Jan. 8, 1935. R. J. CROSS 1,986,920

ELECTROOSMOTIC PROCESS AND APPARATUS

Filed June 28, 1932 2 Sheets-Sheet 1

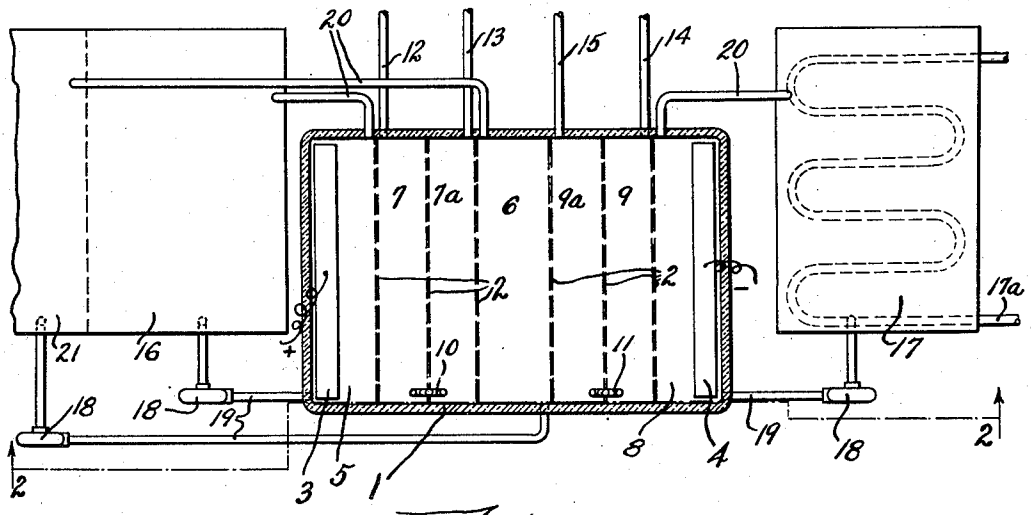


Fig. 1

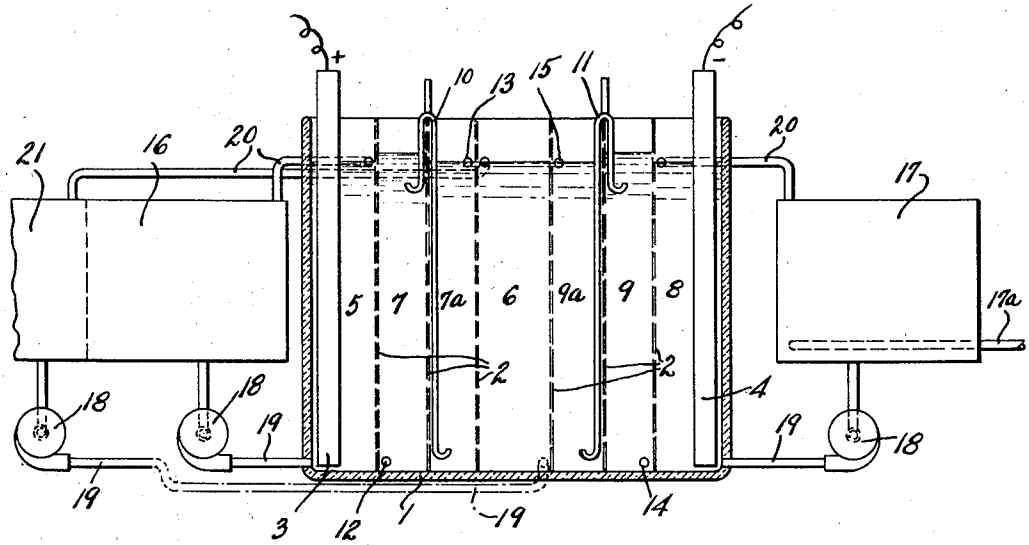


Fig. 2.

