Nov. 6, 1951 W. H. FURNESS 2,573,788

ELECTROLYTIC CELL

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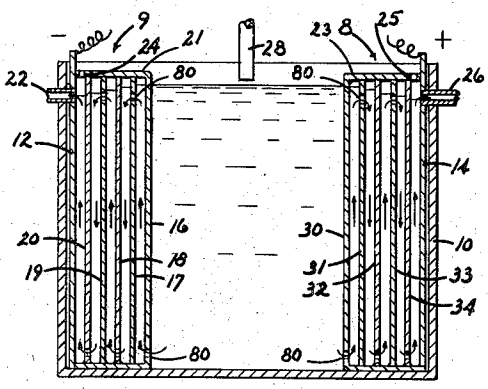


Fig. 1

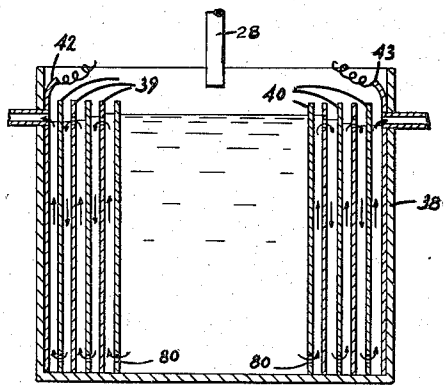


Fig. 2

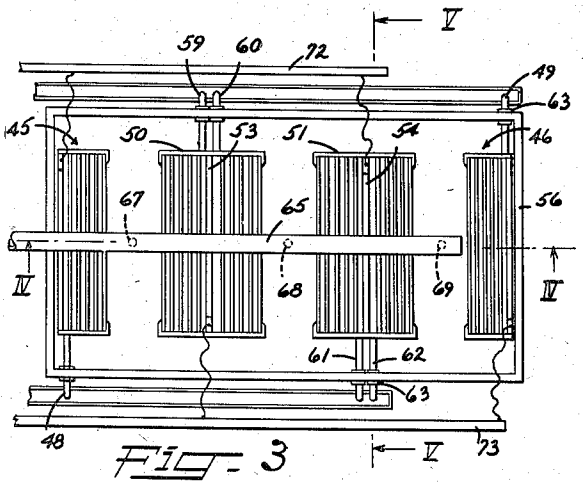


Fig. 3

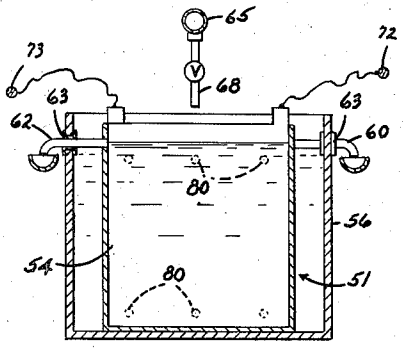


Fig. 5

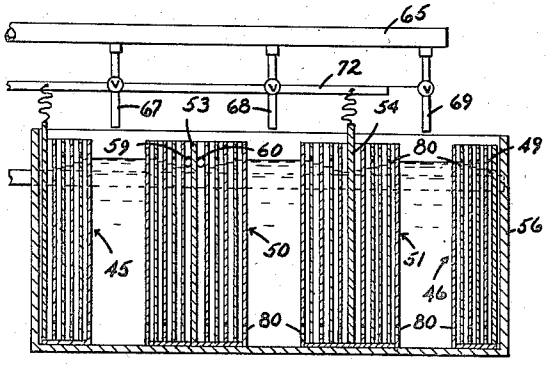


Fig. 4

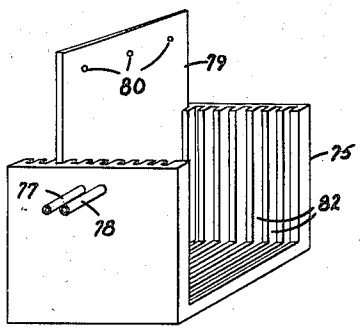


Fig. 6

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ELECTROLYTIC CELL

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8 Claims. (Cl. 204—257)

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This invention relates to an electrolytic cell for recovering acids and alkaline materials from aqueous solutions containing electrolizable parent materials, and particularly for recovering an alkali metal hydroxide and an acid by electrolysis of an alkali metal salt. The invention has particular applicability to recovering soluble wastes of industrial processes. For example, the sodium sulfate occurring in the spent coagulants produced in the manufacturing of viscose rayon filaments may be electrolyzed to obtain caustic soda and sulfuric acid of sufficient concentration to be used in the manufacturing process.

