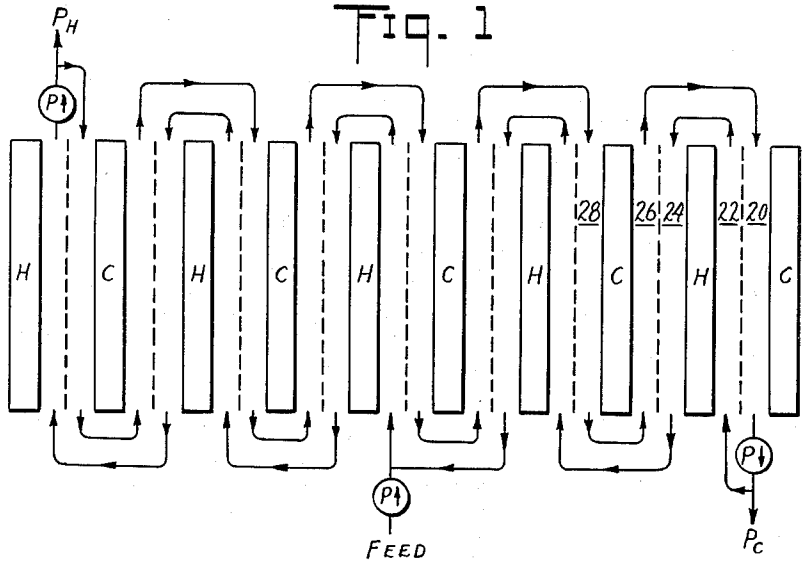
Nov. 15, 1955 W. E. SCOVILL 2,723,759

MULTIPLE SLIT LIQUID THERMAL DIFFUSION APPARATUS

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Fig. 1



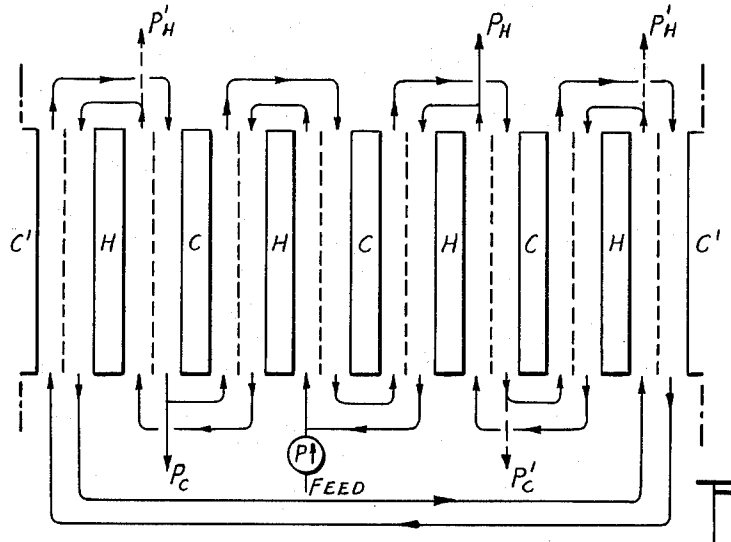


Fig. 6

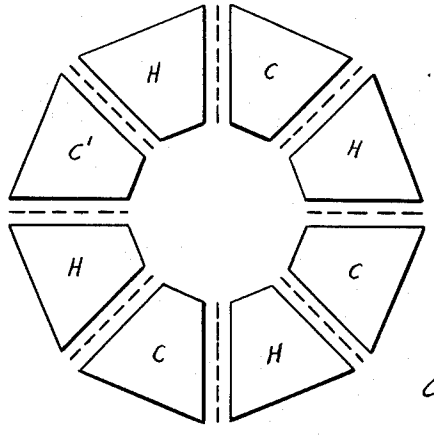


Fig. 5

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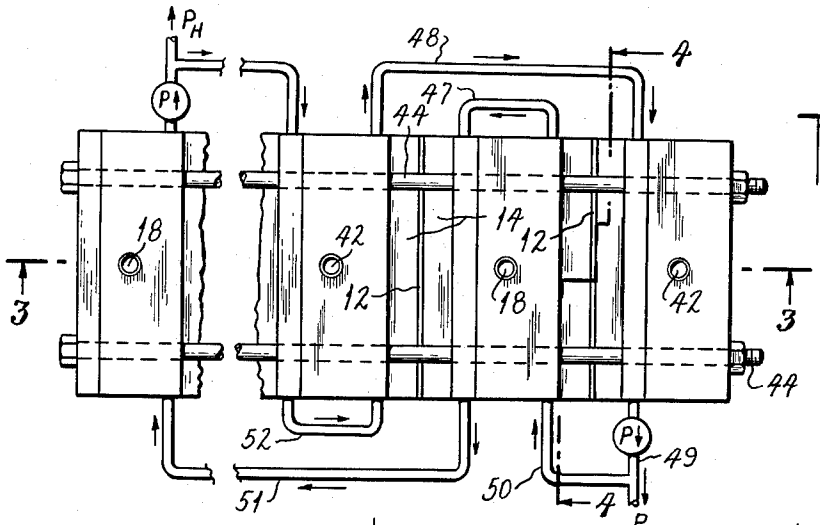


FIG. 2

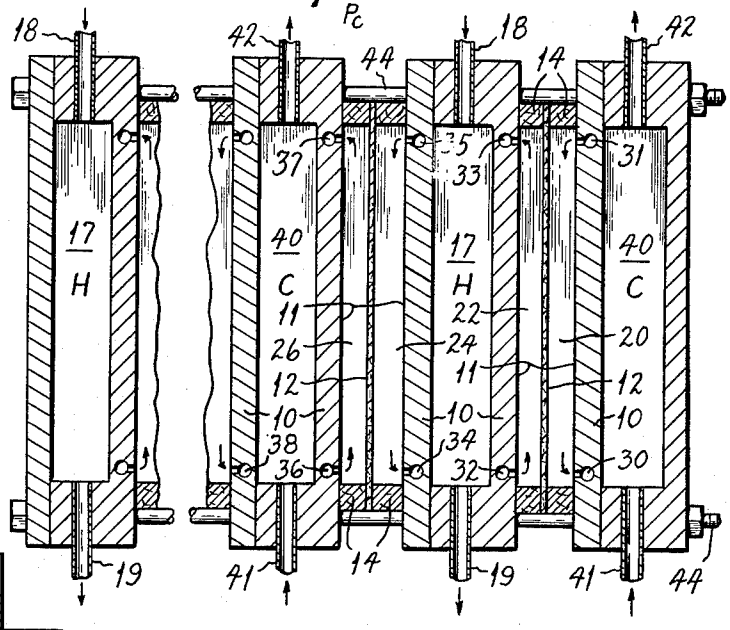


FIG. 3

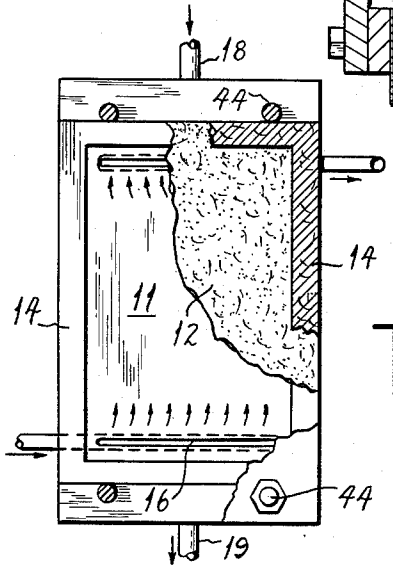


FIG. 4

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2,723,759

MULTIPLE SLIT LIQUID THERMAL DIFFUSION APPARATUS

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Application May 20, 1953, Serial No. 356,284

4 Claims. (Cl. 210—52.5)

The present invention relates to apparatus for separating dissimilar materials in a liquid mixture by continuous liquid thermal diffusion. More particularly, the invention is directed to apparatus having a plurality of liquid thermal diffusion separation chambers each divided into flow chambers by a liquid-permeable membrane.

The art of separating dissimilar materials in a liquid mixture by subjecting the liquid to thermal diffusion dates back almost ninety years but remained largely a laboratory curiosity because of the extremely poor separations, from the standpoint of both quality and quantity, obtained. In recent years, however, interest has been revived in liquid thermal diffusion as a means of separating dissimilar materials in a liquid mixture that are extremely difficult, if not impossible, to separate by other means and to carry out such separations on a scale that would be commercially feasible.