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Fig. 3

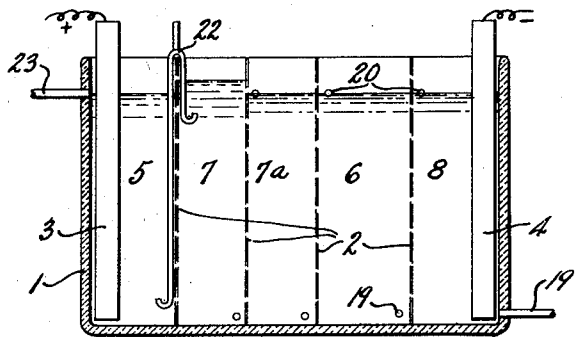


Fig. 4

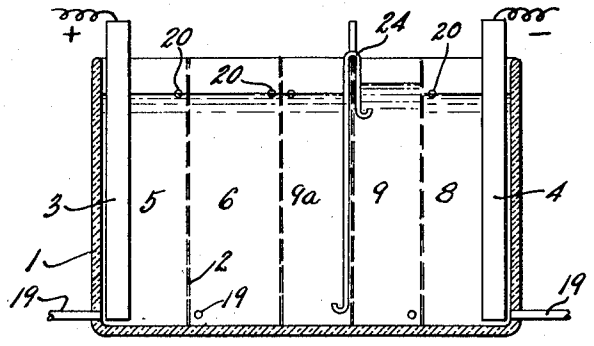
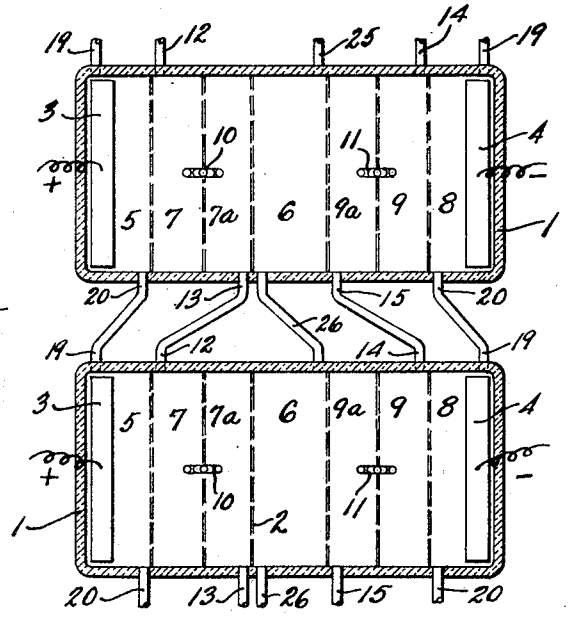


Fig. 5



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ELECTROOSMOTIC PROCESS AND APPARATUS

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3 Claims. (Cl. 204—1)

This invention relates to electro-osmotic method and apparatus, its object being to provide an electro-osmotic cell and a method of operating the same by which more efficient and exact control of the operation may be secured, making it possible to use the method and apparatus for more exact separation or recovery of certain materials, to avoid contamination of one material by another, and to carry out the operation more or less continuously.

A further object of the invention is to provide improved electro-osmotic apparatus in which separation or recovery is secured not only by migrating effects, either electrical or by diffusion, but also by flow conduction of the liquid from place to place, either from compartment to compartment, as will appear, or from a compartment or other part of the electro-osmotic cell to a reservoir, to another cell or the like.

A further object of the invention is to improve the operation of such apparatus by the counter-flow principle, in which flow or travel of the liquid body is produced in a direction contrary to the direction of diffusion of migrating travel of the ions, for any desirable purpose, such as to produce a concentrating effect, or to avoid contamination.

Further objects of the invention are in part obvious and in part will appear more in detail hereinafter.

In the drawings, Fig. 1 is a plan view representing one embodiment of the invention, the containing vessel being shown in section for clearness of illustration; Fig. 2 is a sectional elevation on approximately the line 2—2, Fig. 1; Fig. 3 is a view corresponding to Fig. 2 and showing another arrangement; Fig. 4 is a similar view showing still another arrangement; Fig. 5 is a similar view showing another form. The apparatus shown in the drawings comprises a multiple compartment electro-osmotic cell, which, as to its general form and dimensions, as well as to the form, arrangement and attachment of the semi-permeable membranes, may be constructed in any desirable manner, and is shown for convenience in more or less conventional form. The cell comprises a hollow vessel 1 divided into a series of compartments by semi-permeable membranes 2 through which diffusion and migration of ions can occur. In the end compartments are located respectively a positive electrode or anode 3 and a negative electrode or cathode 4 connected to any suitable source of current. Upon energization of the circuit, with a liquid to be treated in the cell compartments, electro-osmotic action occurs with the migration of anions toward the anode and cations toward the cathode through the several semi-permeable membranes. For various purposes, as will appear more fully hereinafter, I utilize a plurality of semi-permeable membranes, so as to divide the cell to form not only the two end compartments referred to as containing the anode and cathode respectively, and an intermediate or center compartment, but also one, two or more additional guard compartments lying between the center compartment and one or the other or both of the end compartments. Such guard compartments may be located and utilized in a manner to assist in the control of the action for various purposes, such as for providing more exact separation or collection, or for the avoidance of contamination of one material by the other.