Normally, the sodium sulfate is reclaimed as such from the spent solution by successive crystallization, evaporation or a combination of both. However, it is desirable to convert the sulfate into compounds of the type which originally brought about its formation and to use the conversion products, i. e. the caustic soda and the acid, in the manufacturing process. Conventional electrolytic cells are suitable for handling relatively pure solutions but are ill-suited for handling liquids having undissolved suspended impurities of microscopic size which are removable only at prohibitive filtering cost. In a cell constructed according to the usual manner, some of the liquid contained in the cell, as well as the ionized products, is required to pass through the separator plates to the region occupied by an electrode. In such a cell, the separator plates become clogged with undissolved material and substantially if not completely nullify the effectiveness of the cell.

Moreover another disadvantage of conventional cells is that molecules formed by electrolysis in the anode and the cathode chambers, being electrically neutral and unaffected by the electrodes, readily diffuse through the electrolyte to react with each other, thus greatly reducing the efficiency of the cell. This effect is accelerated in the region of the electrodes by the evolution of gas at the surface of the electrode and the subsequent escape of the gas through the electrolyte. The currents consequently produced in the electrolyte tend to increase the rate of diffusion.

It is an object of this invention to provide a durable and inexpensive electrolytic cell capable of remaining in service for long periods while electrolizing relatively impure solutions. It is another object to provide an electrolytic cell which is not wasteful of electrical power. It is still another object to provide electrolytic apparatus which is readily adaptable for use in cells comprising many electrodes with separator

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plates therefor in separately portable units. Other objects, features, and advantages will become apparent as the invention is hereinafter described and illustrated.

In the drawing illustrating the invention:

Fig. 1 is an elevation sectional view of a single cell containing portable electrode units;

Fig. 2 is a section elevation illustrating a unitary cell structure wherein the electrodes and separator are integral with the cell casing;

Fig. 3 is a plan view of a multiple electrode cell;

Fig. 4 is a side elevation view in section taken along lines IV—IV in Fig. 3;

Fig. 5 is an end view in section of the cell illustrated in Figs. 3 and 4 taken along line V—V of Fig. 3; and

Fig. 6 is a pictorial view of a holder illustrating a plate partly inserted for supporting a single electrode and plate assembly.

Briefly, the invention comprises an electrolytic cell having electrodes spaced from each other and each separated from an intermediate region within the cell for receiving the electrolyte, by a series of parallel microporous separator plates or diaphragms which permit the passage of ions through them but which are pervious but highly resistant to the flow or passage of liquid. The plates, however, are provided with apertures through which the liquid passes rather than pass through the material of the diaphragms or plates. The apertures of each separator are spaced substantially the entire length or width of the separator plate from the apertures of the adjacent separator so that liquid may pass progressively through the plates from the feed region to the electrodes over a sinuate path extending first through the apertures of a plate and then through the space between the plate and the next adjacent plate, and then through the apertures of the next plate nearer the electrode, etc.

For the purposes of illustration, the cell illustrated in the drawing will be described with reference to the electrolysis of a sodium sulfate solution. Referring now to Fig. 1, an anode unit 8 and a cathode unit 9 are placed in opposite ends of a container 10. Electrode units 8 and 9 are similar in structure except for the composition of their electrode plates 12 and 14. The cathode unit 9, for example, may be in the form of an envelope or box-like structure comprising separator plates 16, 17, 18, 19 and 20 and the metallic electrode plate 12. A cover 21 in continuous attachment with the side, bottom, and top edges of the plates of the electrode unit 9 completely

encloses the unit except for apertures 80 in the plate 16, the discharge duct 22, and the vent hole 24. The top of the cell may be left open, if desired. A similar cover 23 is used to enclose the unit 8. The covers 21 and 23 may be formed of a material such as rubberized fabric, a fabric impregnated with a vinyl resin, or the material used in making the diaphragms. When the cell is used to accomplish the decomposition of sodium sulfate and to discharge caustic at the cathode, the cathode 12 may be steel, cast iron, nickel, or copper. The discharge duct 22 for the unit 9 should be of a like material. The microporous plates 16, 17, 18, 19, and 20 are of any suitable electrically non-conductive material resisting caustic or acid decomposition such as porous ebonite, acid-resistant asbestos fiber, impregnated glass fiber, carborundum or porous ceramic ware. These plates may be of finer porosity than permissible in conventional cells and may be practically impermeable to the electrolyte. However, it is necessary that they have a slight degree of porosity to permit the transfer of ions directly through the plates to the electrode when attracted by a charged electrode plate. Small apertures 80 are provided through the bottom margin of one microporous plate and through the top margin of the next plate, etc. to permit the flow of electrolyte back and forth along and through successive plates until it reaches the metallic plate 12. The flow of the liquid along the plates is promoted by the formation of molecular hydrogen formed as the result of the decomposition of water in the presence of atomic sodium. This liberated hydrogen ascends to the surface of the liquid, along the surface of the plate and thus produces a percolating action which also causes movement of liquid upwardly along the plate to the duct 22. The gaseous hydrogen is discharged through an aperture 24 through the top of the unit 9.

