Inhomogeneous Fields for Mass Spectrography

The use of a nonuniform electric field perpendicular to a homogeneous magnetic field provides the possibility of tremendously increasing the dispersion in the mass spectral analysis of ions. A detailed discussion of the case where the fields are uniform has already been given[1] wherein it is demonstrated that the trajectories followed will be cycloids. When, in particular, an electric field E_x^0 superposed on a magnetic field H_z are chosen, the parametric equations for the ion paths are

$$\begin{aligned} x&=\alpha_0+(eE_x^0/m\omega^2)+(A/m\omega)\sin\omega t,\\ y&=\beta_0-(eE_x^0/m\omega)t+(A/m\omega)\cos\omega t, \end{aligned} \tag{1}$$

where $\omega=eH_z/mc$ and α_0, β_0, A are constants of integration. Depending on the initial conditions, the cycloids will be curate, prolate or common; and will be the latter when $\dot{x}_0=cE_x^0/H_z$, $\dot{y}_0=\dot{z}_0=0$. Then, the cusps will lie among a line parallel to the y axis; $\Delta y_c/y_c=\Delta m/m$; further, the addition of the electric field does not disturb the directional refocusing characteristic of ion paths in a uniform magnetic field.

Let E_x now be a function of y. In a qualitative way one can readily see what the resulting effects would be. Suppose that E_x increases with increasing negative values of y. Since the paths followed by the heavier ions will be in a region of greater E_x than those of the lighter ones, the former will spread out more along the y axis, and the dispersion will increase progressively with m in a manner depending on the form of $E_x(y)$. Rigorous solutions of the equations of motion are difficult to obtain in this case; a method of successive approximations is applicable.

Let the zeroth approximation be expressed by Eqs. (1), and choose the linearly varying field

$$E_x=E_x^0+\epsilon y,\quad E_y=E_y^0+\epsilon x. \tag{2}$$

Substitute in (2) the results of (1) obtaining E_x and E_y as functions of the time only, as a first approximation. The equations can then be rigorously solved. One finds

$$\begin{aligned} x&=\alpha_1+e(E_x^0+\epsilon\beta_0)/m\omega^2+(1/m\omega)(K_1\sin\omega t-K_2\cos\omega t)\\ &\quad+(e/m\omega)(E_y^0+\epsilon\alpha_0)t,\\ y&=\beta_1+e(E_y^0+\epsilon\alpha_0)/m\omega^2+(1/m\omega)(K_1\cos\omega t-K_2\sin\omega t)\\ &\quad-(1/m\omega)\{e(E_x^0+\epsilon\beta_0)t-(e^2\epsilon E_x^0/2m\omega)t^2\\ &\quad+(e\epsilon A/m\omega^2)\sin\omega t\}, \end{aligned} \tag{3}$$

where α_1, β_1, K_1 and K_2 are, once more, constants of integration. It is a simple matter to solve for the extremal values of x and y as given in (3). One finds that the greater the number of periods taken for these modified cycloids, the more nearly correct becomes the relation $y_m\sim m^2$; a large increase in the dispersion has, therefore, been made possible.

It does not appear desirable at this point to go into details as far as the trajectories given by (3) are concerned until higher approximations have been investigated and other functions giving rise to greater dispersion considered. It is to be pointed out, however, that in order to obtain the full benefit of the large dispersion brought about by the nonuniform field, sharpness in the definition of the traces will probably be sacrificed. Hence it would be of great interest to study the refocusing characteristics of such a field combination. From an experimental point of view, the necessity of increasing the pole-gap separation as well as the precise determination of the nonhomogeneous electric field may offer some difficulties.[2]

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October 31, 1935.

[1] L. Page, Phys. Rev. **33**, 553 (1929); **42**, 101 (1932).
[2] F. W. Aston, *Mass Spectra and Isotopes* (Longmans, Green and Co., 1933), p. 77; A. E. Shaw, Phys. Rev. **44**, 1006 (1933).

A New Experimental Method for Study of the Upper Atmosphere

Calculations and laboratory tests indicate that by projecting a *modulated* searchlight beam and measuring the light scattered from sections of its high altitude path at an observing station some kilometers distant, by using a large mirror with a photo-cell and synchronized amplifier, information can be obtained regarding the molecular density and certain other characteristics of the atmosphere in the almost unexplored region from 30 to 70 km, and possibly for even greater heights. A brief description of the method and its possibilities is given in the December, 1935 issue of the *Journal of Terrestrial Magnetism*. This notice is published to reach the attention of workers in numerous other fields who may be interested.

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Doubly Excited States of Helium—A Correction

In a recent article, Wilson[1] noticed a discrepancy between his value for $(2p)^2\,{}^3P$ obtained by Hartree's method, and that obtained by one of us by the variational method.[2] This discrepancy is unfortunately due to an algebraic error in the latter calculation. The correct value obtained by minimizing the integral for $(2p)^2\,{}^3P$ is $(2p)^2\,{}^3P=-1.3976$, and the normalized wave function for ${}^3P$ is

$$\begin{aligned} &(8/9)^{1/2}[Y_{10}(1)\alpha^{5/2}r_1\exp(-\alpha r_1)\,Y_{11}(2)\beta^{5/2}r_2\exp(-\beta r_2)\\ &\quad-Y_{10}(2)\alpha^{5/2}r_2\exp(-\alpha r_2)\,Y_{11}(1)\beta^{5/2}r_1\exp(-\alpha r_1)], \end{aligned}$$

where $\alpha=0.84$, and $\beta=0.83$. The values for $(2p)^2\,{}^1D$ and $(2p)^2\,{}^1S$ obtained with the variational parameters so determined are $(2p)^2\,{}^1D=-1.326$, $(2p)^2\,{}^1S=-1.217$. Thus the value $(2p)^2\,{}^3P=-1.3976$ from the variational method is quite close to Wilson's value -1.4018.

Ta-You Wu
S. T. Ma

National University of Peking,
October 24, 1935.

[1] Wm. Wilson, Phys. Rev. **48**, 536 (1935).
[2] Ta-You Wu, Phys. Rev. **46**, 239 (1934).