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SOME MEASUREMENTS ABOUT RESOLUTION AND ISOTOPIC CONTAMINATION OF THE KARLSRUHE ELECTROMAGNETIC ISOTOPE SEPARATOR

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The Karlsruhe electromagnetic isotope separator is a 180° sector machine with an inhomogeneous magnetic field ($n = \frac{1}{2}$) and a mean radius of 102.5 cm. A Nielsen-type ion source was used with a maximum beam current of 500 μA. Measurements of the resolving power were made with Pb and Sb at different beam currents, different vacuum pressures, and different source exit apertures. At 0.1% of full line height a maximum resolving power of 1000 was obtained. ^{212}Pb was collected on a thin foil and the collector distribution of the α-activity was measured.

1. Introduction

The Karlsruhe isotope separator is mainly applied for the separation of nuclides for measurements in nuclear spectroscopy. These nuclides are produced by a 50 MeV isochronous cyclotron. To get a general survey of the expected isotopic contamination at our working conditions the dependence of the resolving power on the total collector current and vacuum has been studied. The general lay-out of the separator is shown in fig. 1, ref. [1]). The mean radius is 1025 mm, the inhomogeneity $n = \frac{1}{2}$, the total deflection angle 191°, the sector angle of the magnet 180° and the angle of the collector plane with the direction of the central beam 34°. The vacuum chamber is evacuated by three diffusion pumps. One of them evacuates the ion source region which is connected with the main vacuum chamber

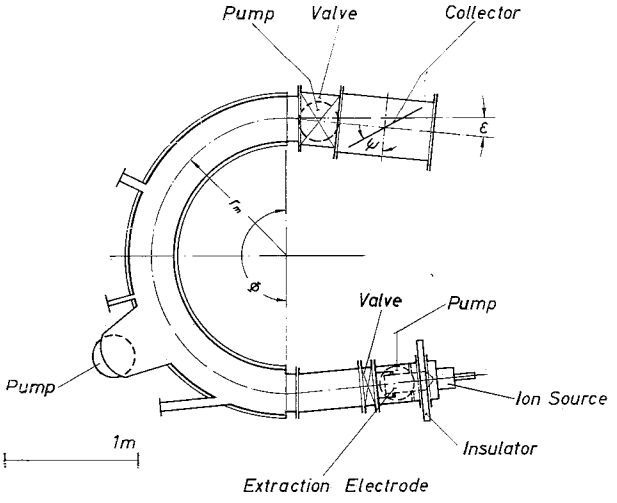

Fig. 1. General lay-out of the Karlsruhe isotope separator.