The anode unit 8 is of similar construction except that the metallic anode plate 14 is lead. The flow of electrolyte through the unit 8 is induced by the formation of molecular oxygen along the inner surface of the plate 14 and its subsequent ascent to the aperture 25 through the top wall of the unit 8. The discharge duct 26 may be of lead also. Units 8 and 9 may be suspended in the casing 10 in any desired manner such as by resting them on the bottom or by lugs attached to the sides of the units extending over the top edge of the casing, or by suspension from an outside support.

Sodium sulfate solution may be introduced into the cell through means such as the tube 28 preferably at the center of the region between the units. Such a solution normally dissociates into sodium anions and sulfate cations. The anions travel through the diaphragms 16, 17, 18, 19, and 20 in a direction normal to their surfaces until they reach the electrode plate 12 where they are forced to give up their charges. In the region of the cathode plate 12, sodium ions combine with the hydroxyl groups of water to form caustic soda and molecular hydrogen. The liquid which is carried through the electrode unit fromthe central region of the cell is essentially a solution of sodium sulfate. The caustic formed at the cathode is carried by the liquid upwardly and out of the unit through the duct 22. Caustic may be separated from the sodium sulfate solution by any desired method such as by selective crystallization. The sulfate ions travel through the microporous plates 30, 31, 32, 33, and 34 to the

surface of plate 14 where they unite with the hydrogen of the water of the solution to liberate molecular oxygen. The sulfuric acid thus formed mixes with the sodium sulfate solution traversing the passages between the plates toward the anode and is carried outwardly through the duct 26. The acid enriched solution thus obtained can be used to make acid coagulating baths since the presence of sodium sulfate is desirable in viscose coagulant, or the sodium sulfate may be crystallized out of the solution to obtain the sulfuric acid in a purer state.

In conventional cells, an appreciable percentage of the material obtained by the electrolytic process is carried away from the region of the electrodes by diffusion and by eddy currents and lost through recombination. The microporous plates of the cell herein described not only prevent the formation of eddy currents but channel the liquid into a desired path so that a current of electrolyte passes between each pair of opposing surfaces. Any molecules passing through a plate in a direction away from the electrode enter the fluid flowing through the spaces between the plates. As the velocity of molecules undergoing diffusion is small, the liquid passing between the plates at right angles to the direction of diffusion carries them toward the apertures which provide entrance to the next space nearer the electrode. The flow rate of the liquid is preferably adjusted to a velocity which causes the molecules to be swept into the next space nearer the electrode before entering the pores of the next plate farther removed from the electrode.

Fig. 2 illustrates a section of a cell similar in operation and construction to the cell just described and illustrated in Fig. 1. The plates and the electrodes are supported between the walls of the container 38 with the side and bottom edges of the electrodes in contact with the walls of the container so that liquid will not flow around the edges of the plates 39 and 40 and thus avoid the desired path of the liquid from the center of the cell to the electrodes 42 and 43. In a cell having only two electrodes the electrodes may be secured to the surfaces of one of the opposite end walls of the container.

Figs. 3, 4, and 5 illustrate a multiple cell having four electrodes. The scheme shown in these figures may be readily expanded to include groups of cells, each cell having a large number of electrodes of the type shown. The electrode units 45 and 46 are of a structure already herein described and illustrated in Fig. 1 except for the manner in which the ducts 48 and 49 are attached. The intermediate cells 50 and 51, however, are adapted for use in multiple electrode cells in which it is desired to use a single electrode plate to attract ionized materials from either side of the electrode. Accordingly, the microporous plates are spaced from both sides of the metallic plates 53 and 54 of these electrodes in an arrangement heretofore described with respect to only one side of the electrode plates in units 8 and 9 of Fig. 1. The electrodes and the microporous plates adjacent thereto may be supported by the casing 56 or built into the removable units similar to the electrode units 8 and 9 in Fig. 1.

