lend support to the suggestion of Owen, Moe, and Cook that a small fraction of the 8-day iodine^{131} atoms, which decay with a 600-kev beta-ray, emit a 286-kev gamma-ray followed by a 165-kev gamma-ray.

* This document is based on work performed under Contract No. W 7405, Eng 26, for the Atomic Energy Project at Oak Ridge National Laboratory.
** Now at Mellon Institute, Pittsburgh, Pennsylvania.
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A Time-of-Flight Mass Spectrometer with Varying Field

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Of several time-of-flight mass spectrometers that have been proposed recently, only that of Goudsmit[1] gives promise of attaining very high resolution because of the favorable focusing property. The perfect focusing in this instrument can be considered a special case of that obtained in uniform crossed electric and magnetic fields[2] with $E=0$ in this case. It has been recognized that the crossed-field instrument with E having a constant value other than zero could also be used as a time-of-flight instrument in the manner proposed by Goudsmit, but this does not possess some of the advantages of the method proposed here.

In Fig. 1, there is a uniform magnetic field H in the x direction and a uniform electric field E in the z direction. The field E has the value E_0 at $t=0$ and decreases linearly with time to the value $E=-E_0$ at $t=T$. In a coordinate system moving with the proper varying velocity, the ions describe circular paths in which the time for one revolution is given as in Goudsmit's case by

$$T_1=670M/H \text{ microseconds},$$

where M is the mass of the ion in atomic weight units and H the magnetic field in gauss. The y component of the velocity of the moving coordinate system is independent of the initial conditions and the mass of the ions. The z component of this velocity is also independent of the initial conditions, but does depend on the mass of the ions (the present discussion is concerned with singly charged positive ions). However, the distance B in the z direction to the exit slit is chosen only large enough to allow the beam to miss the electrode structure around the source and receiver and to provide sufficient space for the source and receiver.

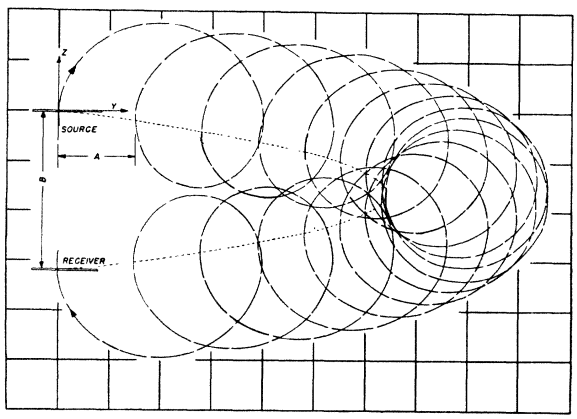

FIG. 1. Path of ions in the case of uniform magnetic field H in the x direction and uniform electric field E in the z direction.

The field E is adjusted so that a selected reference mass M_0 passes through the exit slit after an integral number of cycles n_0. Except for the small z dispersion which has an almost negligible effect in this application but which may be calculated, other ions having the proper mass to undergo an integral number of revolutions n_1 will also be perfectly focused regardless of the initial conditions. Ions having made a non-integral number of revolutions, n, when the moving coordinate system has returned to $y=0$, will be dispersed slightly in the y direction when n does become an integer. This may not be too serious as the exit slit may be made quite wide when a pulsed ion beam is used and the transit time measured in the manner of Goudsmit's instrument. However, as it may be possible to make n_0 very large by a modification of the method of varying E which will be described later, its value could be chosen so that n for the ion being measured will be fairly close to an integer when M_0 is detected. The value n_0 for the reference mass M_0 can be measured experimentally, and the nearest whole number to n may be calculated from the approximate known value of the mass M. The experiment then determines the deviation of n from this whole number by measuring the difference in the arrival times of M_0 and M.

By changing the variation of E with time, the transit time could be increased; for instance, E might be kept at zero at the turning point (maximum value of y) for a period of time while the ions revolve in the magnetic field before increasing E in the negative direction to bring the ions back to the collector. With this technique, the extent of the magnetic field in the y direction may be decreased; in fact, if the variation in E is made in a time less than that for one cycle, a ring-shaped magnet could be used. The displacement of the ion beam might be effected by a small variation in the magnetic field although this compromises somewhat the perfect focusing condition.