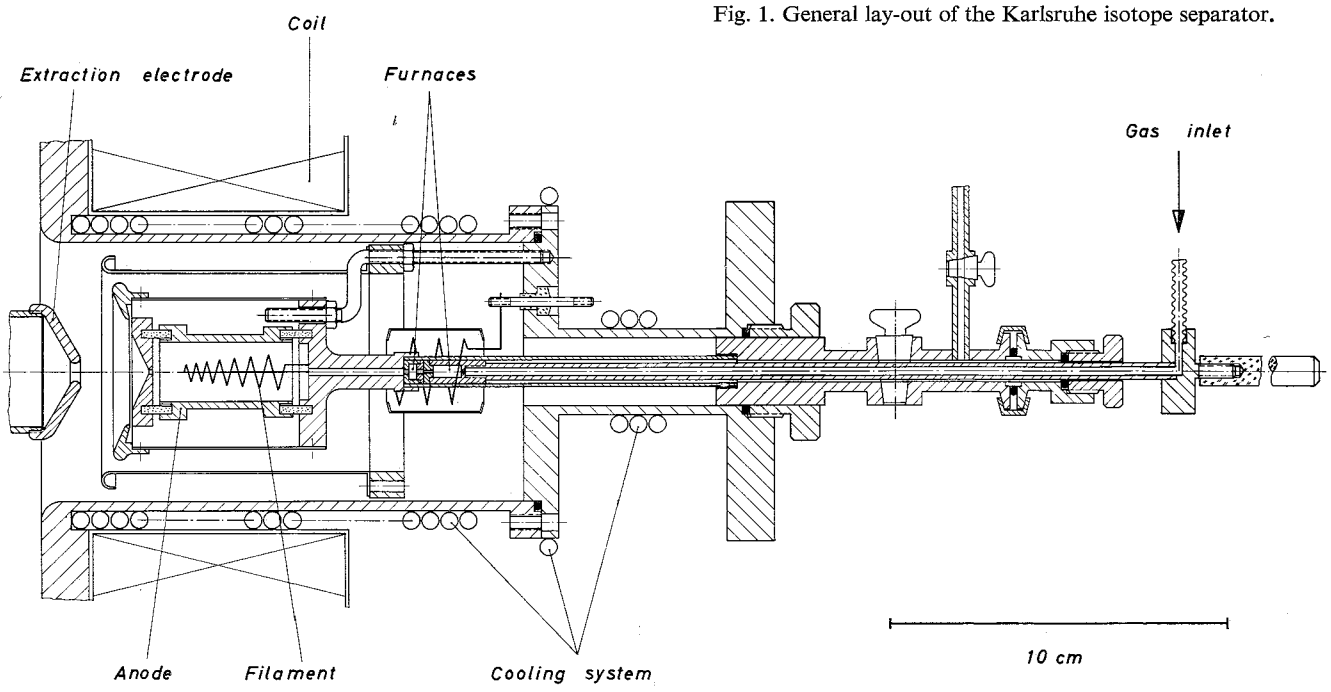

Fig. 2. Ion source.

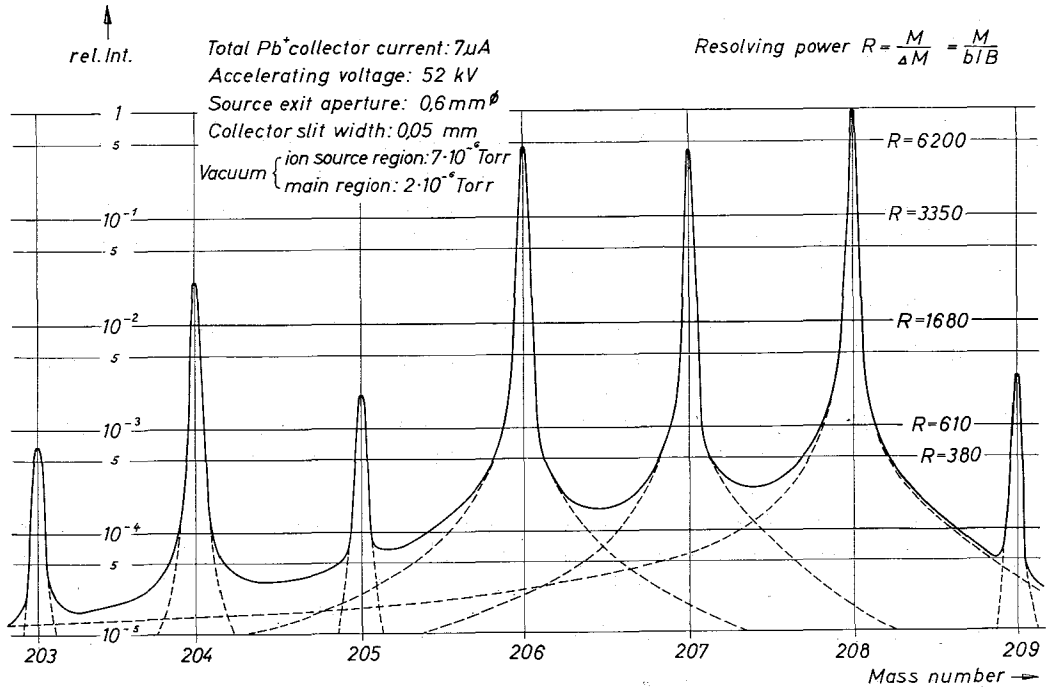

Fig. 3. Mass spectrum of the lead ion beam.

