A Device Producing Ion Beams Homogeneous as to Mass and Energy

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In the production of beams of one definite kind of ions, as, e.g., in many experiments within nuclear physics or in apparatuses for collecting isotopes, a mass-spectrographic analyzer is often used which consists of a homogeneous, magnetic deflecting field only. In order to focus the separated ion beams on a target or on the slit of a collector, it is necessary to keep both the magnetic field and the accelerating potential extremely constant. The former may generally be done by using accumulators for running the magnet. With a high accelerating potential the stabilization of the high tension generator, however, may be rather inconvenient, and in many cases may be replaced by the device described below, which has been used in connection with the construction of a mass spectrograph for the collection of small samples of pure isotopes.[1,2]

The principle of the method is shown in Fig. 1. The ions are accelerated with a potential of about 70 kv in the space between the low voltage capillary ion source I and the earthed cylinder C_1. The ions paths are collimated by means of an electrostatic retardation lens consisting of the cylinders C_1, C_2, and C_3. The ion beam now passes through a small deflecting condenser, one plate of which is earthed. The other plate is connected to a potential E which is proportional to the fluctuation of the average accelerating potential V: $E=E_0\Delta V$. If the accelerating potential is exactly $V(\Delta V=0)$, the beam will not be deflected, but will enter the magnetic field at b, after which it continues along a circular path with a radius of curvature ρ to b' and from there rectilinearly to the slit of the collector at F. If the accelerating potential increases by ΔV, the ion beam will be slightly deflected by passing the condenser and enter the magnetic field at a, from where it continues along a circular path with a somewhat longer radius than before to a', and from there tangentially in the direction of focus F. For negative values of ΔV the ion beam will be deflected in the direction of c, but after passing the magnetic field it will again arrive at focus F.

The deflecting potential is produced as follows. The high tension generator (H. T.) is connected with a resistance R of $70M\Omega$ (which is also used to determine the potential of the electrostatic lens V_l) in series with a much smaller resistance r of $140k\Omega$. If the switch A is on, the current in r may be compensated for a definite accelerating potential V by adjustment of the potentiometer P. If now the accelerating potential fluctuates by ΔV, fluctuations of $r/2R\cdot\Delta V$ will appear on the resistance r $(=r')$. By adjustment of the slider S fluctuations of suitable size may be led to the d.c. linear amplifier, with a constant amplification factor of about 1400, and herefrom to the plate of the deflecting condenser. The battery B_g determines the grid bias of the first valve, while B_a compensates the d.c. anode potential of the output valve.

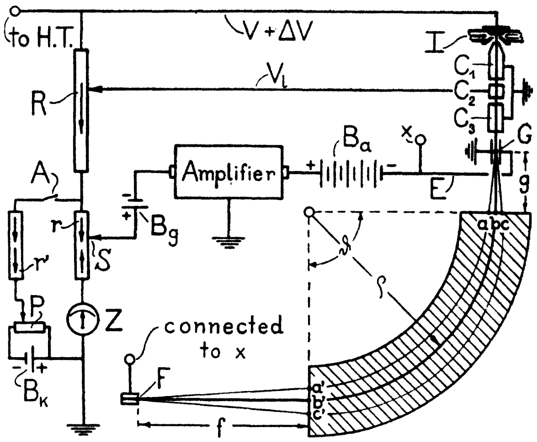

FIG. 1. Diagram of mass-spectrographic analyzer.

After emerging from the deflecting condenser the beam may be taken as radiating from a virtual source G, the angle of deflection being proportional to ΔV. The potential $E(=E_0\Delta V)$ necessary to focus the ion beam coming from G at a point F on the median beam after deflection in a magnetic prism with the central angle ϑ is obtained from the expression

$$E_0=\frac{d}{l}\cdot\frac{1+n\sin\vartheta-\cos\vartheta}{(1-\eta\xi)\sin\vartheta+(\eta+\xi)\cos\vartheta},$$

where $\xi=g/\rho$, $\eta=f/\rho$ (see Fig. 1) and l/d is the ratio between the length of the condenser plates and their mutual distance. In the investigations made with the mass spectrograph of the Institute the following experimental conditions were used: $\rho=80$ cm, $\vartheta=\pi/2$, $\xi=0.38$, $\eta=1$, and $l/d=3.2$, hence $E_0\approx 1$. In spite of the fact that the high tension generator (conventional voltage doubling circuit) was connected directly to the tension of the city mains, no displacements of the lines of the mass spectrum were observed. This result corresponds to a stabilization of the accelerating potential of about $1:10^4$. It should be added that the method described also compensates for the ripple of the accelerating potential and even for much faster fluctuations, which may originate from sudden changes of the working conditions of the accelerating tube.

The ions of course hit the target or the collector with different energies $V+\Delta V$. By mounting these electrodes isolatedly and connecting them to the output potential of the amplifier $E=\Delta V(E_0=1)$ it is, however, possible to make the ions always arrive with the same energy V. This principle may be of importance in experiments within nuclear physics (e.g., investigations on resonance curves) with or without the employment of magnetic analysis of the ion beam.

An account containing the detailed discussion of the focusing method here mentioned, and a description of the apparatuses pertaining to it, will soon be published in *Det Kongelig Danske Videnskabernes Selskabs Mathematisk-fysiske Meddelelsker*. Finally I wish to express my cordial thanks to Professor Niels Bohr for the active interest he has taken in the questions discussed above.

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[1] J. Koch, Diss., Copenhagen (Publ. by Thaning & Appel, 1942).

[2] J. Koch and B. Bendt-Nielsen, Det Kgl. Danske Vid. Sels. Mat.-fys. Medd. **21**, 8 (1944).