The chief difficulties with this scheme appear to be the long ion path and the lack of focusing in the direction of the magnetic field. However, the possibility of detecting some of the ions after a fairly long transit time looks sufficiently promising to justify some exploratory experiments. Furthermore, it appears to be possible to incorporate weak axial focusing if E is kept at zero for an appreciable portion of the time.

A very attractive variation would be to decrease E to zero, allowing the ions to spin at the maximum y displacement of the moving coordinate system and subsequently displace them in a helical path by a weak electrostatic field in the direction of the magnetic field. With this arrangement, perfect focusing is obtained for all masses except for the small z dispersion which is unimportant since this is a time-of-flight device. Using the proton moment[3] to measure the value of the magnetic field, this device could be used to determine e/M (and from it the Faraday) with good accuracy since all measurements would involve only time. Preliminary plans have been completed for the construction of the equipment to do this.

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Search for Stable Pd^{100}, W^{178}, and Pb^{202} *

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April 8, 1949

It has been pointed out[1] that the stability curve got by plotting the mass of the lightest isotope against atomic number shows marked linearity among the heavier elements of even atomic number. Since the breaks in such a stability curve must have significance in a precise theory of nuclear

forces, it is desirable to locate their position accurately. The breaks occurring at palladium, tungsten and lead have been checked by using the Wesleyan University mass spectrograph to search for certain unobserved isotopes of these elements, namely, Pd^{100}, W^{178} and Pb^{202}.

The isotopic constitution of palladium was determined by Dempster[2] in 1935 and an electrical measurement of the isotopic abundances was made by Sampson and Bleakney[3] in the following year. The faintest isotope, Pd^{102}, was found to have an abundance of 0.8 percent. In the present search for Pd^{100}, palladium ions were obtained from a high frequency spark between palladium electrodes. With an exposure of three hours no isotopes of palladium lighter than Pd^{102} were observed on the mass spectrum. On the other hand, Pd^{102} was clearly visible with an exposure of ten seconds. It is concluded that the hypothetical Pd^{100} exists to less than 0.0007 percent. The same limit of abundance can be assigned to Pd^{98}, Pd^{99} and Pd^{101}.

Tungsten is known to consist of five isotopes with mass numbers 180, 182, 183, 184 and 186. Of these, W^{180}, first observed by Dempster[4] in 1937, is much the rarest, constituting, according to Inghram,[5] 0.12 percent of normal tungsten. Although the hypothetical W^{178} has been shown by Inghram to exist to less than 0.002 percent, because of its unique position on the stability curve, a further search for it was made. Tungsten ions were obtained from a high frequency spark between two tungsten electrodes. An exposure of one minute showed the faint W^{180} while an exposure of two hours failed to reveal any isotopes lighter than this. It is concluded that the limit of abundance of W^{178} is 0.001 percent. Also, Inghram's limits of abundance can be lowered to 0.001 percent for both W^{179} and W^{181}.

Lead has four isotopes of which the lightest, Pb^{204}, is the least abundant, constituting, according to Nier,[6] 1.5 percent of normal lead. Using a spark between pure lead electrodes as a source of lead ions, a two-hour exposure failed to reveal any isotopes lighter than Pb^{204}. Pb^{204} itself was clearly visible with an exposure of one second. The limit of abundance of the hypothetical Pb^{202} is reckoned to be 0.0004 percent. The same limit holds for Pb^{203}, Pb^{201} and Pb^{200}.

On the basis of this search it seems reasonable to conclude that stable Pd^{100}, W^{178} and Pb^{202} do not exist. Such a conclusion permits the accurate location of three breaks in the above-mentioned stability curve.

The authors wish to thank Mr. Clifford Geiselbreth for his help in the making of electrodes.

