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MAGNETIC MASS ANALYSIS OF A 200 keV ION BEAM FROM A COCKCROFT AND WALTON ACCELERATOR

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Introduction

For most purposes it is desirable that the ions accelerated in an accelerating tube are all of the same kind and energy. If the ions serve for the production of neutrons by means of $D-D$ and $D-T$ reactions, monoenergetic deuterons are required. However, no ion source gives only one kind of particles. Some impurities are introduced into the source by the gas which is to be ionized. Deuterium gas, in particular, may contain minor quantities of H_2 or HD molecules. Besides the presence of H^+ and D^+ as well as $H_2{}^+$ and $D_2{}^+$ ions, there is a fairly large probability of the formation of HD^+, H_2D^+, $HD_2{}^+$, and $D_3{}^+$ ions due to secondary recombination processes. The primary ion beam, therefore, may contain all masses from one to six a. m. u.

The collision processes leading to the dissociation and formation of molecular ions take place along the whole ion path, especially in the relatively long grounded part of the tube, where the pressure is higher because of the presence of diaphragms limitating the ion beam and because of the outgassing of the surfaces struck by ions. A continuous distribution of the momenta of the particles striking the target is therefore superposed to the momentum spectrum of primary ions. To bombard the target with the atomic or molecular ions of the same kind it is necessary to use a mass separator.

Experimental Arrangement

The ion beam of the 200 kV Cockcroft and Walton accelerator is produced in a high frequency ion source. The source is fed with deuterium gas obtained by electrolysis of heavy water (99,6% D_2O) in the absence of air [1]. After acceleration the ion beam passes through a magnetic mass analyser, which deflects particles at 32°. The magnetic induction of the electromagnet can be varied in the range of 0.2—0.8 teslas. The coils of the electromagnet with 2×6000 windings are fed from a current stabilized DC power supply. The stability of the current is more than 1% for the 10% variation of the voltage of the mains. The diameter of the pole faces is 10 cm and their distance is 4 cm. The magnetic induction B of the field on the axis of the rotational symmetry, as a function of the magnetization current I_m is shown in Fig. 1. The radial variation

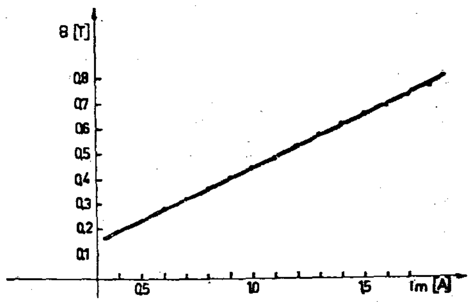

Fig. 1. $B = f(I_m)$

$B(r)$ of the magnetic induction is presented in Fig. 2. These measurements were made with a fluxmeter calibrated by means of an indium-antimonid crystal of known response.

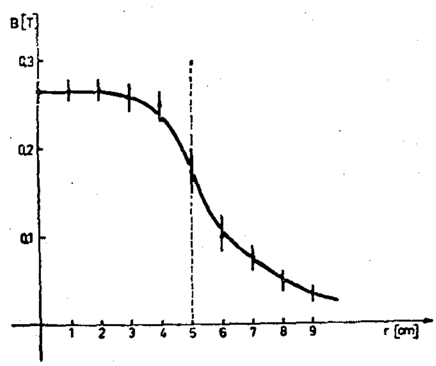

Fig. 2. $B = f(r)$

The drawing of the axial section of the deflection chamber and of the target is shown in Fig. 3. A view of the deflection chamber and the magnet is shown in Fig. 4. The target is electrically insulated from the grounded deflection chamber and is connected to the ground through a current indicating instrument. After passing through a circular diaphragm of diameter 10 mm the ions enter the magnetic field. The deflected beam crosses two further diaphragms, each of them being of diameter 9 mm. They force the beam to strike the target and prevent it from falling either onto the mirror for secondary electrons (at —150 V), or onto other parts of the accelerating tube. If this precaution is not taken, electrons emitted from the bombarded surfaces are collected by the target, and the positive current measured on the target instrument is smaller than the actual one.