The various electrode assemblies may be spaced from each other in the multiple electrode cell at any desired distance which permits ready distribution of the liquid being supplied to the cell for electrolysis along the outer separator plates of each electrode assembly. As the supply of liquid is maintained at a level near the height at

which the discharge ducts 48, 59, 60, 61, 62, and 49 are attached to their respective electrode units, the nozzles are extended through the walls of the casing 56. A seal is established between the ducts and the surfaces of apertures through the casing walls by such means as the resilient grommets 63 or a suitable cement. In order that the nozzles may be readily detached from the sides of the electrode units, the ends of the ducts and the receiving apertures through the electrode units walls are threaded so that ducts may be screwed into the apertures as shown, or if preferred, grommets of suitable bore for receiving the ends of the ducts may be inserted into the outlet apertures of the electrode units. In a multiple electrode cell such as shown in Figs. 3, 4 and 5, the supply liquid is carried to the cell through such a means as the header 65 having dependent outlets 67, 68 and 69 for distributing the liquid to the regions between the electrodes. The current to the electrodes may be supplied from terminal bars 72 and 73, each bar electrically connected with a series of alternate electrodes.

Fig. 6 illustrates a U-shaped holder 75 having grooves 82 along the inner facing surfaces of the legs of the holder and the inner surface of the bottom or base section of the holder which connects the legs. These grooves may be used to support, properly align, and space the plates of a single electrode unit. When an electrode is to be used in a multiple electrode cell and of the type illustrated by electrodes 50 and 51 of Fig. 4, the metallic plate is supported in the middle slot of the holder between outlets of the ducts 77 and 78. Non-conducting porous plates may then be placed in successive slots to either side of the metallic plate. In Fig. 6 a microporous plate 79 is shown partly inserted into a slot. The figure also shows the plate 79 having holes 80 such as provided for the transfer of liquid through the separator plates. In the assembled cell, plates at either side of the plate 79 will have similar apertures in a portion corresponding to the bottom margin of the plate 79. As the side and bottom edges of the plate are sufficiently enclosed by the retainer grooves 82 along the interior surfaces of the holder 75 to prevent the flow of liquid around the edges it is not necessary to provide a cover for the holder contacting the top edges of the plates since the liquid within the cell is maintained below the top edges of the plates, preferably at a height coinciding with that of the ducts 77 and 78. The holder 75 may be of any suitable inert material such as a molded glass, ceramic ware, a vinyl resin, and resin-impregnated glass fiber. The containers for the cells illustrated in the figures such as casings 10, 38, 56, and 75 may be formed in any desired manner, such as by casting, stamping, or other fabricating from rubber vulcanizates, corrosion-proof resinous materials, or metal preferably coated with a noncorrosive composition, or from glass, porcelain, ebonite, asbestos fiber or ceramic ware. The container may be open at the top for convenience in removing electrodes, attaching electrical lines and liquid supply lines, and inspecting the cells.

It is to be understood that the invention as described is illustrative of the many equivalents in structure, materials of construction, and electrolytes which may be processed according to the invention, and that many changes and variations may be made without departing from the scope of the invention as defined in the appended claims.

I claim:

1. An electrolytic cell comprising a container, spaced plate-shaped electrodes, a plurality of spaced parallel plates of microporous liquid-pervious electrically non-conductive material parallel to and progressively spaced with respect to each electrode within a space between the electrodes, said plates adjacent each electrode being spaced from each side thereof facing toward an adjacent electrode, said container being in continuous contact with the side and bottom edges of the electrodes and the plates, each plate being provided with apertures remotely spaced from similar apertures through the immediately adjacent plates for passing a liquid in a serpentine path from regions intermediate the electrodes to the surfaces of the electrodes through the intervening plates, separate duct means positioned at a level near the tops of the plates and the electrodes and connected with the space between each electrode and the immediately adjacent plate for discharging the mixture of electrolyte and electrolytic products produced at the respective electrode.

2. An electrode assembly for an electrolytic cell comprising a U-shaped holder having the legs thereof extending upwardly, parallel grooves extending along the opposing interior surfaces of the legs, a plate-like electrode, a plurality of microporous plate members of electrically non-conductive material each having apertures near one edge, said electrode and plate members each occupying separate grooves and insertable and slidable with respect thereto, said plate members being arranged so that the apertures of each member are spaced with respect to the apertures of an adjacent member to produce a serpentine path for a liquid passing through the member to the electrode, and duct means extending through an upper portion of a leg intermediate of grooves for the electrode and an immediately adjacent member.

