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Design of a Source of Negative Polarized Hydrogen Ions
Using Charge Exchange in Cesium and Argon*

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The use of the metastable state in hydrogen as a means of producing a beam of polarized ions was discussed in the first paper of the 1960 Basel conference by W. Paul¹ referring to the work of Madansky and Owen,² who failed to obtain a usable beam by this technique because they lacked (a) a reaction giving good intensity of $2S_{\frac{1}{2}}$ atoms relative to $1S_{\frac{1}{2}}$ atoms, and especially (b) a means of selectively ionizing $2S_{\frac{1}{2}}$ atoms relative to $1S_{\frac{1}{2}}$ atoms.

In May of 1964 Donnally³ et al published on the cesium charge exchange reaction, which solved problem (a). This article was stimulating and in October the author visited Donnally's laboratory and urged him to look for charge exchange reactions producing negative ions from the metastable state. The direct process avoids the factor of 10^3 loss of intensity experienced by Haeberli, Gruebler, Schwandt, and Extermann^{4,5} in converting polarized positive ions into polarized negative ions by a carbon foil. We are, of course, encouraged by the success of their source now in use on a Tandem Van de Graaff at Madison.

The yield of the argon charge exchange reaction just reported by Donnally is as good as we dared to hope for last year, and so problem (b) has been solved. The Lamb and Retherford⁶ polarization scheme now appears quite practical. We have designed apparatus which we hope will yield a relatively large intensity of polarized negative ions.

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This apparatus is now under construction and is depicted in simplified form in Fig. 1. Note that the magnetic field is axial; it will be approximately 575 gauss, and covers a region 132 cm long x 48 cm diameter. The components in order from left to right are: the 500 eV ion source, the cesium exchange cell, the deflecting plates, 1500 Mc r.f. cavity, the differentially pumped argon exchange tube, focussing gap, and gap for acceleration to approximately 100 keV. A spin precession device will be needed but is not shown.

One problem that introduces considerable awkwardness into the design is the fact that the negative ions must be generated in the apparatus at approximately 100 kV negative potential in order to satisfy our Tandem Van de Graaff acceptance requirements. Inasmuch as argon, hydrogen, and cesium vapor must be continuously removed from the vacuum regions, three 500 l/s diffusion pump assemblies will be attached at the positions shown; these are at ground potential. Each will have removable liquid nitrogen cooled chevron baffles and the entire vacuum assembly will be bakeable to 200°C to prevent cesium accumulation on surfaces.

It will be necessary to neutralize space charge in the beam in the vicinity of the cesium cell because quenching of the metastable atoms would otherwise be too high. It will also be necessary to deflect the charged particles out of the beam since there is a sizeable beam of negative ions formed in the cesium cell.

In order to obtain large currents, we hope to be able to neutralize space charge in the 500 volt acceleration gap by feeding the electrons into the discharge at 500 eV energy. The neutralization requires

an energy distribution of electrons which varies approximately as the inverse velocity and we hope the ionization processes will give about this distribution. We must expect plasma oscillation to set in and limit the output at some value, but we have no good idea as to the value of space charge neutralized current that can be delivered across a 500 volt acceleration gap. The source must deliver the protons with a small energy spread and this will also limit the output. The 500 eV source problem must be regarded as the most difficult one that we have to solve.

We elected to have the magnetic field span the cesium and argon regions because competing reactions may thereby be reduced. The net yield at 575 gauss could be as much as 7 times larger than what Donnally et al have measured with zero field; we do not know nearly enough about the competition to predict the increased yield, if any. The use of a 575 gauss field over the argon exchange region makes it necessary to use an r.f. transition to depopulate the $M_J = +\frac{1}{2}, M_I = -\frac{1}{2}$ level but the result should be nearly 100% polarization. We plan to use magnetic dipole coupling so the transition is to the $M_J = -\frac{1}{2}, M_I = -\frac{1}{2}$ level of the $2S_{\frac{1}{2}}$ states and this rapidly mixes into a level in the short lived $2P_{\frac{1}{2}}$ state.

The source at this time is exciting in that it appears reasonably certain to yield 0.25 μA of H^+ ions, but 100 times this current is possible with success on the proton source and with a break on the charge exchange yield at 575 gauss.

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POLARIZED ION SOURCE