U. S. Patents 2,541,069, 2,541,070 and 2,541,071, granted February 13, 1951, to Jones and Hughes, describe a method of continuous liquid thermal diffusion and apparatus therefor wherein a thin stream of liquid mixture is introduced into a separation chamber defined by closely spaced walls. The walls are relatively heated and cooled to maintain a temperature gradient across the thin stream of liquid in the chamber. As a result of the heating of the portion of the liquid adjacent the wall having the relatively higher temperature, referred to as the "hot wall" or "relatively hot wall," and the cooling of the liquid adjacent the wall maintained at the relatively lower temperature, referred to as the "cold wall" or "relatively cold wall," a thermal circulation is set up wherein the liquid adjacent the hot wall rises in the chamber and the liquid adjacent the cold wall descends. This thermal circulation brings about a countercurrent flow of liquid within the chamber. The thermal diffusion force created by the temperature gradient across the liquid in the chamber operates to move one component of or in the liquid mixture toward the cold wall and another toward the hot wall with the result that the two countercurrent streams in the chamber are each enriched by one component or the other. The molecular movement in the liquid across the chamber and the gross movement of the liquid upwardly along the hot wall and downwardly along the cold wall due to thermal circulation cooperate to concentrate a liquid fraction enriched with a first component at the top of the chamber and another liquid fraction enriched with another component or impoverished in said first component at the bottom of the chamber. In carrying out the method and utilizing the apparatus described in these patents, it is important that the rate of feed of liquid into the chamber should not be such as to disturb the laminar flow of the countercurrent streams in the chamber and promote physical mixing thereof at the interface.

A further improvement in the liquid thermal diffusion art, involving the provision of a liquid-permeable membrane intermediate the hot and cold walls forming the chamber, has been proposed in application Serial No. 218,944 of Jones and Milberger, filed April 3, 1951, now Patent No. 2,712,386, July 5, 1955 and assigned to the same assignee as the present application. This membrane makes it possible to force the liquid into the chamber at higher rates without interfering with the molecular movement of the components to be separated from one side to another due to the thermal diffusion effect and, furthermore, without causing physical mixing of the different fractions. The permeable membrane apparently functions as a barrier to gross flow between, or physical intermixing of the liquid adjacent to the hot and cold walls while permitting the molecules in the liquid to pass freely through its pores and thus bring about a separation of the dissimilar components or materials in the initial liquid mixture by continuous thermal diffusion.

The term "liquid mixture" is used broadly in the present application and is intended to refer to a liquid comprising a mixture of two or more components in a liquid or liquefied state, to a solution of two or more different materials as well as to liquid or liquefied solution containing only one solute. Examples of such liquid mixtures are lubricating oils containing components of different viscosity indices, liquid mixtures of isomeric hydrocarbons and solutions thereof, fatty oils having glyceride esters of fatty acids of different molecular weights and saturation, liquid mixtures of hormones, viruses, antibiotics, etc., an azeotropic mixture of benzyl alcohol and ethylene glycol, fish oil containing active vitamins and substances not having vitamin activity, and the like.

The difference between the dissimilar components in or of a liquid mixture may be extremely minute. Thus, for example, they may have the same empirical formula but differ slightly in structure or molecular weight.

The term "separation" as used hereinafter is intended to include not only separation in the ordinary sense of the word but also rectification, concentration, enrichment, and purification. Thus, for example, "separation into two or more fractions" includes the separation of petroleum products in a liquid mixture thereof; the separation of benzyl alcohol and ethylene glycol from an azeotropic mixture of the same into two fractions, one of which is richer in benzyl alcohol and the other of which is richer in ethylene glycol than the starting mixture; the concentration or enrichment of active vitamins in or from a mixture of ordinarily inseparable components, one of which may have vitamin activity and the other not having such activity; the separation or concentration of antibiotics and other biological products containing the same; the separation or concentration of viruses; and the separation of vegetable oils, fats and waxes into components having different degrees of unsaturation, melting point and indices of refraction, the separation of lubricating oil into fractions having different viscosity indices, and the like.