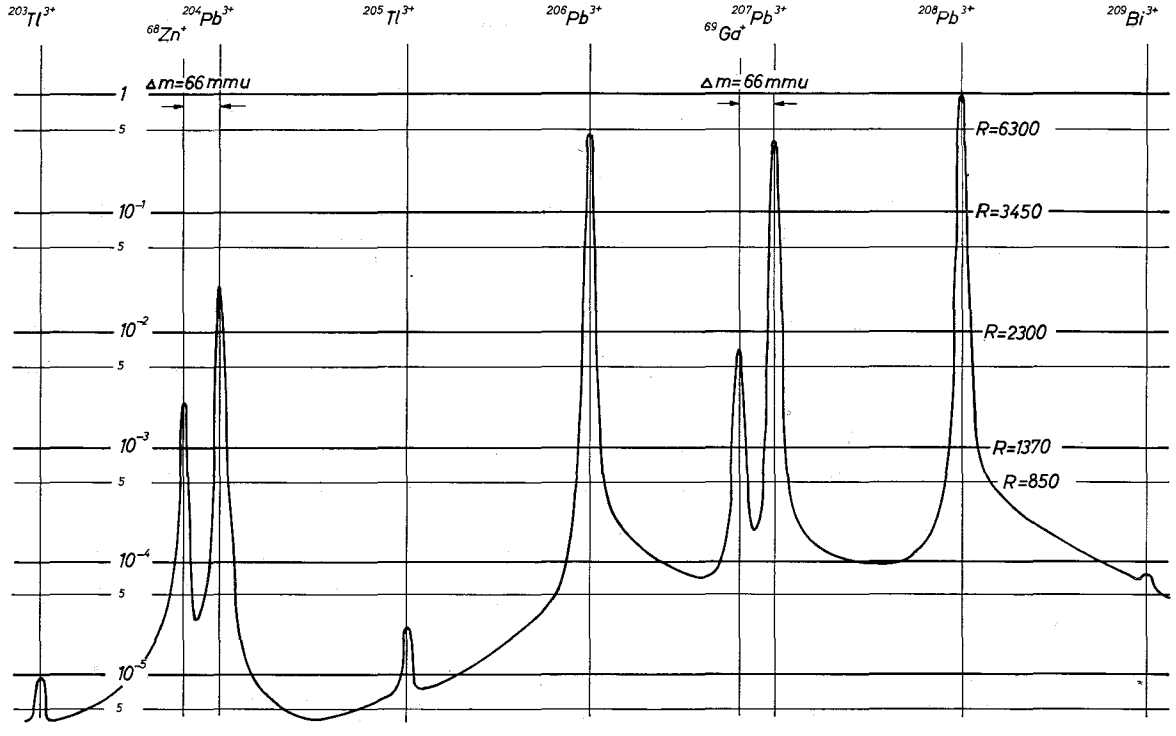

Fig. 4. Mass spectrum of Pb^{3+}.

only by the small aperture of the extraction electrode (differential pumping). The extraction electrode can be moved continuously along the optical axis. The high voltage equipment allows to work with voltages up to 70 kV and with extracted ion beams up to 500 μA. The separated isotopes can be collected on a thin foil of 50 cm length which is placed along the focal plane. The collector has a mass range of $\Delta m = \pm 7\%$ of the medium mass value. The beam shape is controlled by a beam scanner during the time of separation. A pin stabilization system reacting on the high voltage supply by means of a feed-back loop fixes the beam position at the collector. Fig. 2 shows the Nielsen-type ion source[2]). The cathode is able to heat the discharge chamber to 1000° C. When separating short-lived nuclides we use two furnaces which are arranged one behind the other and which are heated by the same heater. The first cylindrical furnace having a circular hole contains the inactive carrier-material which is used for reaching stable running conditions in the ion source and for beam stabilization. The second furnace containing the active material can be moved up to the first furnace by using an insulating stick while the separator remains running. A vacuum lock permits this movable furnace to be easily exchanged. When the charge materials are present as oxides with a low vapour pressure chlorine is directly introduced into the furnace by way of a needle valve[3]).

