UE502050

Critical Potentials

EXPERIMENT PROCEDURE

- **Measure the collector current I_R as a function of the accelerating voltage U_A.**
- **Compare the positions of the current maxima with the known critical potentials of the helium atom.**
- **Identify the doublet structure in the term scheme of helium (ortho and para helium).**

OBJECTIVE

Determine the critical potentials of a helium atom.

SUMMARY

The expression "critical potential" is a general name for all the excitation and ionisation energies in the electron shells of an atom. The corresponding electronic states can be excited in various ways, for example by inelastic collisions with electrons. If the kinetic energy of the electron corresponds to a critical potential, the electron can lose all its kinetic energy in an inelastic collision. An experiment set-up originally designed by Gustav Hertz is used here to determine critical potentials.

REQUIRED APPARATUS

Quantity	Description	Number
1	Critical Potential Tube S with He-Filling	**U18560**
1	Tube Holder S	**U185001**
1	Control Unit for Critical Potential Tubes	**U18650**
1	DC Power Supply, 0–5 V, 2 A, e.g.	**U33020-230** or **U33020-115**
1	3B NET*log*™ (230 V, 50/60 Hz) 3B NET*log*™ (115 V, 50/60 Hz)	**U11300-230** or **U11300-115**
1	3B NET*lab*™	**U11310**
1	Set of 15 Experiment Leads, 75 cm 1 mm²	**U13800**

BASIC PRINCIPLES

The expression "critical potential" is a general name for all the excitation and ionisation energies in the electron shells of an atom. The corresponding electronic states of the atom can be excited in various ways, for example by inelastic collisions with electrons. If the kinetic energy of the electron corresponds exactly to a critical potential, the electron can transfer all its kinetic energy to the atom in an inelastic collision. Using an experiment set-up originally designed by Gustav Hertz, this effect can be used to determine the critical potentials.

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In a tube that has been evacuated and then filled with helium, free electrons are accelerated by a voltage UA to form a divergent beam passing through a space at a constant potential. To prevent the walls of the tube becoming charged, the inner surface is coated with a conducting material and connected to the anode A (see Fig. 1). In the tube there is a ring-shaped collector electrode R, through which the divergent beam can pass without touching it, even though the ring is at a slightly higher potential.

However, a small current IR, with a value in the order of picoamperes, is measured at the collector ring, and is found to depend on the accelerating voltage UA. It shows characteristic maxima, which are caused by the fact that the electrons can undergo inelastic collisions with helium atoms during their passage through the tube. The kinetic energy E of an electron is as follows:

(1) $$E = e \cdot U_A$$

e: elementary electron charge

If this energy corresponds exactly to a critical potential of the helium atom, all the kinetic energy may be transferred to the helium atom. In this instance the electron can then be attracted and collected by the collector ring, thus contributing to an increased collector current I_R.

As the accelerating voltage is increased, successively higher levels of the helium atom can be excited, until finally the kinetic energy of the electron is enough to ionise the helium atom. As the accelerating voltage is increased further, the collector current shows a steady increase.

EVALUATION

The positions of the observed current maxima are compared with quoted values for the excitation energies and the ionisation energy of the helium atom. Account must be taken of the fact that the maxima will be shifted relative to the quoted values by an amount corresponding to the so-called contact voltage between the cathode and the anode.

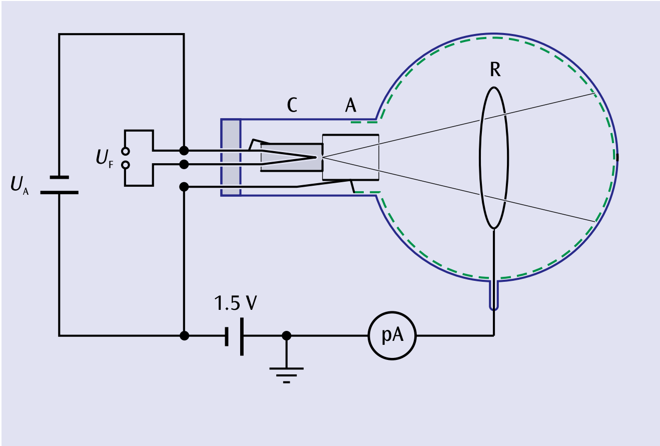

Fig. 1: Schematic diagram of critical potential tube.

