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Memorandum

A NOTE ON THE PRODUCTION OF INTENSE BEAMS OF NEGATIVE HEAVY IONS

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J. H. FREEMAN W. TEMPLE D. CHIVERS

Chemistry Division,
Atomic Energy Research Establishment,
Harwell, Berkshire.

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A NOTE ON THE PRODUCTION OF INTENSE BEAMS

OF NEGATIVE HEAVY IONS

by

J. H. Freeman
W. Temple
D. Chivers

Abstract

Some preliminary experiments on the use of a lithium vapour charge-exchanger with an isotope separator heavy ion source to produce negative ions is described. High intensity isotopically resolved beams of a range of elements and compound ions were readily obtained ($\geq 200 \mu\text{A Te}^-$; $\geq 50 \mu\text{A Ni}^-$; $\geq 25 \mu\text{A Fe}^-$; $\approx 1 \mu\text{A U}^-$).

Chemistry Division,
U.K.A.E.A. Research Group,
Atomic Energy Research Establishment,
HARWELL.

February, 1971.

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Illustrations

1. Negative ion spectrum obtained using nickel chloride in the ion source.
2. (a) Negative ion spectrum obtained using uranium tetrachloride in the ion source.
The sharply resolved peaks are due to simple charge-exchange reactions (e.g. $U^+ \rightarrow U^-$, $UCl^+ \rightarrow UCl^-$). The broader peaks are due to charge-exchange and dissociation (e.g. $UCl_n^+ \rightarrow UCl_{n-1}^-$).
(b&c) the calculated mass positions and relative isotope abundances corresponding to the measured spectrum.
3. Isotopic spectrum of a 40keV, 200 μA Te^- beam.

There is currently a considerable interest in the production of negative ions of a wide range of elements for injection into high energy tandem accelerators. Such beams are required for nuclear studies and also for ion implantation at high energies. In particular metallic ions are of interest for the simulation of neutron damage in reactor fuel element and constructional materials.

Certain negative ions can be extracted directly from discharge sources^{1,2}. Collisional attachment processes in which a fraction of a beam of fast positive ions may pick up two electrons in successive collisions, have also proved suitable for a wide range of elements.

A typical collision attachment ion gun consists of a conventional positive ion source fitted with a gas target canal. Conventional gaseous ion source assemblies are adequate for the production of suitable ion currents of hydrogen, helium and certain electronegative elements³ but the problem of obtaining suitable intensities of metallic ions is more severe. The use of alkali metal vapours in the collision chamber^{4,5}, although technically more difficult, has resulted in higher beam intensities, and Dawton⁶ has reported the production of microampere beams of a variety of elements in this way.

Separator ion sources of the type used at Harwell⁷ are capable of producing milliampere intensities of positive ions of most elements. We have found that the installation of a single lithium charge-exchanger between such a source and the analysing magnet of an experimental isotope separator leads to the formation of sharply focused high intensity negative ion beams of a wide range of elements ($\geq 200 \mu\text{A Te}^-$; $\geq 50 \mu\text{A Ni}^-$; $\geq 25 \mu\text{A Fe}^-$, $\approx 1 \mu\text{A U}^-$).

For the ionisation of low vapour pressure elements more volatile compounds such as the chlorides are commonly used as ion source feed materials. These result in a complex spectrum of positive ions which can readily be resolved in the isotope separator. It is interesting to note that the negative ion spectrum after charge-exchange of the extracted positive ion is of similar complexity and has peaks which can be ascribed both to elemental and compound ions. Fig. 1 shows a typical negative ion spectrum obtained using nickel chloride in the ion source. (The Fe^- impurity peak is due to ion source contamination arising from previous measurements with FeCl_2 .) The spectra also show quite strong, but less sharply resolved Aston Bands produced by dissociation of positive molecular ions in the exchanger. This can be seen more readily in Fig. 2a which shows a part of the spectrum obtained using UCl_4 in the ion source. In this case the beams of U^- , UCl^- , UCl_2^- and UCl_3^- are accompanied by a number of peaks produced by the dissociation $\text{UCl}_n \rightarrow \text{UCl}_{n-1} + \text{Cl}$. The calculated shapes and positions of these groups of ions are shown in Fig. 2b & c, it can be seen that these agree closely with the measured spectra.

The degree of ion scattering in the lithium vapour is low and the resolving power of the separator after charge-exchange remains high. Fig. 3 shows the isotopic spectrum of a 40 keV, 200 $\mu\text{A Te}^-$ beam. Such low emittance isotopically separated beams of negative ions would be suitable for injection into tandem Van der Graaffs.

The small size of laboratory isotope separators of the type used at Harwell⁸* would make them acceptable for use as negative ion injectors for such accelerators.

Acknowledgements

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AERE - M 2491 Fig. 1
Negative ion spectrum obtained using nickel chloride in the ion source.

AERE - M 2491 Fig. 2(a)

Negative ion spectrum obtained using uranium tetrachloride in the ion source. The sharply resolved peaks are due to simple charge-exchange reactions (e.g. $U^{+} \rightarrow U^{-}$, $UCl^{+} \rightarrow UCl^{-}$). The broader peaks are due to charge-exchange and dissociation (e.g. $UCl_n^{+} \rightarrow UCl_{n-1}^{-}$).

AERE - M 2491 Fig. 2(b) & (c)

The calculated mass positions and relative isotope abundances corresponding to the measured spectrum.

AERE - M 2491 Fig. 3
Isotopic spectrum of a 40 keV, 200 μ A Te^- beam.