[14] Hough, L., *Nature*, **165**, 400 (1950).

[15] *Polarimetry, Saccharimetry and the Sugars*, National Bureau of Standards Circular C440 (Washington: Government Printing Office, 1942), p. 507.

[16] Neumann, H., *Experientia*, **4**, 74 (1948).

[17] All melting points are uncorrected. Microanalyses were performed by Midwest Microlab, Inc. Infrared spectra were determined with a Perkin-Elmer Model 237 spectrophotometer.

THE IONIC CENTRIFUGE CAN GIVE FUSION NUCLEAR POWER

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Different equations for the behavior of plasmas have been given by different authors. Since the results of experiments on the Ionic Centrifuge seem to accord better with one of these than with another, it seems desirable to compare them, particularly as the Ionic Centrifuge seems to offer the possibility of successful nuclear fusion.

1. *The Equations Offered by Spitzer.*—The equations offered by Spitzer in his book[1] (p. 18) are for the positive ions

$$n_i m_i\left(\frac{\partial \mathbf{v}_i}{\partial t} + \mathbf{v}_i\cdot\nabla\mathbf{v}_i\right) = \frac{n_i Ze}{c}(\mathbf{E} + \mathbf{v}_i \times \mathbf{B}) - \nabla\cdot\boldsymbol{\psi}_i - n_i m_i\nabla\Phi + \mathbf{P}_{ie}, \quad \text{Sp(2–4)}$$

$$\mathbf{v}_i = \frac{1}{n_i\Delta V}\sum\mathbf{w}_i, \quad \text{Sp(2–5)}$$

$$\boldsymbol{\psi}_i = \frac{m_i}{\Delta V}\sum(\mathbf{w}_i - \mathbf{v}_i)(\mathbf{w}_i - \mathbf{v}_i), \quad \text{Sp(2–6)}$$

where Φ is the gravitational potential, $\mathbf{v}_i$ the mean velocity of the positive ions in an element of volume ΔV, $\mathbf{w}_i$ the actual velocity of the individual ion, and $\boldsymbol{\psi}_i$ is the stress tensor or dyadic of the ions. $\mathbf{P}_{ie}$ is the total momentum transferred to the ions per unit volume per unit time by "collisions" with the electrons.

The corresponding equations for the electrons are obtained by replacing the quantities $\mathbf{v}_i$, n_i, m_i, $\boldsymbol{\psi}_i$, $\mathbf{P}_{ie}$ with $\mathbf{v}_e$, n_e, m_e, $\boldsymbol{\psi}_e$, $\mathbf{P}_{ei}$. Z is replaced by -1.

Of course, by Newton's laws, $\mathbf{P}_{ei} + \mathbf{P}_{ie} = 0$, but it cannot be concluded that $\mathbf{P}_{ei} = 0$ and $\mathbf{P}_{ie} = 0$, no matter what the density of the ions and electrons may be, so long as the electric field and magnetic field are determined by the over-all current, $\mathbf{j} = eZn_i\mathbf{v}_i - en_e\mathbf{v}_e$.

Spitzer then gives as an approximate equation (ref. 1, p. 21)

$$\rho\frac{\partial \mathbf{v}}{\partial t} = \mathbf{j} \times \mathbf{B} - \nabla p - \rho\nabla\phi, \quad \text{Sp(2–11)}$$

where

$$\mathbf{v} = \frac{1}{\rho}(n_i m_i \mathbf{v}_i + n_e m_e \mathbf{v}_e), \quad \text{Sp(2–8)}$$

$$\mathbf{j} = \frac{e}{c}(n_i Z \mathbf{v}_i - n_e \mathbf{v}_e), \qquad \text{Sp(2–9)}$$

$$\rho = n_i m_i + n_e m_e. \qquad \text{Sp(2–10)}$$

I am not able to verify the appearance of $\rho(\partial\mathbf{v}/\partial t)$ instead of $\rho(d\mathbf{v}/dt) = \rho(\partial\mathbf{v}/\partial t) + \rho\mathbf{v}\cdot\nabla\mathbf{v}$ on the left of equation Sp(2–11), which otherwise checks with equation (7.47) of the book of Ferraro and Plumpton.[2]

2. *The Equations Offered by Ferraro and Plumpton.*—The equations by Ferraro and Plumpton (quoting from their book,[2] p. 125) are

$$``\rho_i \frac{d_i\bar{\mathbf{v}}_i}{dt} + \nabla\cdot\mathbf{p}_i - \rho_i\mathbf{F}_i - \nabla\cdot(\rho_i\overline{\mathbf{V}}_i\overline{\mathbf{V}}_i) = \int m_i\mathbf{v}_i\frac{\partial_e f_i}{\partial t}d\mathbf{v}_i. \qquad (7.49)$$

"It is therefore appropriate to introduce the relative pressure tensor $\mathbf{P}_i$ defined by

$$\mathbf{P}_i = \rho_1\overline{\mathbf{V}}_i\overline{\mathbf{V}}_i - \rho_i\overline{\mathbf{V}_i\mathbf{V}_i}, \qquad (7.50)$$

so that equation (7.49) becomes

$$\rho_i\frac{d_i\bar{\mathbf{v}}_i}{dt} + \nabla\cdot\mathbf{P}_i - \rho_i\mathbf{F}_i = \int m_i\mathbf{v}_i\frac{\partial_e f_i}{\partial t}d\mathbf{v}_i. \qquad (7.51)$$

"This corresponds to equation (2.4) page 18 given by L. Spitzer in his book on ionized gases. It should, however, be noted that Spitzer's definition of the pressure tensor does not coincide with that given in equation (7.50), i.e. with the Chapman-Cowling definition."