2. Resolution

2.1. Mass spectra

Fig. 3 shows the mass spectrum of lead. The spectrum is taken with an X-Y-recorder. By changing the accelerating voltage the mass scale is displayed on the x-axis. On the y-axis which is divided logarithmically the collector current is recorded by a logarithmic electrometer amplifier. The diameter of the ion source exit aperture is 0.6 mm, the collector slit width 0.05 mm. The resolving power R is given for various fractions of full line height. The resolving power, in this context, is defined as follows: $R = M/(\Delta M) = M/(b/B)$. Here b is the width of the focal line in the respective height, B is the distance between the masses m and $(m+1)$. As can be seen the resolving power is 6200 at 50% height and 610 at 0.1% height. Thallium and bismuth are present in the discharge chamber as a result of preceding separations. The mass spectrum of the triply charged lead is shown in fig. 4. The running conditions are nearly the same as in fig. 3. The tails on the low mass sides, mainly resulting from charge transfer near the ion source outlet, are smaller in the spectrum of the triply charged lead because the transfer processes to Pb^{3+} have low cross sections. In the spectrum of the triply charged lead two doublets can be seen. The mass differences of the $^{207}Pb^{3+}$–$^{69}Ga^{+}$ and $^{204}Pb^{3+}$–$^{68}Zn^{+}$ doublets are 66 millimass units each. Fig. 5 shows a spectrum in the medium mass

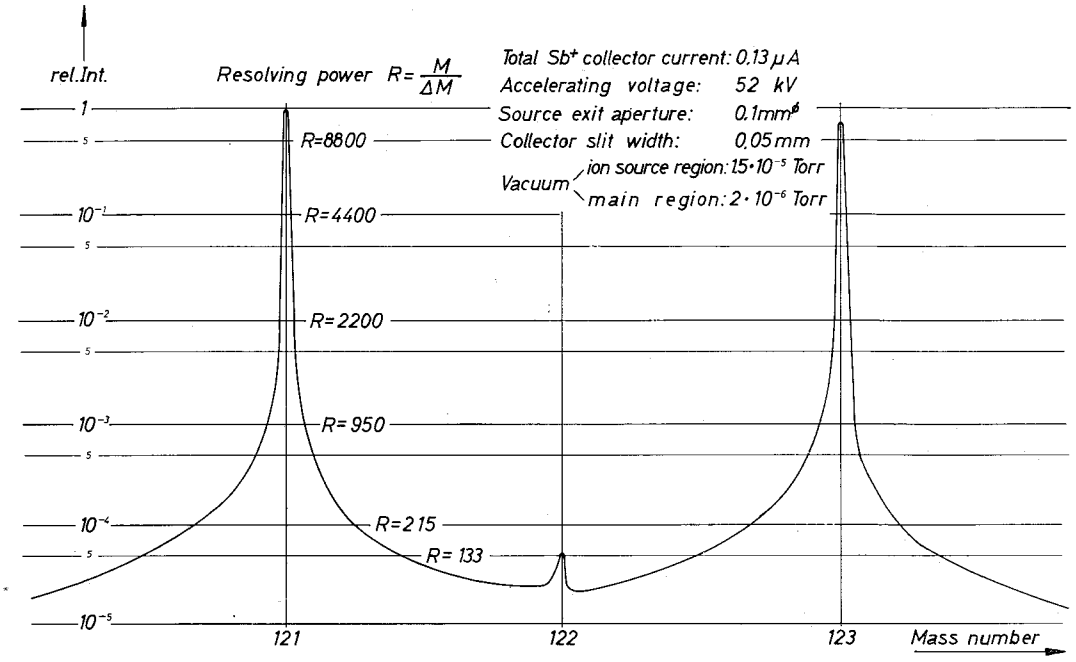

Fig. 5. Mass spectrum of the antimony ion beam.