Generally the apparatus of the present invention comprises a series of heat exchange elements having plane, vertical, smooth and liquid-impervious exterior walls forming a series of substantially vertical and uniformly narrow separation chambers between adjacent heat exchange elements. The chamber-forming walls of adjacent heat exchange elements in the series are substantially coextensive with, parallel to and closely spaced from one another and means are provided for relatively heating the separation chamber-forming walls of alternate heat exchange elements in the series and relatively cooling the separation chamber-forming walls of the heat exchange elements between said alternate heat exchange elements so that each separation chamber is formed by a relatively hot wall and a relatively cold wall. The relatively hot walls of two adjacent separation chambers are

formed by the exterior walls of a single heat exchange element and the relatively cold walls of two other adjacent separation chambers are formed by the exterior walls of another single heat exchange element. Liquid-permeable membranes are provided in the separation chambers intermediate, spaced from and substantially parallel to the separation chamber-forming walls for dividing each separation chamber into parallel flow chambers so that each separation chamber contains one flow chamber adjacent a relatively hot wall and another flow chamber adjacent a relatively cold wall. The combined width of the flow chambers in any one separation chamber may vary between about 0.01 and about 0.15 inches, combined widths between 0.02 and 0.08 inches being preferred. Inlet means are provided for continuously introducing a liquid mixture into at least one of the flow chambers. One outlet means is provided for continuously withdrawing a first fraction of the liquid mixture from a flow chamber in another of the series of separation chambers and another outlet means is provided for continuously withdrawing the second fraction of the liquid mixture from a flow chamber in still another of the series of the separation chambers. Further similar outlet means may be provided for withdrawing additional fractions from other flow chambers. Conduits are provided for interconnecting the flow chambers adjacent the relatively hot walls and the flow chambers adjacent the relatively cold walls in such a manner that liquid moving through flow chambers adjacent the hot walls will move alternately upwardly and downwardly in alternate separation chambers and that liquid moving through the flow chambers adjacent the cold walls will alternately move downwardly and upwardly adjacent the cold walls. As a result, the direction of movement of liquid in the flow chambers of each separation chamber is countercurrent. In alternate separation chambers the flow is also in the same direction as thermal circulation but in the other chambers between the alternate chambers the flow is countercurrent to the direction of thermal circulation.

To facilitate an understanding of the apparatus of this invention and of a typical flow pattern therethrough, reference is made to the accompanying drawing wherein:

Figure 1 is a schematic flow diagram illustrating the manner in which one embodiment of the apparatus of the invention can be used effectively and further illustrating diagrammatically the basic features of the apparatus;

Figure 2 is a schematic plan view of a thermal diffusion apparatus embodying the basic principles of this invention;

Figure 3 is an elevation in section taken on section line 3—3 of Figure 2; and

Figure 4 is an end view in section taken on section line 4—4 of Figure 2;

Figure 5 is a schematic plan view diagrammatically illustrating another embodiment of the apparatus of the invention; and

Figure 6 is a schematic flow diagram showing the manner in which the embodiment illustrated in Figure 5 may be employed.

In Figure 1 the heat exchange elements are diagrammatically represented by rectangles containing the letters H or C, each letter H signifying a heat exchange element that is relatively heated so that its vertical walls will become hot walls, and each letter C signifying a heat exchange element that is relatively cooled so that its vertical walls will become cold walls. The spaces between adjacent heat exchange elements in Figure 1 signify thermal diffusion separation chambers. The dashed lines signify liquid-permeable membranes which divide the separation chamber into flow chambers. The solid lines with arrow heads indicate the direction of transfer of liquid from one flow chamber to another and incidentally also the direction of gross flow of liquid within each flow chamber.

The apparatus illustrated by way of example in Figures 2, 3 and 4 includes a plurality of adjacent heat exchange elements each comprising at least one plane, vertical, liquid-impervious and chamber-forming wall **10** of heat conductive material having a smooth exterior face **11**. The chamber-forming walls **10** of adjacent heat exchange elements are substantially parallel to one another and spaced apart to form a plurality of substantially parallel, vertical and uniformly narrow separation chambers each divided, by a liquid-permeable membrane **12**, into flow chambers, five of which are designated, for convenience in describing a typical operation of the apparatus, by reference numerals **20**, **22**, **24**, **26** and **28**. The permeable membranes **12** may be conveniently maintained between the opposed chamber-forming walls by gaskets **14** as well as by other means described in more detail hereinafter.