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Concentrating Holes and Electrons by Magnetic Fields

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IN the Hall effect for electrons alone or holes alone the carriers flow parallel to the specimen and the electric field has a transverse component. When both carriers are present, the net transverse current is zero due to compensating flows of holes and electrons to the same side. For low electric fields, recombination and generation keep the concentrations at their equilibrium values. Holes injected by transistor action at e in Fig. 1 were largely concentrated on one side of the germanium filament by virtue of the high electric fields ($\sim$20 v/cm) and small dimensions employed.

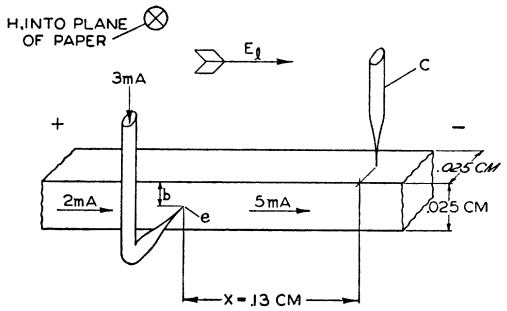

FIG. 1. Experimental arrangement of specimen, currents, and electric and magnetic fields.

The hole concentration at a distance x from the emitter was measured with the aid of a collector point c operated in the reverse direction so as to draw 10 μa. Figure 2 shows the conductance of this point *versus* H for the current conditions shown in Fig. 1. The conductance in excess of the value for $H=-20{,}000$ gauss is considered as proportional to hole concentration and is denoted by g on the left scale. Plus magnetic fields tend to concentrate holes on the collector side and the admittance rises; however, for $H>10{,}000$, the holes are concentrated near the surface and recombine with electrons on the surface so that the hole current decays before reaching c, and g decreases. For minus H, the holes are deflected away from c and g decreases monotonically.

The equations for p, the concentration of holes, are readily derived for: (1) hole concentration much less than electron concentration, (2) equal mobilities and concentrations for holes and electrons; in this case the space charges cancel, producing no transverse field. For (1) the transverse forces on the holes are approximated by a transverse electric field $E_2=E_l\sin(\theta_p+\theta_n)\cong E_l(\theta_p+\theta_n)$, where E_l is the longitudinal electric field $\theta_{p,n}=10^{-8}(R\sigma)_{p,n}H$ and $(R\sigma)_{n,p}=$mobility for electrons and holes ($\cong$1700 cm^2/v sec. for holes), and H is the magnetic field. (For (2), $E_2\cong E_l\theta_p$.) $\varphi=eE_2b/2kT\equiv KE_lH$, where $2b$ is the width of the filament, is a measure of the transverse concentration.

Recombination of holes with electrons on the surface of the filament takes place according to the law (component of hole flux normal to surface) $=s$ times (concentration of holes at the surface). For $H=0$ the concentration across the filament varies as $\cos\beta y$, where y is measured from the center and $\beta b\tan\beta b=sb/D\equiv\psi$, where $D=$diffusion constant.

For the following limiting cases, the values of p are:

for $\varphi\ll1$	$p=1+\varphi+(\varphi/\psi)\sin^2\beta b$,
large $+H$, $\varphi>1$	$p_+=[(4\varphi/\psi)-2]\exp[-A\psi(2\varphi-1)]$,
large $-H$	$p_-=p_+[1-(\psi/\varphi)]\exp(2\psi-4\varphi)$,

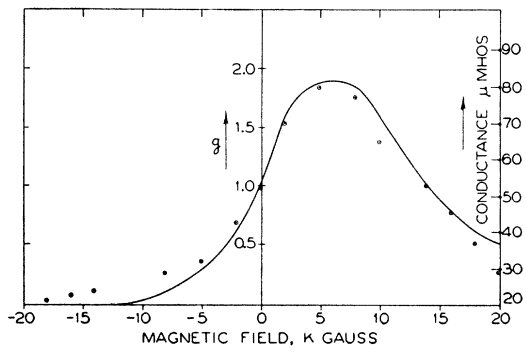

FIG. 2. Conductance of collector point, taken as measure of hole density, *versus* magnetic field.