Values of μ_p, F, and M_p/m_e Using the Omegatron

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IN an earlier note,[1] we described a method of measuring the cyclotron frequency of ions with an instrument which we called the omegatron. In illustration of the promise of this method, we presented a preliminary value of the ratio of the cyclotron frequency of the proton ν_c to its precessional frequency ν_n in the same magnetic field. Because this preliminary value has been used by others in several publications, we feel that our most recent results should be made available, although further work will probably improve the accuracy.

A careful study made it apparent that the resonant frequency could be shifted by more than 1 part in 5000 by sufficiently varied operating conditions. A consistent method of correcting for these shifts, which are attributable largely to space charge, has now been developed. Since the frequency shift is proportional to the mass, the true cyclotron frequency can be determined by using the isotopic weights of the ions. The frequency shift can thus be determined by making measurements under identical experimental conditions on several masses. Consistent results for the proton have been obtained by correcting with H_2^+, D_2^+, and H_2O^+. A detailed description will be presented later. Our result is now

$$\nu_n/\nu_c = 2.79268 \pm 0.00006,$$

where ν_n was measured in water. This ratio is μ_p, the proton moment in nuclear magnetons[2] (without diamagnetic correction). Using the gyromagnetic ratio of the proton,[3]

$$\gamma_p = (2.67523 \pm 0.00006) \times 10^4 \text{ sec.}^{-1} \text{ gauss}^{-1}$$

(no diamagnetic correction), and the isotopic weight of the proton,[4] $A_p = 1.007580$, the faraday is

$$F = 9652.03 \pm 0.3 \text{ e.m.u./g (physical scale).}$$

Combining our result on the frequency ratio with the measurement of Gardner and Purcell[5] one obtains

$$M_p/m_e = 1836.12 \pm 0.05.$$

[1] Hipple, Sommer, and Thomas, Phys. Rev. **76**, 1877 (1949).
[2] L. W. Alvarez and F. Bloch, Phys. Rev. **57**, 111 (1940).
[3] Thomas, Driscoll, and Hipple, Phys. Rev. **78**, 787 (1950).
[4] K. T. Bainbridge, "Isotopic Weights of the Fundamental Isotopes," Preliminary Report No. 1, Nat. Res. Council (June, 1948).
[5] J. H. Gardner and E. M. Purcell, Phys. Rev. **76**, 1262 (1949).

A New Method for Determining the Value of the Faraday

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IN a program on the redetermination of the value of the faraday at the National Bureau of Standards twelve determinations were made during the summer of 1949 by anodically oxidizing Bureau of Standards Standard Sodium Oxalate No. 40e in a sulfuric acid solution. As much as 12 g of oxalate was oxidized in a single determination. The average of all but the first result is 9651.93±0.26 e.m.u. Eq^{-1} (physical scale). The first result obtained is omitted from the average because it was agreed that a result obtained in a pilot run should not be averaged with the rest. Its inclusion would change the average less than 1 part in 100,000.

Final publication of the results is being delayed because the authors wish to assure themselves that the reaction,

$$C_2O_4^{--} - 2e \rightarrow 2CO_2,$$

is a pure one. All the evidence so far obtained indicates that this is so, but several additional rather difficult experiments will be required to verify the conclusions on the purity of the reaction. The final determinations are to be made by oxidizing an equivalent weight (67 g) of sodium oxalate. Tests have shown that this can be done. The purity of the sodium oxalate is taken as 99.96$_0$ percent. This value was most painstakingly established by the analytical work of H. B. Knowles and W. Stanley Clabaugh of this Bureau.

The value of the faraday determined electrolytically by the use of sodium oxalate should be of interest to those workers interested in the re-evaluation of the fundamental atomic constants[1,2] because the atomic weights of sodium, carbon, and oxygen are involved instead of the more conventional silver. Furthermore, approximately one-half of the sodium oxalate molecule, $Na_2C_2O_4$, consists of oxygen, whose atomic weight is given by definition. As far as the authors know, this reaction has never before been used to determine a value of the faraday.

Another part of the program at this Bureau is concerned with the anodic solution of pure silver and the cathodic deposition of silver in an electrolyte containing silver perchlorate and perchloric acid. The preliminary results obtained with the two methods involving silver are slightly higher than those obtained with oxalate, but the work has not progressed to the point where final values can be given. However, the average of all the results (25) obtained by the three methods is 9652.33±0.62 e.m.u. Eq^{-1} (physical scale).

In accordance with DuMond's suggestion (Phys. Rev. **77**, 411 (1950)) our values for one gram of singly charged ions of unit isotopic weight might be expressed on the physical scale as 9651.93±0.26 e.m.u./g and 9652.33±0.62 e.m.u./g, respectively. The electrochemist, however, prefers the definition in terms of an equivalent because this definition is an operational one.

[1] J. W. M. DuMond, Phys. Rev. **75**, 1267 (1949).
[2] J. A. Bearden and H. M. Watts, *A Reevaluation of the Fundamental Atomic Constants* (The Johns Hopkins University Radiation Laboratory, July 31, 1950).

Selection Rules for Closed Loop Processes

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TRANSITIONS which can be described by closed loop Feynman diagrams[1] are sometimes forbidden by the symmetry existing between particles and antiparticles. Furry[2] dealt with the case in which electrons and positrons are the particles associated with the closed loop.

A proof of Furry's theorem which can be modified easily for the nucleon case is given in this note. The proof is so modified as to apply to the case of closed nucleon loops connecting meson lines.

The existence of a matrix C such that

$$X^T = \pm C X C^{-1} \tag{1}$$

is well known.[3] Here X is a Dirac matrix and T denotes the operation of transposition. The upper sign holds for[4]

$$X = 1, \quad \gamma_\mu\gamma_\nu\gamma_\sigma(\mu \neq \nu \neq \sigma), \quad \gamma_1\gamma_2\gamma_3\gamma_4,$$

while the lower sign holds for

$$X = \gamma_\mu, \quad \gamma_\mu\gamma_\nu(\mu \neq \nu).$$

The first (second) group of matrices is called even (odd).

Consider the transition

$$\beta_1 \rightarrow \beta_2 + \beta_3 \tag{2}$$

between three neutral bosons (photons or neutral mesons), the process taking place by means of the virtual creation and annihilation of fermions. According to reference 1, the Feynman diagram will be a closed triangle of fermion and antifermion lines with boson lines at the vertices.

Let X_i ($i = 1, 2, 3$) be the Dirac matrices for the fermion-boson interactions. Suppose the fermion and antifermion are created