Note that $i = (1, 2)$ is a running variable with $i = 1$ for positive ions and $i = 2$ for electrons and that to change from Ferraro and Plumpton's variables to Spitzer's variables,

$$F\,\&\,P\left\{\begin{array}{l} \mathbf{v}_1 = \mathbf{w}_i \\ \bar{\mathbf{v}}_1 = \mathbf{v}_i \\ \rho_1 = n_i m_i \\ \mathbf{p}_1 = \psi_i \\ \mathbf{F}_1 = \dfrac{Ze}{m_i}(\mathbf{E} + \mathbf{v}_i \times \mathbf{B}) \\ \displaystyle\int n_1\mathbf{v}_1\frac{\partial_e f_1}{\partial t}d\mathbf{v}_1 = \mathbf{P}_{ie} \\ \text{omitted} = \Phi \end{array}\right\}Sp. \qquad F\,\&\,P\left\{\begin{array}{l} \mathbf{v}_2 = \mathbf{w}_e \\ \bar{\mathbf{v}}_2 = \mathbf{v}_e \\ \rho_2 = n_e m_e \\ \mathbf{p}_2 = \psi_e \\ \mathbf{F}_2 = \dfrac{e}{m_e}(\mathbf{E} + \mathbf{v}_e \times \mathbf{B}) \\ \displaystyle\int n_2\mathbf{v}_2\frac{\partial_e f_2}{\partial t}d\mathbf{v}_2 = \mathbf{P}_{ei} \end{array}\right\}Sp.$$

$$\mathbf{P}_1 = \mathbf{p}_i - \rho_1\overline{\mathbf{V}}_1\overline{\mathbf{V}}_1 \qquad \mathbf{P}_2 = \mathbf{p}_e - \rho_2\overline{\mathbf{V}}_2\overline{\mathbf{V}}_2$$

$\mathbf{V}_1$ and $\mathbf{V}_2$ are vectors defined on page 122 by

$$\mathbf{V}_1 = \mathbf{v}_1 - \mathbf{v}_0 \qquad \mathbf{V}_2 = \mathbf{v}_2 - \mathbf{v}_0 \qquad \text{F\&P(7.28)}$$

where the mean mass velocity $\mathbf{v}_0$ is defined by

$$\rho_0\mathbf{v}_0 = \rho_1\overline{\mathbf{V}}_1 + \rho_2\overline{\mathbf{V}}_2 \qquad \text{F\&P(7.27)}$$

where $n_0 = n_1 + n_2 \qquad \rho_0 = \rho_1 + \rho_2$ F&P(7.26)

The following equation is then universally true:

$$\rho_1\overline{\mathbf{V}}_1 + \rho_2\overline{\mathbf{V}}_2 = 0. \qquad \text{F\&P(7.29)}$$

Making a few reasonable assumptions as to the nature of the "collisions" between ions and electrons, Ferraro and Plumpton replace the integral expressions on the right of 7.49, getting the equations on page 138.

$$\rho_1 \frac{d_1\overline{\mathbf{V}}_1}{dt} + \nabla \mathbf{P}_1 - \rho_1 \mathbf{F}_1 = -\frac{\rho_1\rho_2}{\rho_0 \tau}(\overline{\mathbf{V}}_1 - \overline{\mathbf{V}}_2) \qquad \text{F\&P(7.112)}$$

$$\rho_2 \frac{d_2\overline{\mathbf{V}}_2}{dt} + \nabla \mathbf{P}_2 - \rho_2 \mathbf{F}_2 = \frac{\rho_1\rho_2}{\rho_0 \tau}(\overline{\mathbf{V}}_1 - \overline{\mathbf{V}}_2) \qquad \text{F\&P(7.113)}$$

τ is a finite number and equals zero, when $\bar{V}_1 = 0$ and $\bar{V}_2 = 0$.

3. *The First Discharge of the Ionic Centrifuge.*—By the Ionic Centrifuge[3, 4] is meant a central low-voltage arc source of ionization maintained at low voltage at the center of a rather long circular cylinder through which a longitudinal magnetic field passes. The end-plates which bound the vacuum space longitudinally are maintained at one voltage; the cylinder which bounds the space circumferentially is maintained at another voltage. The anode of the arc is taken as zero voltage.