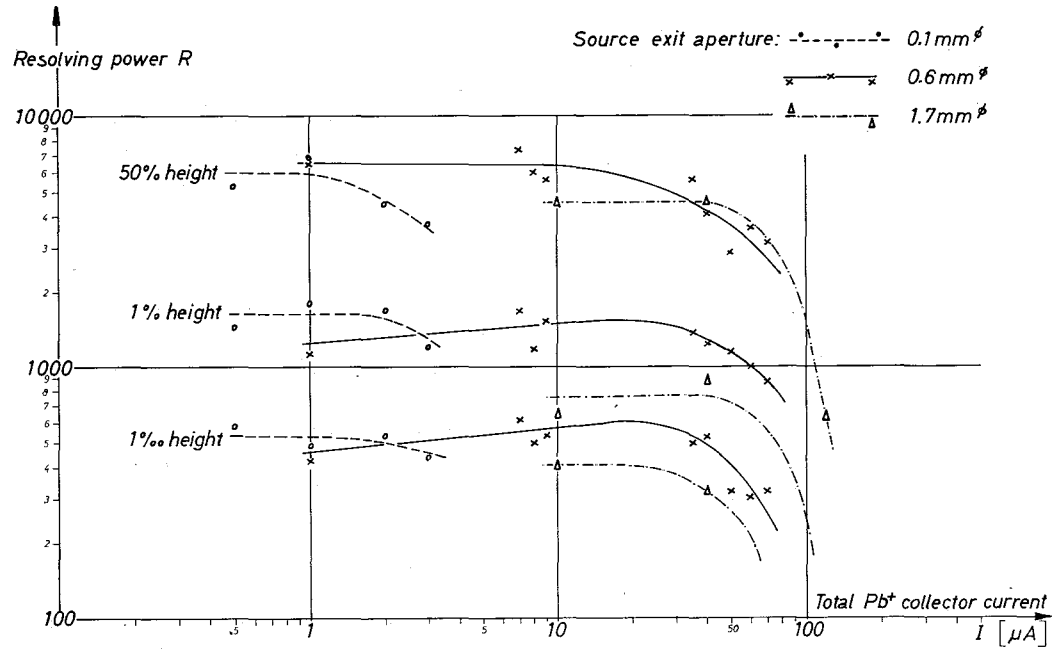

Fig. 6. Resolving power vs collector current for various source exit apertures.

range. In the presented spectrum of antimony we have the case of distant masses, a small source exit aperture, and a small collector current. The resolving power is 950 at 0.1% peak height.

2.2. Influence of beam current and vacuum pressure

The resolving power corresponding to 50%, 1% and 0.1% height, as a function of the lead collector current for various ion source outlets, is given in fig. 6. The exit hole diameters are 0.1 mm, 0.6 mm and 1.7 mm respectively. The resolving power measured with the 0.6 mm aperture is nearly constant up to about 50 μA collector current. For larger currents space charge effects cannot be compensated with our relatively simple accelerating optics. Using the 0.1 mm dia.