In the arrangement shown in Figs. 1 and 2, for purposes of illustration and not in any sense of limitation, I have located two of the guard compartments between the middle compartment and each of the two end compartments. That is to say, between the anode compartment 5 and the center compartment 6 I locate two anode guard compartments 7, 7*a*, and between the cathode compartment 8 and the center compartment 6 I locate two cathode guard compartments 9, 9*a*, the several compartments being formed, as stated, by the provision of the proper semi-permeable membranes 2. Furthermore, I establish communication between each pair of the guard compartments in any suitable manner, such as by a connection of the compartments 7, 7*a* by a siphon 10 and of compartments 9, 9*a* by a siphon 11. Guard compartment 7 is provided with a supply pipe 12 and compartment 7*a* with an overflow discharge pipe 13, while guard compartment 9 is provided with a supply pipe 14 and compartment 9*a* with an over-flow discharge pipe 15, this arrangement enabling a continuous stream of liquid to be supplied to each of the compartments 7, 9, from which the liquid flows or travels by the siphons to the compartments 7*a*, 9*a* and thence outwardly therefrom through the discharge pipes 13, 15.

With such an apparatus the operation is as follows:—

Assuming liquid in the several compartments at the level indicated in Fig. 2, the material to be treated is supplied to the center compartment 6. If all compartments except the center compartment contain distilled water, simple diffusion will occur through the semi-permeable membranes, so that ultimately crystalline mate-

rials dissolved in the liquid supplied to the center compartment will reach all other compartments. However, when an electric current is caused to flow through the liquids in the cells, the migration of ions is promoted and accelerated, and, more important, such acceleration varies with different materials. For example, with a mixture of glutamic acid, which is comparatively acid in its properties, with other amino acids which are more basic in character or more nearly neutral, migration of the ions of the glutamic acid is accelerated to a greater degree than the migration of ions of the other acids. The counter-flow principle involved in the guard compartment arrangement and operation is here intended and utilized to wash back toward the center cell those substances which are undesired. For example, in the instance given, it is made use of to wash back the other amino acids and to permit the glutamic acid to proceed by reason of the greater acceleration of its ions, for the ultimate purpose of separating glutamic acid from the other amino acids.

As a result, the liquid to be treated, containing, for example, glutamic acid and other more basic or more nearly neutral amino acids, is introduced into the center compartment and while the cell is energized by the passage of electric current water is introduced at 12 and the over-flow at 13 is caught and saved if desired. The more slowly migrating ions of the basic and more nearly neutral amino acids are washed back from 7 into 7*a* by the counter-flow of liquid through the siphon 10 and while this action is proceeding, the migration of the ions of glutamic acid proceeds and is accelerated at a greater rate so that the ions of glutamic acid travel beyond the compartment 7 and into the end compartment 5. The ultimate result is the possibility of collecting one substance, such as glutamic acid, in the end compartment, free of contamination with undesirable materials, such as other amino acids, which are washed back toward the center compartment. The compartments 7, 7*a* and 9, 9*a* are therefore guard compartments which shield the end compartments 5, 8 from receiving undesirable materials which otherwise might reach them. Stated in another way, the effect is to utilize the counter-flow principle to wash back or return toward the center compartment and away from the anode (or from the cathode, as the case may be) undesirable substances at a rate fast enough to counteract travel by natural diffusion, but still slow enough so as not to materially interfere with the desired migration of the desirable substances to the anode compartment (or cathode compartment) and its accumulation there.

