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Childs

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[54] **SHALLOW-BED ELECTROCHEMICAL CELL**

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[52] **U.S. Cl.** ..... **204/270,** 204/59 F, 204/246, 204/263, 204/265, 204/266, 204/269, 204/275, 204/277, 204/278

[51] **Int. Cl.**..... **B01k 1/00,** B01k 3/04, C07b 29/06

[58] **Field of Search** ..... 204/219, 270, 275, 257, 204/263, 267, 269, 59 F, 248, 246, 247, 258, 265, 266, 277, 278

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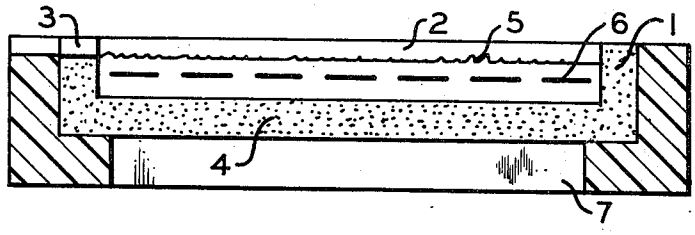
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[57] **ABSTRACT**

An electrochemical cell with a porous electrode is constructed with a shallow electrolyte bed and a small gap between electrodes to provide a decreased tendency to flood the porous electrode. The cell is useful in electrochemical conversions, particularly electrofluorination.