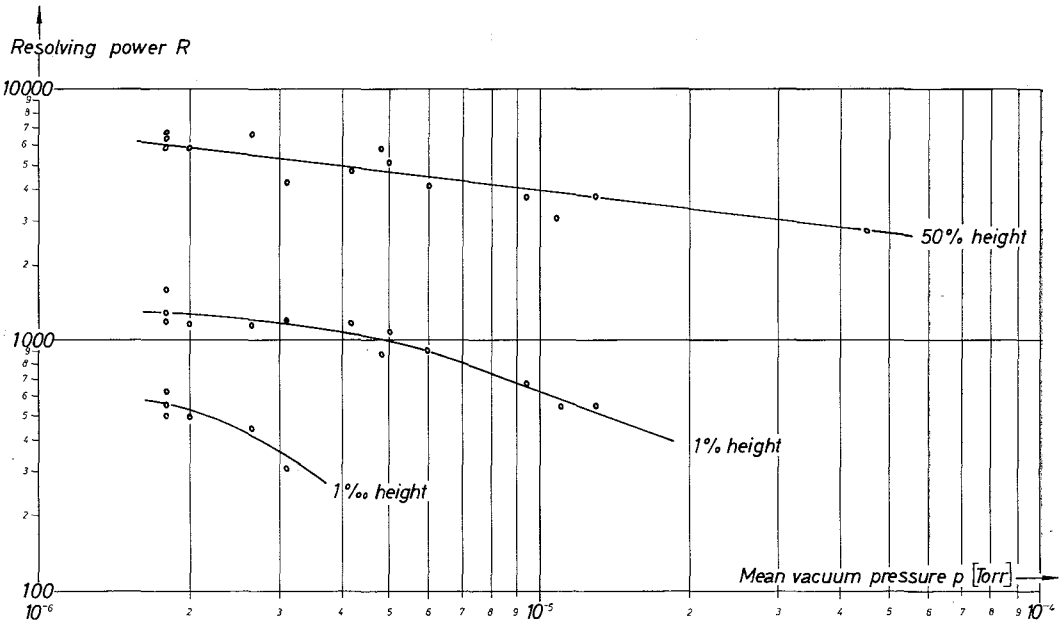

Fig. 7. Resolving power vs vacuum pressure.

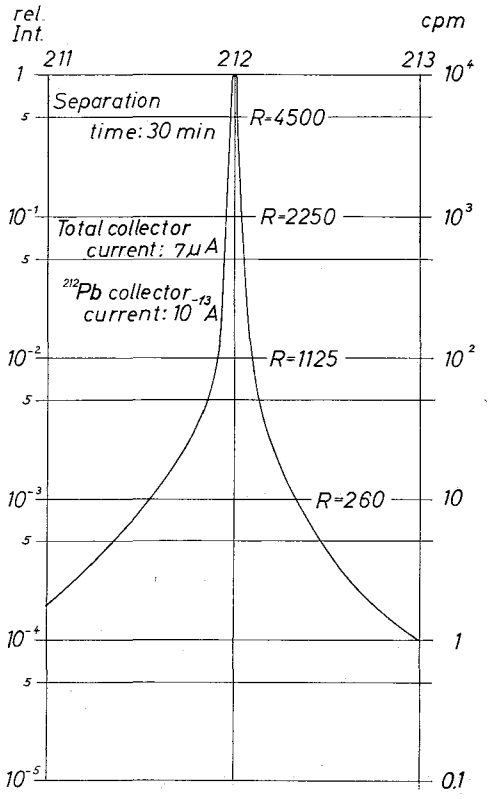

Fig. 8. Activity distribution of separated ^{212}Pb collected along the focal plane.

aperture only little improvement can be achieved even with small currents. Fig. 7 shows the resolution as a function of the vacuum pressure. By letting in air through a needle valve into the vacuum chamber the pressure is varied. When the pressure is increased the tails of the lines are broadened by scattering and charge exchange.

3. Collector distribution

The distribution of separated ^{212}Pb on the collector along the focal plane is measured by the α-activity of its daughters (fig. 8). The distance between the masses 212 and 213 is 20 mm. The stabilization of the beam position was obtained by using ^{205}Tl and the separation time was 30 min. The radioactive isotope is deposited carrier-free on a copper wire which is brought into the furnace. The separated ^{212}Pb is collected on a thin foil and the α-activity measured with a semiconductor detector by moving the foil with a velocity of 20 mm/h below a slit of 0.4 mm width. The counting rate is continuously recorded. We may compare this ^{212}Pb distribution with the spectrum shown in fig. 3 where the dashed curves are the components of the different masses, which add to the total spectrum. This comparison shows that for longer separation times the additional beam contamination resulting from instabilities in the ion source is small. In the case of the ion beam spectrum of fig. 3 the relative intensities at the distance $\Delta m = 1$ are 6×10^{-5} at the low mass side and 4×10^{-5} at the high mass side. In the case of the collector distribution (fig. 8) these intensities are 1.8×10^{-4} and 1×10^{-4}.

The results show that a very high purity of separated samples for measurements in nuclear spectroscopy can be obtained in our low intensity isotope separator.

References

1) A. Hanser, S. Göring and H. J. Langmann, Conf. Physics of the E. M. Separation Method (Orsay, 1962, unpublished).
2) K. O. Nielsen, Nucl. Instr. **1** (1957) 289;
O. Almén and K. O. Nielsen, Nucl. Instr. **1** (1957) 302.
3) J. Uhler and T. Alväger in *Electromagnetic Separation of Radioactive Isotopes* (ed. M. J. Higatsberger and F. P. Viehböck, Springer-Verlag, Vienna, 1961).