$$\alpha = p\left(\frac{2m\mu + \mu^2}{m^2 + p^2}\right)^{1/2};$$

$$B_1(k) = \frac{2k^2}{\pi}\int_0^{\infty} \frac{dk'}{k'(\mu^2 + p^2 + k'^2)^{1/2}}\left[\frac{A_-(k', p)}{(\mu^2 + p^2 + k'^2)^{1/2} - (\mu^2 + p^2 + k^2)^{1/2}} + \frac{A_+(k', p)}{(\mu^2 + p^2 + k'^2)^{1/2} + (\mu^2 + k^2 + p^2)^{1/2}}\right]$$

$$+ \frac{2k^2}{\pi}\int_0^{\alpha} \frac{dk'}{k'(\mu^2 + p^2 - k'^2)^{1/2}}\left[\frac{A_-(ik', p)}{(\mu^2 + p^2 + k^2)^{1/2} - (\mu^2 + p^2 - k'^2)^{1/2}} - \frac{A_+(ik', p)}{(\mu^2 + p^2 - k'^2)^{1/2} + (\mu^2 + p^2 + k^2)^{1/2}}\right]$$

$$- \frac{g^2(\mu^2 + 2p^2)(m^2 + p^2)^{1/2}k^2}{2m^3(\mu^2 + p^2)\{(\mu^2 + p^2 + k^2)^{1/2} - (\mu^2 + 2p^2)/2(m^2 + p^2)^{1/2}\}}. \qquad (14)$$

* After the present work was completed (January 1956) the author learned that B. L. Ioffe and A. Salam had also obtained the relation (8).

[1] M. L. Goldberger, Phys. Rev. 99, 979 (1955).

[2] Goldberger, Miyazawa, and Oehme, Phys. Rev. 99, 986 (1955).

[3] Y. Nambu, Phys. Rev. 100, 394 (1955).

[4] A. Salam, Nuovo Cimento 3, 424 (1956).

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A New Impulse Technique for Ion Mass Measurements

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PRECISE measurement of the mass of isotopes makes it possible to determine the binding energy of nucleons in a nucleus. The existing method of measuring masses through the use of a mass spectrograph involving magnetic deflection is not of sufficient accuracy for medium and heavy nuclei. Consequently, there is justification for proposing a new method of measuring masses.

We are familiar with the existing technique[1-3] for mass analysis which is based on measurement of the time of flight of ions with given energy over a specified distance. However, the energy spread of the ions formed in the source sets a limit of the order of 100 to 200 on the resolving power of this type of instrument. In the following a new method of energy focusing is proposed which is applicable to this type of spectrometer and which can considerably increase its resolving power.

This mass spectrometer has the form of a drift tube which is bounded at both ends by retarding fields with a linear potential distribution. The entire instrument is placed in a weak longitudinal magnetic field. A bunch of ions from the pulsed source is injected into the tube with simultaneous switching-off of the retarding field. Having entered a "potential well' the bunched ions begin to move from one repeller to the other, but the gain in the time of flight by the faster ions over the slower ions with given e/M will be balanced by loss of velocity in the retarding field. Ions with identical e/M and different energies will be focused at a certain point in the drift tube*. After a sufficient number of cycles, when ions with close values of e/M have been separated out, that is, their shift in time of arrival at the focal point is greater than the duration of the pulses, the latter are deflected and recorded. In view of the fact that bunches of ions of different masses will be oscillating in the tube the voltage which must be applied to the deflecting plates will be switched off only at the instant when ions of the masses to be measured are passing. The transit time of ions with mass M, charge Ze and energy U (in volts) in a drift of length l is

$$t_0 = l\sqrt{M/2UZe}. \qquad (1)$$

The time of motion of the ions in a retarding electric field of constant strength E until they are stopped is

$$t = E^{-1}\sqrt{2UM/Ze}. \quad (2)$$

Thus the time of a complete cycle with retarding fields E_1 and E_2 is

$$T = l\sqrt{2M/UZe} + 2(1/E_1+1/E_2)\sqrt{2UM/Ze}. \quad (3)$$

The condition $\partial T/\partial U = 0$ gives

$$1/E_1 + 1/E_2 = l/2U_0. \quad (4)$$

If the magnitudes of U_0, l, E_1 and E_2 are chosen to satisfy the relation (4) we shall achieve first-order space-time grouping (focusing) of ions of different energies. In that event, the time of a complete cycle will be

$$T_0 = 2l\sqrt{2M/U_0Ze}. \quad (5)$$

However, this will not satisfy the condition for second-order focusing

$$\partial^2 T/\partial U^2 = l\sqrt{M/2ZeU_0^5}$$

and the spread in time of a cycle for ions of identical mass but energy spread ΔU is

$$\Delta T_U \approx (l/2)\sqrt{M/2ZeU_0^5}\,(\Delta U)^2.$$

The difference in the period of a cycle for ions of mass difference ΔM but identical energy is

$$\Delta T_M \approx l\sqrt{2/ZeMU_0}\,\Delta M.$$

By equating these quantities we obtain a formula for the limit of resolution which is determined by the energy spread of the ions:

$$\Delta M/M = {}^1/_4(\Delta U/U_0)^2. \quad (6)$$

The precision of the measurements is determined by the duration of a pulse or its linear size. Thus the ratio of the duration of an ion pulse to its transit time must be smaller than the resolution limit. Since in the error formula $\Delta M/M = 2\Delta T/T$, the magnitude of $\Delta M/M$ is given, whereas ΔT is limited by the experimental possibilities, for the purpose of improving accuracy, it is necessary either to lengthen the tube (which is impracticable) or to cause the ions to complete the number of cycles which is required by the formula

$$N = (2M/\Delta M)\,\Delta T/T. \quad (7)$$

On the assumption that the retarding fields and the accelerating potential are supplied by the same source of power the stability of the latter is given by $\Delta V/V = \Delta M/M$. The strength of the longitudinal magnetic field is set at a value such that increase in the sensitivity of the instrument will not diminish its resolving power, that is, it will focus ions whose transverse energy component is below the limit given by

$$H \sim R^{-1}\sqrt{(2M/Ze)\,\Delta U}, \quad (8)$$

where R is the radius of the tube.

Thus ions which are scattered by the residual gas will be lost in the walls at scattering angles which are greater than the permissible values. If, for example, the parameters are as follows: U_0 = 100 v, ΔU = 0.2 v, l = 50 cm, M = 100, ΔT = 0.05 μsec, we obtain T_0 = 145 μsec, $\Delta M/M$ = 10^{-6} and N = 690. At a pressure of $1 - 5 \times 10^{-6}$ mm Hg, the number of ions which reach the detector is a few percent of the initial number.

* Of course it would be possible to employ a field with a quadratic potential distribution so that the oscillation period of the ions would be absolutely independent of their energies, but there are great experimental difficulties involved in the generation of such a field.

[1] A. E. Cameron and D. F. Eggers, Rev. Sci. Instr. 19, 605 (1948).

[2] I. I. Ionov and B. A. Mamyrin, J. Tech. Phys. (U.S.S.R.) 23, 2101 (1953).

[3] H. S. Katzenstein and S. S. Friedland, Rev. Sci. Instr. 26, 324 (1955).

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Electron Broadening of Spectral Lines

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THERE is considerable experimental evidence of the fact that collisions with electrons play an important part in the broadening of atomic spectral lines in a plasma[1-5]. Moreover, there is every