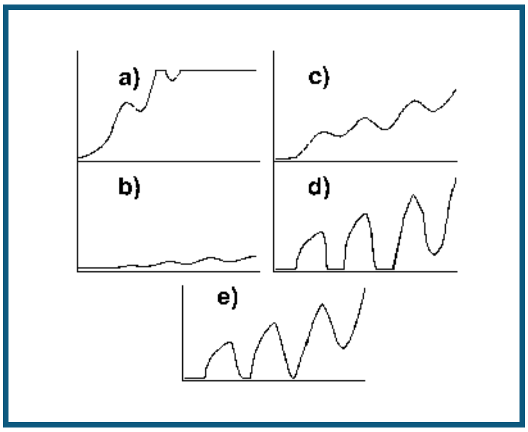
1	Sensor-CASSY	524 010 or 524 013
1	CASSY Lab 2	524 220
1	Ne Franck-Hertz tube	555 870
1	Holder with socket	555 871
1	Connecting cable for Ne-FH	555 872
1	Franck-Hertz supply unit	555 880
2	Pairs of cables, 100 cm, red and blue	501 46
1	PC with Windows XP/Vista/7/8	

Experiment setup (see drawing)

- Clamp the Ne Franck-Hertz tube in the socket on the holder and connect by means of a connection cable to the socket "Franck-Hertz tube" of the Franck-Hertz supply unit.
- Set the operating-mode switch on the Franck-Hertz supply unit to RESET.
- Connect voltage input A for the Sensor-CASSY to output U_A for the voltage proportional to the collector voltage and the voltage input B of Sensor-CASSY at output $U_2/10$ for the acceleration voltage.

Carrying out the experiment

- Load settings
- Set the driving potential U_1 = 1.5 V and the braking voltage U_3 = 5 V and record the Franck-Hertz curve in the "Ramp" operating mode. To do this, start the measurement by pressing and immediately set the operating mode switch to "Ramp". The measurement is automatically stopped after 40 s, then return the operating mode switch to RESET.



1) Optimizing U_1

A higher driving potential U_1 results in a greater electron emission current.

If the Franck-Hertz curve rises too steeply, i.e. the overdrive limit of the current measuring amplifier is reached at values below U_2 = 80 V and the top of the Franck-Hertz curve is cut off (a):

- Reduce U_1 until the curve steepness corresponds to (c).

If the Franck-Hertz curve is too flat, i.e. the collector current I_A remains below 5 nA in all areas (b):

- Increase U_1 until the curve steepness corresponds to (c).
- If necessary, optimize the cathode heating as described in the Instruction Sheet for the Franck-Hertz supply unit.

2) Optimizing U_3

A greater braking voltage U_3 causes better-defined maxima and minima of the Franck-Hertz curve; at the same time, however, the total collector current is reduced.

If the maxima and minima of the Franck-Hertz curve are insufficiently defined (c):

- Alternately increase first the braking voltage U_3 and then the driving potential U_1 until you obtain the curve form shown in (e).

If the minima of the Franck-Hertz curve are cut off at the bottom (d):

- Alternately reduce first the braking voltage U_3 and then the driving potential U_1 until you obtain the curve form shown in (e).

The Ne Franck-Hertz tube in the experimental example was measured using the parameters U_1 = 1.5 V and U_3 = 7.9 V.

Evaluation

The recorded curve is evaluated by drawing vertical lines (by eye) to find the distance between the subsequent maxima. In the experimental example, an average value of U_2 = 18.2 V is found. This value is much closer to the excitation energies for the 3p-levels of neon (18.4-19.0 eV) than to the energies of the 3s-levels (16.6–16.9 eV). Thus, the probability of excitation to the latter due to inelastic electron collision is significantly less.

The substructure in the measured curve shows that the excitation of the 3s-levels cannot be ignored altogether. Note that for double and multiple collisions, each combination of excitation of a 3s-level and a 3p-level occurs.

In the Ne Franck-Hertz tube, luminous zones can be observed which depend on the acceleration voltage. They directly correlate with the minima of the Franck-Hertz curve.