Parallel to and adjacent the upper and lower ends of each chamber-forming wall **11** there are provided passages, nine of which, for convenience in describing the operation of the apparatus, are designated by reference numerals **30** to **38**. These passages communicate with the flow chamber immediately adjacent the wall in which the passages are located by means of one or more openings such as a groove **16** shown best in Figure 4. The other ends of the passages are interconnected, as illustrated best in Figure 2 and most completely in Figure 1. Means for relatively heating alternate heat exchange elements are shown diagrammatically as comprising chambers **17** for receiving and discharging a heating medium such as steam, by way of lines **18** and **19**. Heat exchange elements that are relatively cooled are shown as comprising chambers **40** supplied with a cooling medium by way of lines **41** and lines **42**.

In the embodiments shown in Figures 2 to 4 the various heat exchange elements of the apparatus are held together by tension bolts, or the like, shown at **44**.

The walls **10** may be of any suitable material, such as stainless steel, copper, aluminum, glass, brass or other alloys, that is liquid-impervious, heat conductive, and inert to any of the materials being separated. The width of the separation chamber, exclusive of the thickness of the membrane, i. e., the combined width of the two flow chambers in each chamber, may be up to about 0.15 inch. Theoretically, there is no minimum combined width of flow chambers that would be too small, but as a practical matter, it is difficult to fabricate the walls and the permeable membrane within sufficiently small tolerances to obtain clearances between both sides of the membrane and the respectively adjacent wall faces without making the combined width of the flow chambers at least about 0.01 inch. Combined widths of the order of about 0.02 to about 0.06 inch are feasible structurally and preferred as optimum for most liquid thermal diffusion operations. Excellent results are obtainable, however, due to the much higher flow rates and separations made possible by the membrane, when the combined width of the flow chambers is as great as about 0.08 inch.

Generally, the membrane must be permeable and reasonably inert with respect to, and unaffected as to permeability by, all components of the liquid to be subjected to continuous thermal diffusion. It is preferred to make the membrane thin or a good conductor or both. The optimum thickness is necessarily a compromise between a minimum for the requisite heat conductivity and a maximum for strength. If necessary to avoid complete or partial blocking of the flow chambers, the membrane may be supported, on one or both sides, against lateral displacement by spacers or the like such as are described in application Serial No. 271,182 of Jones and Milberger, filed February 12, 1952, and assigned to the same assignee as the present application.

It has been found that membranes having a large number of very small pores give better results than membranes having a smaller number of larger pores, possibly because larger pores tend to permit gross flow of the

liquid as distinguished from movement of molecules or the like through the pores due to thermal diffusive forces. The minimum size of the pores in the membrane is that sufficient to permit free movement, due to thermal diffusive forces, of all of the molecules or other particles in the liquid subjected to thermal diffusive forces. There is no critical upper limit to the size of the pores but it is generally preferable that the average pore size be not appreciably greater than about 5 to 10 microns on the average. Larger pore sizes do not by any means render the thermal diffusion process inoperable. They are undesirable, however, because such larger pore sizes promote gross flow of the liquid therethrough to an extent that results in a physical remixing of the enriched liquid fractions on the two sides of the membrane while adding nothing to the ease with which the molecules in the liquid may move across the separation chamber due to the forces of thermal diffusion.

Papers such as duplicator paper, 16-, 20- and 24-lb. bond paper, and tracing paper have been found quite suitable as membrane material. Films of bentonite clay, thin sheets of porous stainless steel, and a laminate of fiber-glass material impregnated with a finely divided filler such as clay have also been found suitable.

The shape of the separation chamber-forming walls has no appreciable effect upon the degree of separation obtainable. The chambers formed by the opposed walls may be long and narrow, as in the liquid thermal diffusion apparatus described in U. S. Patent No. 2,541,069 wherein no membrane is provided, or it may be square, trapezoidal or of any other shape.