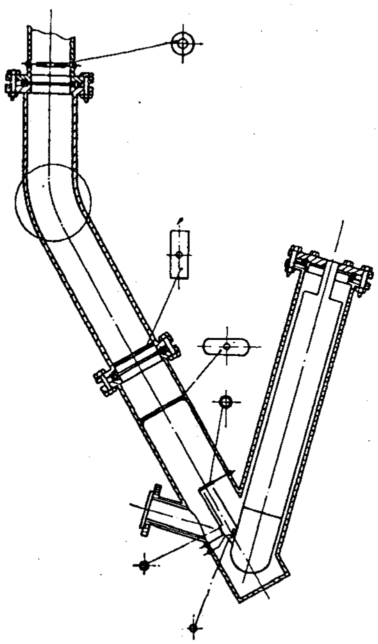

Fig. 3. *The axial section of the deflection chamber and of the target.*

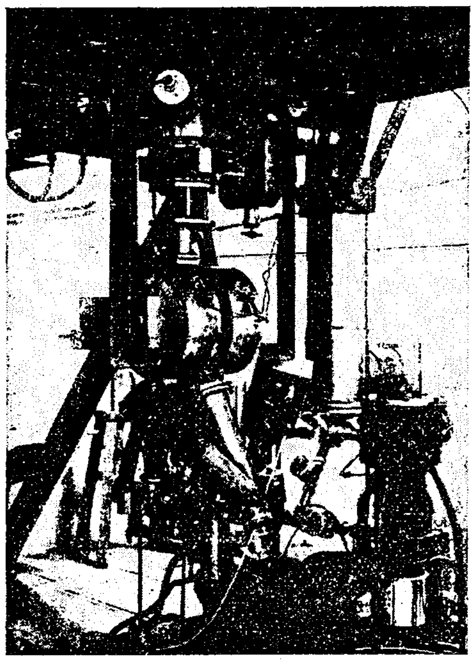

Fig. 4. *A view of the grounded part of the accelerating tube showing also the magnet, the deflection chamber, and the target.*

On the target there is a Faraday cylinder of diameter 15 mm and 75 mm high, with the mirror for secondary electrons at its end. (A lateral hole in the cylinder allows the protons from the associated $D(d, p)T$ reaction to reach a crystal detector.) The heavy water vapour is introduced into the target chamber by a thin

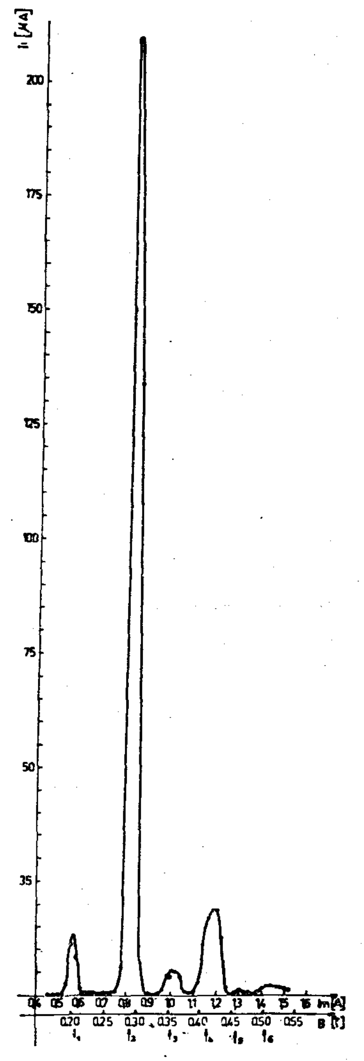

Fig. 5. *The ion current as a function of the magnetization current or the magnetic induction, showing maxima at different ion masses.*

copper tube shaped like a loop of diameter 15 mm. It is placed near the target and surrounds the spot of the ion beam. Through the pinholes on the inner side of the loop the heavy water vapour pours from all sides onto the focus of the beam on the target. The loop is electrically insulated from other parts of the equipment and connected to the ground by a microammeter. This instrument shows a negative current which is about 20% of the positive current on the target. The measurement of the negative current through the loop is a way of controlling the focalization of the ion beam and the localization of the focus on the target.

Results

Fig. 5 shows the ion current I_i on the target as a function of the magnetization current I_m. The numbers marked by arrows denote the calculated magnetization current corresponding to the single charged ions from one to six a. m. u., accelerated up to 200 keV. By introducing helium into the source and under the same working conditions of the source, less than 1% of helium atoms with two elementary charges was obtained. For that reason we neglected the occurence of double charged particles in our ion beam. The spectrogram shows that the current between the peaks is not zero. This current is caused by molecular ions dissociated during the passage through the accelerating tube. A small peak of the current is observed in the position where an H_2O^+ ion is expected. That is not shown in Fig. 5.

The mass spectrum of the ion beam is given in Table I.

Table I.

