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Methodological Notes

DEMONSTRATION OF THE RAMSAUER EFFECT

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AMONG the experiments whose explanation required allowance for the wave nature of microparticles, a prominent place is occupied by the Ramsauer experiment (1921), in which the exceptional transparency of heavy inert gases (Ar, Kr, Xe) to a beam of electrons of energy lower than 1 eV was observed.

Whereas the classical concepts call for the effective scattering cross section of an electron beam to decrease monotonically with increasing electron velocity, the experiment has revealed a distinct minimum of scattering, say at 0.7 eV in xenon. In spite of the small number of demonstrations on atomic physics, this experiment, insofar as the author knows, is not being demonstrated. Yet by using a TG-3-0.1/1.3 or TG-1-01/1.3 thyratron, which is filled with a krypton-xenon mixture, this phenomenon can be easily demonstrated in lectures.

The demonstration can be performed because of the unique shape of the thyratron electrodes, which differs from that in ordinary vacuum tubes (Fig. 1). In the figure, 1 is the control grid of the thyratron, 8 a cylinder, 5 and 7 the first and second screen grids, 2 the cathode, 6, the anode, and 3 and 4 the filament.

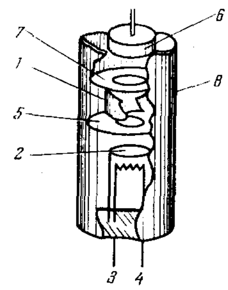

FIG. 1

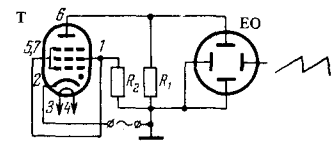

FIG. 2

By applying a sinusoidal voltage of approximate frequency 2 kHz from a GZ-1 sound generator or equivalent (it is important that the amplitude of the alternating voltage be not less than 10–15 V; the grid voltage must not be too high, to avoid shock excitation of the gas molecules), or else a sawtooth voltage from an oscilloscope sweep generator (say from an Orion EMG-1541 scope), we obtain a different distribution of the electron currents to the anode and to the cylinder with the grids. The larger the scattering experienced by the electrons when interacting with the krypton and xenon molecules, the smaller the current to the anode, and vice versa.

Since the effective scattering cross section is minimal at an approximate accelerating voltage 0.7 V, the current to the anode is maximal in this case, and the current decreases when the velocity and energy are further increased within certain limits.

The installation used for the demonstration is very simple, and its diagram is shown in Fig. 2. Here T is a TG-1-0.1/1.3 thyratron, $R_1 = 10\ k\Omega$, $R_2 = 100\ \Omega$, and EO is an EO-7 oscilloscope. We note that the filament is fed from three or four alkaline storage batteries.

A similar scheme was proposed in[1] for use in laboratory experiments for point-by-point plotting the dependence of the anode current on the voltage and for measuring the current in the anode circuit with a galvanometer. Kukolich[1], however, merely confines himself to mentioning the feasibility of the demonstration. The 2D21 thyratron used in[1] is analogous to the Soviet TG-3-0.1/1.3, and produces a much less pronounced oscillogram than the TG-1-0.1/1.3 we employ in the demonstration. To verify that the observed anode-current maximum (and the minimum of the interaction cross section) is indeed due to collisions with the heavy inert gas molecules, the thyratron is cooled with liquid air. The freezing decreases the gas pressure from 0.05 to 10^{-3} Torr. The anode current then increases practically linearly with increasing accelerating voltage. The picture obtained on the screen of the EO-7 oscilloscope is shown in Fig. 3.

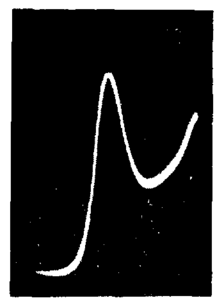

FIG. 3

An idea explaining the effect was proposed by N. Bohr. The problem was considered theoretically and rigorously by Faxen and Holtsmark, on the basis of Rayleigh's work on the scattering of sound waves. In this case, the de Broglie wave is scattered by the gas molecules. The theory of the phenomenon is detailed in[2] and[3].

[1] S. G. Kukolich, Amer. J. Phys. 36(8), 701 (1968).
[2] H. S. W. Massey and E. H. S. Burhop, Electronic and Ionic Impact Phenomena, Oxford, 1952.
[3] N. F. Mott and H. S. W. Massey, Theory of Atomic Collisions, Oxford, 1965.