7 Claims, 4 Drawing Figures



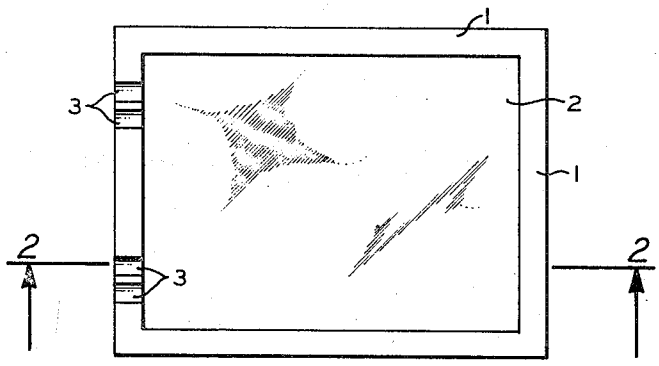


FIG. 1

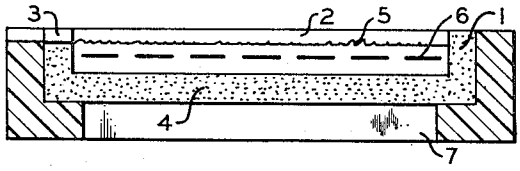


FIG. 2

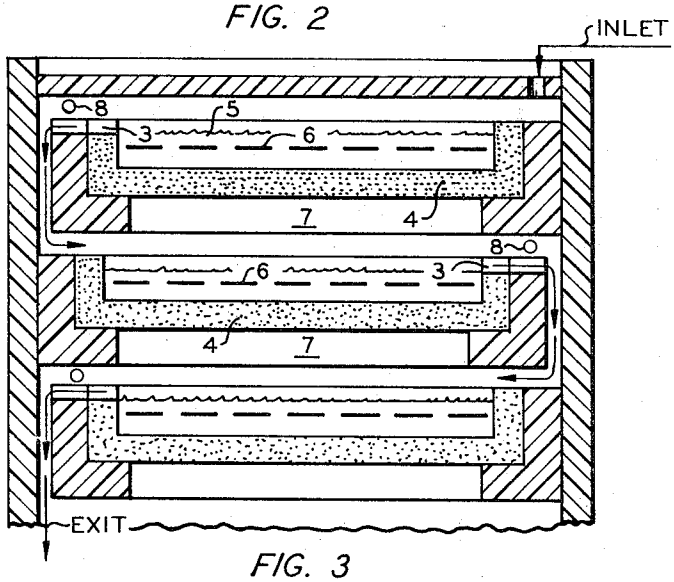


FIG. 3

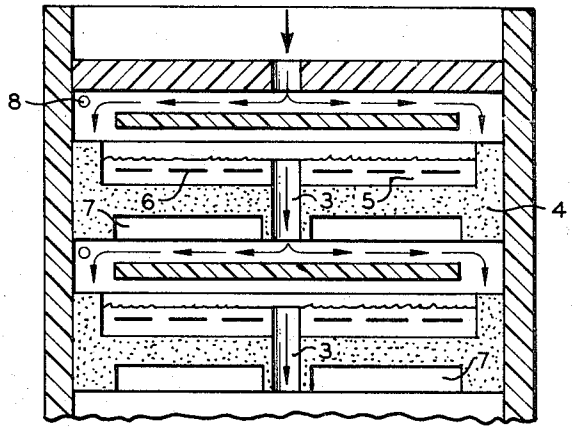


FIG. 4

SHALLOW-BED ELECTROCHEMICAL CELL

BACKGROUND OF THE INVENTION

This invention relates to electrolysis cells and processes for electrochemical conversion. In one of its aspects, this invention relates to the configuration and alignment of the electrode elements in an electrolysis cell. In another of its aspects, this invention relates to the use of a porous electrode element in an electrolysis cell of particular configuration.

There are many variations of electrolysis processes which include the use of porous electrode elements and the distribution of feedstock within a porous electrode element to the electrolyte interface. In electrochemical processes the configuration of the electrode elements can call for a relatively wide spacing between the electrode elements and therefore a relatively large amount of electrolyte within the body of the cell. The preferred embodiment of the electrolysis cell of this invention is built of such configuration that the distance between the electrode elements can be minimized and the amount of electrolyte used within the cell can also be brought to a minimum.

It is therefore an object of this invention to provide an electrolysis cell for electrochemical conversion reactions which has improved economics of construction and operation. It is another object of this invention to provide an electrolysis cell requiring a minimal amount of electrolyte in the cell cavity. It is another object of this invention to provide an electrolysis cell of decreased tendency to flood. It is a concept of this invention to provide a process for electrochemical conversion reactions using an electrolysis cell having a minimal gap between the electrode elements and requiring a minimal amount of electrolyte within a cell so configured that flooding of the porous electrode of the cell is minimized.

SUMMARY OF THE INVENTION

In accordance with this invention, an electrolysis cell for electrochemical conversion reactions is provided which comprises an impervious, nonconducting jacket provided with openings for inlet and egress of electrolyte, feed and product; an anode plate of dished configuration to hold a level of electrolyte preferably two inches or less in depth; a cathode plate removed from said anode plate a suitable distance which can be as small as one sixteenth inch; electrolyte filling the dished configuration of the anode plate; and appropriate connections to an electrical source to provide flow of current through the cell.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings, forming a part of this specification, in which like reference characters denote like parts in the various views,

FIG. 1 is a top plan view of the anode plate of the electrolysis cell of this invention;

FIG. 2 is a cross-section view of the plate in FIG. 1 shown in alignment with the cathode plate and electrolyte as used in the process and apparatus of this invention.

FIGS. 3 and 4 show cross-sectional views of electrolysis cells of FIG. 2 aligned for operation of a battery of cells.

As stated above, the concept of this invention of providing a process for electrochemical conversion reactions using an electrolysis cell having a minimal gap between the electrode elements and requiring a minimal amount of electrolyte within the cell produces an electrolysis cell in which the tendency of the cell to flood is minimized. In the apparatus of this invention the trough within which the electrolyte is contained is so configured that the maximum depth of electrolyte is not in excess of 6 inches. Preferably, the depth of electrolyte in the electrolysis cell will not exceed about 2 inches. The cathode plate is removed from the anode plate a distance not in excess of 3 inches and preferably is removed from the anode plate a distance not exceeding one-sixteenth inch. It has been found that configuration of the electrolysis cell so that the spacings of the elements as stated above can be achieved produces an electrolysis cell that is not prone to flood the porous electrode while in operation.

The electrode assemblies of the invention can be employed in any convenient cell configuration or electrode arrangement in conformity with the statement of the invention above. The only requirements are that the cell body and the electrodes in the cell be fabricated of materials which are resistant to the action of the contents of the cell under reaction conditions. Materials such as steel, iron, nickel, polytetrafluoroethylene (Teflon), carbon, and the like can frequently be employed for the cell body. When a nonporous cathode or a nonporous anode is employed the nonporous cathode or anode can be fabricated in any suitable shape or design or can be made of any suitable conducting material, such as iron, steel, nickel, alloys of said metals, carbon, and the like. For example, the nonporous cathode can be fabricated from a metal screen or gauze, a perforated plate, and can have a shape complimentary to the shape of the anode.