The magnetic analysis of the ion beam

Mass and kind of particle	1 H^+ and D^+_{2-1}	2 H^+_2 and D^+	3 HD^+ and H^+_3	4 D_2^+ and H_2D^+	5 HD_2^+	6 D_3^+
Magnetization current (A)	0.57	0.82	1.00	1.18	1.32	1.44
Ion current (A)	13.2	210.0	5.2	18.8	0.84	1.84
Percentage abundance	5.30	84.2	2.09	7.55	0.34	0.74

The percentage of ions in the first maximum which corresponds to protons of 200 keV is about 5%. It also contains the atomic deuterium ions of 100 keV energy, resulting from the dissociation of D_2^+ ions previously accelerated up to 200 keV. The contribution made by D_2^+ dissociated ions to the 1 a. m. u. peak is very likely to be small, the main contribution coming from H^+ ions, in spite of the purity of the heavy water used. The fact is that the relative percentage of 3 a. m. u. ions is also fairly large, which undoubtedly indicates the presence of ^1H in the form of HD^+ ions. The question where the hydrogen is coming from into the accelerating tube can only be tentatively answered: degassing of previously absorbed H_2

and H_2O on the walls of the apparatus, water leaking in continuously from the atmosphere, degassing of organic compounds from rubber rings, vapour of silicones coming from the diffusion pumps, degassing of iron pieces,...

The percentage of different ions present in the beam and the total ion current under various working conditions are given in Table II.

Table II.

The percentage abundance of the ions in the beam under various working conditions

accelerating voltage kV	oscillator power W	m (a. m. u.)	1	2	3	4	5	6	total ion current I
153	60	% I	5.42	72.6	4.3	14.3	1.3	2.08	92.4
178	60	% I	4.11	79.3	2.86	11.6	0.58	1.56	138.6
178	42	% I	4.80	84.2	1.98	7.37	0.38	1.09	168.5
178	90	% I	5.30	84.2	2.09	7.55	0.34	0.74	249.9
198	49	% I	4.23	82.2	2.43	9.38	0.48	1.18	138.6

The variation of the accelerating voltage from 153 to 198 kV and the power of the oscillator from 42 to 90 W do not considerably effect the relative mass spectrum. They, however, influence the total ion current. The higher excitation gives a higher total ion current and a higher accelerating voltage improves the focalization, which, in turn, gives a higher ion current.

The obtained mass spectrum is similar to the ion spectrum with a lower accelerating voltage obtained by Thonemann et al. (2).

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MAGNETSKA ANALIZA MASA IONA NA COCKCROFT I WALTON AKCELERATORU OD 200 kV

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Sadržaj

Kod Cockcroft-Walton akceleratora poželjno bi bilo da ubrzani ioni budu svi iste vrste. Kod neutronskog generatora za D—D i D—T reakciju obično se koriste monoenergetski deuteroni. Deuterij, koji se dovodi u izvor, sadrži izvjestan postotak H_2 i HD molekula. Naknadni procesi osim H^+, D^+, H_2^+, D_2^+ i HD^+ dovode do stvaranja H_2D^+, HD_2^+ i D_3^+ iona. Zato, da bi se bombardiranje cilja vršilo jednovrsnim ionima, potrebno je snop ubrzanih iona rastaviti na pojedine komponente.

U tu svrhu izgrađen je na neutronskom generatoru [1] elektromagnet, kojemu se magnetska indukcija može mijenjati od 0,2—0,8 tesla. Kut otklona je 32^0. Magnetska indukcija B polja na osi rotacione simetrije, kao funkcija struje magnetizacije, prikazana je na sl. 1., a radijalna ovisnost magnetske indukcije na sl. 2. Presjek komore za otklon i cilj vidi se na sl. 3., a fotografija na sl. 4. Faradayev cilindar na cilju sprečava pogreške u mjerenju struje pozitivnih iona zbog sekundarnih elektrona. Tik uz metu postavljena je u obliku petlje savijena cjevčica promjera 15 mm za dovod teške vode. Ona okružuje spot snopa, no na nju ne udara ionski snop.

Struja iona na cilju u ovisnosti o struji magnetizacije vidi se na sl. 5. Sa strelicama i brojevima od 1—6 označene su jedinice atomske mase iona. Na tabeli I. prikazan je postotak pojedinih vrsta iona.

Postotak protona i disociranih deuterona iz D_2^+ je oko 5%. Također znatan je postotak iona, koji odgovara HD^+ i H_3^+ ionima. Na tabeli II. prikazan je postotak pojedinih vrsta iona u funkciji različitih radnih uvjeta akceleratora.

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