If desired, the operation may be made more or less continuous and with the further possibility of quite exact regulation of certain conditions in each of the several compartments, such, for example, as the regulation of the hydrogen ion concentration, which is of considerable importance in the separation of various materials from each other, such, for example, as the separation of certain amines as a group from other amines, or the separation of one amine from others of the same group. Thus, by careful regulation of the hydrogen ion concentration, arginine, lysine and histidine, all of which have a high isoelectric point, may be separated from other amines, and by more accurate regulation histidine may be separated from arginine and lysine. Such result I accomplish by connecting certain of the compartments of my cell to outside reservoirs, as it were, so that the reservoirs become parts of the compartments themselves, but capable of containing a larger mass of liquid with the possibility of more exact regulation of the hydrogen ion concentration in the respective compartments. In Fig. 1, for example, the end compartments 5, 8 communicate respectively with reservoirs 16, 17, by way of pumps 18, supply pipes 19 and over-flow pipes 20, while the center compartment 6 communicates with a reservoir 21 by a corresponding pump and supply and discharge pipes. The operation may be carried out as before, with a counter-flow effect or operation in the pairs of guard compartments and with the collection or separation of desirable substances there, but the pH may be readily regulated in the reservoirs containing the large masses of liquid with a corresponding regulation in the compartments with which they communicate. Furthermore, such an arrangement enables the semi-permeable membranes to be placed very close together so as to materially reduce the actual capacities of the compartments themselves, with the possibility of bringing the anode and cathode very close together to reduce the total electric power consumption. Again, the large reservoirs offer a means of readily dissipating any heat produced, because they may be readily provided with cooling pipes or other heat dissipating means, as at 17*a*. Further, the large reservoirs with their larger liquid capacity make it possible to maintain unchanged practically any desired hydrogen ion concentration or any other variable condition, wtihout the rapid or wide fluctuations which occur when the liquid mass is small.

In certain cases, where re-combination with products given off at either anode or cathode might be injurious to the products desirably recovered, the guard compartment next to an end compartment may be worked in tandem with it. Thus, in Fig. 3 it is assumed that the products to be recovered are those which migrate toward the anode, so that guard compartments 7, 7*a* are located between the center compartment 6 and the anode compartment 5. Guard compartment 7 is in circulatory communication, not with the guard compartment 7*a*, as in Fig, 1, but with the end compartment 5, by the siphon 22. Here, a constant stream of liquid is introduced into the guard compartment 7, from which it flows toward and into the anode compartment 5 and thence through the discharge pipe 23 to either the sewer or to a reservoir, with the result of continuously and completely washing all anode products out of the cell so as to keep them entirely separate from the material which is to be collected, which is drained off directly from the guard compartment 7*a*. This compartment, as shown, is not in circulatory communication with any other compartment.

Fig. 4 shows another arrangement in which it is desirable to collect only those materials migrating toward the cathode, the guard compartments 9, 9*a* being in circulatory communication by a siphon 24 in the same manner illustrated in Fig. 1.

Fig. 5 shows still another arrangement in which a plurality of cells are connected successively to each other for successive action on the same material. The cell as a whole may be of the same arrangement shown in Fig. 1 and may be assumed to include all features utilized in connection with the cell of Fig. 1 such as the reservoirs, etc., but in the form shown the center compartment 6 is provided with an in-flow pipe

25 and a discharge pipe 26, which communicates with the center compartment 6 of the next cell, and so on through a series of any number of cells. Likewise, the several end compartments of successive cells may communicate, as a result of which some recovery or collection may occur in any of the compartments of the first cell, such as in the guard compartments or the end compartments, followed by further recovery from the corresponding compartments of each of the following cells.

Other arrangements will readily occur to those skilled in the art.

What I claim is:

1. Electro-osmotic apparatus, comprising a cell provided with semi-permeable membranes forming two electrode compartments, a center compartment between them, a plurality of guard compartments between the center compartment and each of the electrode compartments, and means for causing flow or travel of liquid from guard compartment to guard compartment independently in each set of such compartments.

2. Electro-osmotic apparatus, comprising a cell provided with semi-permeable membranes forming two electrode compartments, a center compartment between them, a plurality of guard compartments between the center compartment and each of the electrode compartments, and means for causing flow or travel of liquid from one of the guard compartments of each set of such compartments toward the corresponding electrode compartment.

3. The method of separating glutamic acid from a mixture containing less acidic amino acids which comprises subjecting a solution containing such mixture to an electrical potential to accelerate the passage of glutamate ions through a semi-permeable membrane at a higher rate of speed than the ions of the less acidic amino acids, simultaneously causing a flow of solution around said membrane in the opposite direction to the movement of the glutamate ions at a rate of speed counteracting the diffusion of the less acidic constituents but slow enough not to interfere materially with the progress of the glutamate ions, passing the glutamate ions through another semi-permeable membrane and collecting glutamic acid.

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