In certain applications of this invention, such as fluorination, the anode will be porous. In other applications, such as hydrogenation, a porous cathode is used. When porous elements are used in the electrode assemblies of this invention, the porous electrode can be fabricated from any suitable conducting porous electrolyte resistant material which is compatible with the system: nickel, iron, various metal alloys, graphite, carbon, or treated metals, which are not wetted by the electrolyte. Porous carbon, which is economical and readily available in ordinary channels of commerce, is presently preferred for the porous element. In many instances it is advantageous to provide a metal element in contact with the porous carbon element. For instance, a porous carbon anode can have a nickel screen wrapped around it. Various grades of porous carbon can be used in the practice of the invention. For the section of the electrode element in contact with the electrolyte if used for fluorination, it is preferred to employ porous carbon which has been made from carbon produced by pyrolysis, and not graphitic carbon. Porous electrodes can be fabricated in any shape or design suitable to the invention as stated above, but must be arranged and provided with a suitable means for introducing the feed reactant material into the pores of the porous element.

The electrode assemblies of the invention can be employed in a wide variety of electrochemical conversion processes. Some examples of such processes are electrochemical halogenation, electrochemical cyanation, and cathodic conversions such as the reduction of alcohols to hydrocarbons or the reduction of acids to alcohols. One electrochemical conversion process in which

the electrode assemblies of the invention are particularly valuable is the electrochemical fluorination of fluorinatable materials in the presence of an essentially anhydrous liquid hydrogen fluoride-containing electrolyte. Thus, for purposes of convenience, and not by way of limitation, the electrode assemblies of the invention are primarily described in terms of being employed as an anode in the electrochemical fluorination of fluorinatable materials when using said hydrogen fluoride-containing electrolyte.

As referred to hereinabove, the instant invention is applicable to electrochemical conversion reactions wherein a current-conducting essentially anhydrous liquid hydrogen fluoride electrolyte is electrolyzed in an electrolysis cell provided with a cathode and a porous anode (preferably porous carbon), a fluorinatable organic compound is introduced into the pores of said anode and therein at least a portion of said organic compound is at least partially fluorinated within the pores of said anode, and fluorinated compound products are recovered from said cell. The present invention provides improved electrode assemblies which are especially suited to be employed in such a process to produce partially fluorinated materials and/or to fluorinate organic compounds with little or no scission of carbon to carbon bonds.

Very few organic compounds are resistant to fluorination. Consequently, a wide variety of feed materials, both normally liquid and normally gaseous compounds, can be used as feedstocks in this process. Organic compounds which are normally gaseous or which can be introduced in gaseous state into the pores of a porous anode under the conditions employed in the electrolysis cell, and which are capable of reacting with fluorine, are presently preferred as starting materials. However, starting materials which are introduced into the pores of the anode in liquid state can also be used. Generally speaking, desirable organic starting materials which can be used are those containing from one to 20, preferably one to 14, carbon atoms per molecule. However, reactants which contain more than 20 carbon atoms can also be used. If desired, suitable feed materials having boiling points above cell operating temperatures can be passed into the pores of the porous anode in gaseous state by utilizing a suitable carrier gas. Thus, a suitable carrier gas can be saturated with the feed reactant (as by bubbling said carrier gas through the liquid reactant), and then passing the saturated carrier gas into the pores of the porous anode. Suitable carrier gases include the inert gases such as helium, argon, krypton, neon, xenon, nitrogen, etc. Normally gaseous materials such as hydrocarbons containing from one to four carbon atoms can also be used as carrier gases. These latter gases will react, but in many instances this will not be objectionable. The above-described carrier gases, and particularly said inert gases, can also be used as diluents for the feedstocks which are normally gaseous at cell operating conditions.