It has been found that the degree of separation obtained with the apparatus of this invention is dependent primarily, all other conditions being equal, upon the area of the permeable membrane. For structural simplicity, therefore, it has been found preferable to utilize flat and substantially square sheets of metal as the walls.

The openings such as opening **16** in the chamber-forming walls and the passages with which they communicate are preferably positioned and constructed in such manner as to minimize turbulence in the flow of the liquid entering or leaving the flow chamber with which they communicate. Typical constructions that are desirable are described and illustrated in application Serial No. 273,737 of Jones, Seelbach and Frazier, and in applications Serial Nos. 273,738 and 273,739 of Jones, all filed February 27, 1952, and assigned to the same assignee as this application.

In operation, the apparatus illustrated by way of example in Figures 2 to 4 and further illustrated diagrammatically in Figure 1, is filled with the feed, i. e., the liquid mixture, and the heat exchange elements are respectively heated and cooled, bearing in mind that the temperature at the hot walls should not be above the boiling or decomposition point of the liquid or any of its components and that the temperature at the cold walls should not be below the freezing point or crystallization temperature of the liquid or any of its components, nor so low as to render it too viscous.

The liquid is then forced through the apparatus by means of pumps or the like, as indicated in Figure 1, at a speed that is in excess of the normal speed of thermal circulation referred to earlier. As shown in Figures 1 and 3, the liquid moving upwardly along the hot wall in flow chamber **22**, for example, is transferred by way of passage **33**, conduit **47** and passage **35** to an adjacent flow chamber **24** for movement downwardly along the hot wall and from there is transferred, by way of passage **34** and conduit **51**, to another adjacent separation chamber for movement upwardly along a hot wall. The liquid moving downwardly along the cold wall in flow chamber **28**, for example, is on the other hand, transferred, by way of passage **38**, conduit **52** and passage **36**, to the flow chamber **26** in an adjacent separation chamber for movement upwardly along the cold wall and then, by way of passage **37**, conduit **48** and passage **31**, to the flow chamber **20** in another adjacent separation chamber for movement downwardly along the cold wall, and so on. At one end of the series of separation chambers, as shown best in Figures 1–3, a portion of the liquid fraction in flow chamber **20** adjacent a cold wall is withdrawn from the apparatus by way of passage **30** and conduit **49** as product P_C, the remainder being recycled by way of conduit **50** to flow chamber **22**. At the other end of the series of separation chambers, as shown in Figure 1, a portion of another liquid fraction in a flow chamber adjacent a hot wall is withdrawn from the apparatus as product P_H, the remainder being recycled to an adjacent flow chamber.

While these movements describe the gross flow of the liquid, it is to be borne in mind that due to the temperature gradient across each separation chamber there is also a molecular movement of materials across each separation chamber and through the membranes which results in a preference of some molecules for the flow chamber adjacent the hot wall and of other molecules for the flow chamber adjacent the cold wall. The molecules are then carried along with the gross flow of the liquid in the flow chamber and said liquid, being thus enriched in the particular component represented by these molecules, becomes further enriched in successive passages through successive chambers until it is withdrawn either from adjacent a hot wall at one end of the apparatus as product P_H or at the other end of the apparatus as from adjacent a cold wall as product P_C.

The apparatus illustrated in Figures 5 and 6, and its operation, is essentially similar to that shown in Figures 1 to 4 except that the heat exchange elements, indicated by H and C, are arranged differently and several alternate points of withdrawal for fractions P_H and P_C are indicated at P'_H and P'_C.

The apparatus of this invention is to be distinguished from apparatus utilized in conducting separation methods based on osmosis and dialysis as well as from apparatus utilized in gaseous thermal diffusion and static liquid thermal diffusion methods.

In osmosis the separation or concentration of a solute in a solvent depends upon the semi-permeability of a membrane permeable to the solvent and impermeable to the solute. Thus, for example, an aqueous sugar solution confined at least in part by a suitable membrane will become more concentrated due to the fact that the water will readily pass through the membrane whereas the sugar molecules cannot. In the method of the present invention the membrane intermediate the hot and cold walls is equally permeable to all of the materials initially introduced including the dissimilar materials to be separated.