3. An electrolytic cell comprising a container, spaced electrodes, a plurality of spaced generally parallel plates of microporous liquid-pervious electrically non-conductive material resistant to the flow of liquid therethrough positioned between the electrodes adjacent to and generally parallel to each electrode, said container being in continuous contact with the side and bottom edges of the electrodes and the plates, each plate being provided with apertures remotely spaced from similar apertures through the immediately adjacent plates for the passage of liquid in a serpentine path from regions intermediate the electrodes to the surfaces of the electrodes through the intervening plates, and means whereby an electrolyte can be introduced initially into the intermediate region.

4. An electrolytic cell comprising spaced electrodes, a plurality of spaced parallel plates of electrically non-conductive material positioned between the electrodes adjacent to and parallel to each electrode, the plates being highly resistant to the flow of liquid therethrough but permeable to ions, a container for the electrodes and plates in continuous contact with the side and bottom edges thereof, each plate being provided with apertures remotely spaced from apertures of the immediately adjacent plates for the passage of liquid in a serpentine path from regions intermediate the electrodes to the surfaces of the electrodes through the intervening plates, and means for introducing an electrolyte into said intermediate regions.

5. An electrolytic cell comprising a container, spaced electrodes, a plurality of spaced parallel plates of microporous liquid-pervious electrically non-conductive material, the plates being resistant to the flow of liquid therethrough but permeable to ions and positioned between the electrodes adjacent to and parallel to each electrode, said container being in continuous contact with the side and bottom edges of the electrodes and the plates, each plate being provided with apertures remotely spaced from apertures through the immediately adjacent plates for the passage of liquid in a serpentine path from regions between the electrodes to the surfaces of the electrodes through the intervening plates.

6. An electrolytic cell consisting of a plurality of spaced electrode units and a container therefor, each unit comprising a plate electrode, a plurality of spaced microporous plates supported in parallel and spaced arrangement adjacent both sides of the electrode, a cover extending around the side and bottom edges of the electrode and the plates in continuous contact therewith, each microporous plate being provided with apertures remotely spaced from apertures through the microporous plates immediately adjacent thereto for the passage of liquid in a serpentine path from regions intermediate the electrodes to the surfaces of electrodes through the intervening plates, said cell comprising also other electrolytic units in the ends of the cell, each of said other units in the cell ends comprising an electrode and parallel microporous plates similarly arranged as in the first named units with respect to one side only of the electrodes, a cover extending in continuous contact about the side and bottom edges of the plates of each electrode and the adjacent plates leaving as the only entrance for electrolyte the apertures of the plate of each unit farthest from a surface of the electrode, and means for introducing an electrolyte into said intermediate regions.

7. An electrolytic cell comprising spaced electrodes, a plurality of spaced parallel plates of microporous liquid-pervious electrically non-conductive material highly resistant to the flow of liquid therethrough but permeable to ions, the plates being positioned between the electrodes adjacent to and parallel to each electrode, a container for electrodes and plates in continuous contact with the side and bottom edges of the plates and the electrodes, duct means for withdrawing electrolytic product from a space between an electrode and the nearest adjacent plate, means for maintaining the level of the electrolyte within the container substantially at the level of the duct means, each plate being provided with apertures remotely spaced from apertures through the nearest adjacent plates for the passage of liquid in a serpentine path from regions intermediate the electrodes to surfaces of the electrodes through the intervening plates, and means for introducing an electrolyte into the said intermediate region.

8. An electrolytic cell comprising spaced plate-like electrodes, a plurality of microporous electrically non-conductive plates progressively spaced between the electrodes in parallel arrangement from each electrode, each plate being provided with apertures remotely spaced from similar apertures in the immediately adjacent plates for the passage of liquid in a serpentine path from regions between adjacent electrodes to the surfaces of the electrodes through the intervening plates, a U-shaped holder for each electrode and the spaced microporous plates connected therewith having a plurality of grooves extending along the inner facing surfaces of the legs of the holder and the inner surface of the section of the holder which joins the legs, said grooves conforming in continuous engagement to the side and bottom surfaces of the electrode and the plates, ducts extending laterally from the holders, each duct connected with each space between an electrode and an adjacent plate for withdrawing electrolytic products, said holders being spaced from each other by electrolyte-receiving regions, and means for introducing an electrolyte into said regions.

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