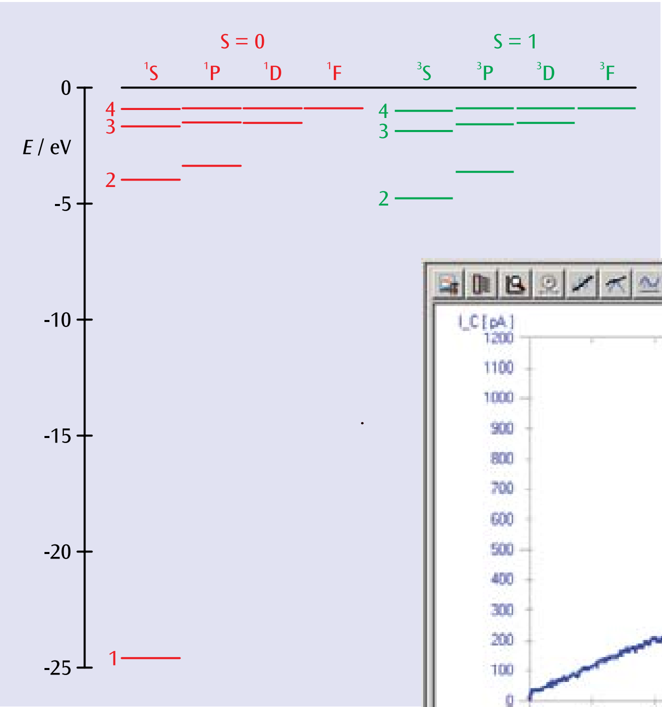

Fig. 2: The term scheme of helium
red: total spin $S = 0$ (para helium),
green: total spin $S = 1$ (ortho helium)

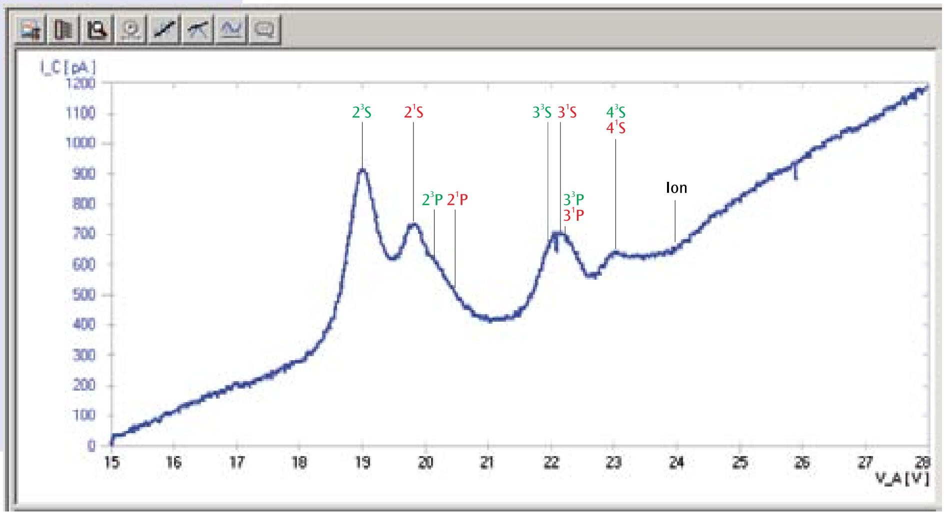

Fig. 3: Collector current I_R as a function of accelerating voltage U_A