In dialysis, a mixture of a colloid and a non-colloid can be separated by the action of a semi-permeable membrane. Thus, for example, where an aqueous solution of both an ionized solute and a colloid is confined at least in part by a suitable membrane, the colloid will remain while the ionized solute will pass through because the membrane is permeable only to the latter.

In contrast to separation by osmosis or dialysis, separation by liquid thermal diffusion is dependent upon the existence of a temperature gradient across a thin stream of the liquid and upon the ability of dissimilar molecules therein to move from the hot side to the cold side, or vice versa, without any substantial restraint. The membrane used in the method of this invention, which has been described heretofore, in detail, is pervious to all molecules in the liquid and is therefore a barrier only in the sense that it minimizes physical mixing of the liquids adjacent the hot and cold walls and hence permits forced flow pattern.

It is evident that many modifications in structure

and flow pattern will become apparent to those skilled in the art upon reading this description. It is to be understood that all such modifications are intended to be included within the scope of the invention as defined in the accompanying claims.

I claim:

1. Liquid thermal diffusion apparatus comprising a series of heat exchange elements having plane, vertical, smooth and liquid-impervious exterior walls, the exterior walls of adjacent heat exchange elements in the series being substantially parallel to and closely spaced from one another to form a series of substantially vertical and uniformly narrow thermal diffusion separation chambers; means for relatively heating the separation chamber-forming walls of alternate heat exchange elements in the series of heat exchange elements and relatively cooling the separation chamber-forming walls of the heat exchange elements between said alternate heat exchange elements for providing a relatively hot wall and a relatively cold wall for each separation chamber, whereby the relatively hot walls of two adjacent separation chambers are formed by the walls of a single heat exchange element and the relatively cold walls of two other adjacent separation chambers are formed by the walls of another single heat exchange element; liquid-permeable membranes in the separation chambers intermediate and spaced from the separation chamber-forming walls for dividing each separation chamber into flow chambers having upper and lower ends, one flow chamber in each separation chamber being adjacent a relatively hot wall and another flow chamber in each separation chamber being adjacent a relatively cold wall; inlet means for introducing a liquid mixture into one of the flow chambers in said series of separation chambers; first outlet means for withdrawing a first fraction of said liquid mixture from a flow chamber adjacent the relatively hot wall of another of the series of separation chambers; second outlet means for withdrawing a second fraction of said liquid mixture from a flow chamber adjacent a relatively cold wall of still another in the series of separation chambers; and means interconnecting the flow chambers of adjacent separation chambers for moving liquid, in alternate separation chambers, upwardly through the flow chambers adjacent the relatively hot wall and downwardly through the flow chambers adjacent the cold walls, and for moving the liquid, in separation chambers between said alternate separation chambers, downwardly through flow chambers adjacent the hot walls and upwardly through flow chambers adjacent the cold walls.

2. Liquid thermal diffusion apparatus comprising a series of substantially parallel heat exchange elements having plane, vertical, smooth and liquid-impervious exterior walls, the exterior walls of adjacent heat exchange elements in the series being substantially parallel to and closely spaced from one another to form a series of substantially vertical, parallel and uniformly narrow thermal diffusion separation chambers; means for relatively heating the separation chamber-forming walls of alternate heat exchange elements in the series of heat exchange elements and relatively cooling the separation chamber-forming walls of the heat exchange elements between said alternate heat exchange elements for providing a relatively hot wall and a relatively cold wall for each separation chamber, whereby the relatively hot walls of two adjacent separation chambers are formed by the walls of a single heat exchange element and the relatively cold walls of two other adjacent separation chambers are formed by the walls of another single heat exchange element; liquid-permeable membranes in the separation chambers intermediate and spaced from the separation chamber-forming walls for dividing each separation chamber into flow chambers having upper and lower ends, one flow chamber in each separation chamber being adjacent a relatively hot wall and another flow chamber in each separation chamber being adjacent a relatively cold wall; inlet means for introducing a liquid mixture into one of the flow chambers in said series of separation chambers; first outlet means for withdrawing a first fraction of said liquid mixture from a flow chamber adjacent the relatively hot wall of another of the series of separation chambers; second outlet means for withdrawing a second fraction of said liquid mixture from a flow chamber adjacent a relatively cold wall of still another in the series of separation chambers; and means interconnecting the flow chambers of adjacent separation chambers for moving liquid, in alternate separation chambers, upwardly through the flow chambers adjacent the relatively hot wall and downwardly through the flow chambers adjacent the cold walls, and for moving the liquid, in separation chambers between said alternate separation chambers, downwardly through flow chambers adjacent the hot walls and upwardly through flow chambers adjacent the cold walls.