In the first type of discharge, the end plates were given a high enough negative voltage, and the cylinder was allowed to float. To our very great surprise, the floating cylinder voltage rose with the negative end-plate voltage until it reached the Larmor potential for that radius, $-(e/c^2 8m_1)\mathbf{B}^2 r^2$, and beyond that, it stayed constant.[5] The current of ions, uranium mostly, received by the cylinder was the same as was collected on the end-plates in amount. Making $\overline{\mathbf{V}}_1 = 0$, $\overline{\mathbf{V}}_2 = 0$, and therefore $\tau = 0$, at the floating cylinder, we get the constant voltage of $-(e/c^2 8m_1)\mathbf{B}^2 r^2$, with a constant ion current of one half the whole given by the central arc. This result was found when the arc current was varied from one to one hundred amperes, and the magnetic field was varied over a wide range in more than one hundred tests.

These results are all consistent with the equations of Ferraro and Plumpton, and inconsistent with the approximate equation of Spitzer,[1] page 21.

4. *The Second Discharge of the Ionic Centrifuge.*—If we keep the voltage of the end-plates sufficiently high and that of the cylinder low, then presumably the current taken by the end-plates will be low, limited by space charge, and the whole ion current will be received by the cylinder. If the end-plates are energized with a high enough positive potential and if the circular cylinder at low potential is made up of many slats to permit the escape of neutralized positive ions, then presumably we will realize the conditions for nuclear fusion by using a gas capable of nuclear fusion.

Figures 4, 5, and 6 in reference 3 show the presumed currents.

Summary.—The first book[1] gives the general equations of a completely ionized plasma by equations (2–4), (2-5), and (2-6), page 18, agreeing with the second book[2] in equations (7.49), (7.50), and (7.51), page 125. However, the first book, by making an unjustified (to the writer) assumption (ref. 1, p. 20), arrives at an unjustifiable equation (2-11), page 21. The second book makes a justifiable (to the writer) assumption as to the nature of collisions and obtains equations (7.112) and (7.113), page 138. Comparison with the results of experiments on the ionic centrifuge[3, 4] in its first type of discharge over a wide range indicates that the

second book is right in its conclusions. The Ionic Centrifuge in the second type of discharge would seem to offer the possibility of successful nuclear fusion.

[1] Spitzer, L., Jr., *Physics of Fully Ionized Gases* (New York: Interscience Publishers, Inc., 1956).

[2] Ferraro, V. C. A., and C. Plumpton, *Magneto-Fluid Mechanics* (Oxford University Press, 1961).

[3] Slepian, J., these PROCEEDINGS, **47**, 313–319 (1961).

[4] Slepian, J., these PROCEEDINGS, **48**, 913–914 (1962).

[5] Slepian, J., *J. Franklin Inst.*, **263**, 129–139 (1957).

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*SUPPRESSOR GENE ALTERATION OF PROTEIN PRIMARY STRUCTURE**

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Some suppressor genes are known to act by restoring an enzymatic activity that is specifically lacking in a mutant strain. This could be accomplished in many ways, with or without the alteration of the enzyme in question.[1–3] Suppressor mutations have been detected which affect the A protein of the tryptophan synthetase of *Escherichia coli*. Previous studies have shown that alterations in the primary structure of this protein can result from forward mutation,[4, 5] reverse mutation,[6] and recombination[6] within the structural gene (the A gene) for this protein. The present paper indicates that a suppressor mutation in a region of the genome distant from the A gene also leads to a change in the primary structure of the A protein.

Pertinent Characteristics of the Tryptophan Synthetase System.—The *Escherichia coli* tryptophan synthetase consists of two separable protein subunits, designated A and B. Together these proteins catalyze the following three reactions:[7] (1) indole + L-serine → L-tryptophan; (2) indoleglycerol phosphate ⇌ indole + 3-phosphoglyceraldehyde; (3) indoleglycerol phosphate + L-serine → L-tryptophan + 3-phosphoglyceraldehyde.[8] Reaction (3) is believed to be the physiologically essential reaction in tryptophan biosynthesis.[7, 9] Many A mutant strains produce an altered A protein, designated A-CRM, which reacts with antibody to the normal A protein.[9] All of the A-CRM's detected to date can combine with the normal B protein component, and this complex can catalyze the In → Tryp reaction, but not the other two reactions, i.e., reactions (2) and (3).

Materials and Methods.—The A mutants and suppressed A mutants listed in this paper were produced by ultraviolet irradiation of the K-12 strain of *E. coli*.[9, 19] The methods employed for the preparation of transducing lysates of phage Plkc and for transduction with this phage have been described previously.[10] All cultures of suppressed A mutants used for the preparation of extracts were examined for possible changes in the cellular population, such as reversion in the A gene, by appropriate plating and transduction techniques.

Enzymatic assays,[7] and procedures for the heat-treatment and acid-treatment of crude extracts,[11] have been described previously. Procedures used for the isolation of the A protein,[12] as well as the methods for the digestion of the protein with