3. Liquid thermal diffusion apparatus comprising a series of heat exchange elements having plane, vertical, smooth and liquid-impervious exterior walls at an angle to one another, the exterior walls of adjacent heat exchange elements in the series being substantially parallel to and closely spaced from one another to form a series of substantially vertical and uniformly narrow thermal diffusion separation chambers disposed radially of a vertical reference axis; means for relatively heating the separation chamber-forming walls of alternate heat exchange elements in the series of the heat exchange elements and relatively cooling the separation chamber-forming walls of the heat exchange elements between said alternate heat exchange elements for providing a relatively hot wall and a relatively cold wall for each separation chamber, whereby the relatively hot walls of two adjacent separation chambers are formed by the walls of a single heat exchange element and the relatively cold walls of two other adjacent separation chambers are formed by the walls of another single heat exchange element; liquid-permeable membranes in the separation chambers intermediate and spaced from the separation chamber-forming walls for dividing each separation chamber into flow chambers having upper and lower ends, one flow chamber in each separation chamber being adjacent a relatively hot wall and another flow chamber in each separation chamber being adjacent a relatively cold wall; inlet means for introducing a liquid mixture into one of the flow chambers in said series of separation chambers; first outlet means for withdrawing a first fraction of said liquid mixture from a flow chamber adjacent the relatively hot wall of another of the series of separation chambers; second outlet means for withdrawing a second fraction of said liquid mixture from a flow chamber adjacent a relatively cold wall of still another in the series of separation chambers; and means interconnecting the flow chambers of adjacent separation chambers for moving liquid, in alternate separation chambers, upwardly through the flow chambers adjacent the relatively hot wall and downwardly through the flow chambers adjacent the cold walls, and for moving the liquid, in separation chambers between said alternate separation chambers, downwardly through flow chambers adjacent the hot walls and upwardly through flow chambers adjacent the cold walls.

4. Liquid thermal diffusion apparatus comprising a series of heat exchange elements having plane, vertical, smooth and liquid-impervious exterior walls, the exterior walls of adjacent heat exchange elements in the series being substantially parallel to and closely spaced from one another to form a series of substantially vertical and uniformly narrow thermal diffusion separation chambers; means for relatively heating the separation chamber-forming walls of alternate heat exchange elements in the series of the heat exchange elements and relatively cooling the separation chamber-forming walls of the heat exchange elements between said alternate heat exchange elements for providing a relatively hot wall and

a relatively cold wall for each separation chamber, whereby the relatively hot walls of two adjacent separation chambers are formed by the walls of a single heat exchange element and the relatively cold walls of two other adjacent separation chambers are formed by the walls of another single heat exchange element; liquid-permeable membranes in the separation chambers intermediate and spaced from the separation chamber-forming walls for dividing each separation chamber into flow chambers having upper and lower ends, one flow chamber in each separation chamber being adjacent a relatively hot wall and another flow chamber in each separation chamber being adjacent a relatively cold wall; inlet means for introducing a liquid mixture into one of the flow chambers in an intermediate separation chamber of said series of separation chambers; first outlet means for withdrawing a first fraction of said liquid mixture from a flow chamber adjacent the relatively hot wall of a separation chamber at one end of the series of separation chambers; second outlet means for withdrawing a second fraction of said liquid mixture from a flow chamber adjacent a relatively cold wall of a separation chamber at the other end of the

series of separation chambers; and means interconnecting the flow chambers of adjacent separation chambers for moving liquid, in alternate separation chambers, upwardly through the flow chambers adjacent the relatively hot wall and downwardly through the flow chambers adjacent the cold walls, and for moving the liquid, in separation chambers between said alternate separation chambers, downwardly through flow chambers adjacent the hot walls and upwardly through flow chambers adjacent the cold walls.

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