Some general types of starting materials which can be used include, among others, the following: alkanes, alkenes, alkynes, amines, ethers, esters, mercaptans, nitriles, alcohols, aromatic compounds, and partially halogenated compounds of both the aliphatic and aromatic series. It will be understood that the above-named types of compounds can be either straight chain, branched chain, or cyclic compounds. Partially chlorinated and the partially fluorinated compounds are the preferred partially halogenated compounds. The presently preferred starting materials are the saturated and unsaturated hydrocarbons (alkanes, alkenes, and alkynes) containing from one to 20 carbon atoms per molecule. The presently more preferred starting materials are the normally gaseous organic compounds, and particularly said saturated and unsaturated hydrocarbons, containing from 1 to 10 carbon atoms per molecule.

Since fluorine is so reactive, no list of practical length could include all starting materials which can be used. However, representative examples of the above-described starting materials include, among others, the following: methane, ethane, propane, butane, isobutane, pentane, n-hexane, n-octane, n-duodecane, n-tetradecane, cyclopropane, cyclopentane, cyclohexane, cyclooctane, 1,2-dichloroethane, 1-fluoro-2-chloro-3-methylheptane, ethylene, propylene, cyclobutene, cyclohexene, 2-methylpentene-1, 2,3-dimethylhexene-2, butadiene, vinyl chloride, 3-fluoropropylene, acetylene, methylacetylene, vinylacetylene, 4,4-dimethylpentyne-2, allyl chloride, methylamine, ethylamine, diethylamine, 2-amino-3-ethylpentane, 3-bromopropylamine, triethylamine, dimethyl ether, diethyl ether, methylethyl ether, methyl vinyl ether, 2-iodoethyl methyl ether, di-n-propyl ether, methyl formate, methyl acetate, ethyl butyrate, ethyl formate, n-amyl acetate, methyl 2-chloroacetate, methyl mercaptan, ethyl mercaptan, n-propyl mercaptan, 2-mercaptohexane, 2-methyl-3-mercaptoheptane, acetonitrile, propionitrile, n-butyronitrile, acrylonitrile, n-hexanenitrile, methanol, ethanol, isopropanol, n-hexanol, 2,2-dimethylhexanol-3, n-butanol, ethylene-bromohydrin, benzene, toluene, cumene, o-xylene, p-xylene, and monochlorobenzene.

In addition to such fluorinatable organic materials described above, carbon monoxide and oxygen can be used as feedstocks to provide carbonyl fluoride and oxygen difluoride, respectively.

The electrochemical fluorination process is carried out in a medium of hydrogen fluoride electrolyte. Although said hydrogen fluoride electrolyte can contain small amounts of water, such as up to about 5 weight percent, it is preferred that said electrolyte be essentially anhydrous. The hydrogen fluoride electrolyte is consumed in the reaction and must be either continuously or intermittently placed in the cell.

Pure anhydrous liquid hydrogen fluoride is nonconductive. The essentially anhydrous liquid hydrogen fluoride described above has a low conductivity which, generally speaking, is lower than desired for practical operation. To provide adequate conductivity in the electrolyte, and to reduce the hydrogen fluoride vapor pressure at cell operating conditions, an inorganic additive can be incorporated in the electrolyte. Examples of suitable additives are inorganic compounds which are soluble in liquid hydrogen fluoride and provide effective electrolytic conductivity. The presently preferred additives are the alkali metal (sodium, potassium, lithium, rubidium, and cesium) fluorides and ammonium fluoride. Other additives which can be employed are sulphuric acid and phosphoric acid. Potassium fluoride, cesium fluoride, and rubidium fluoride are the presently preferred additives. Potassium fluoride is the presently most preferred additive. Said additives can be utilized in any suitable molar ratio of additive to hydrogen fluoride within the range of from 1:4.5 to 1:1, pref-

erably 1:4 to 1:2. The presently most preferred electrolytes are those which correspond approximately to the formulas KF·2HF, KF·3HF, or KF·4HF. Such electrolytes can be conveniently prepared by adding the required quantity of hydrogen fluoride to KF·HF (potassium bifluoride). In general, said additives are not consumed in the process and can be used indefinitely. Said additives are frequently referred to as conductivity additives for convenience.

The electrochemical fluorination can be effectively and conveniently carried out over a broad range of temperatures and pressures limited only by the freezing point and the vapor pressure of the electrolyte. Generally speaking, the fluorination process can be carried out at temperatures within the range of from minus 80° to 500°C. at which the vapor pressure of the electrolyte is not excessive, e.g., less than 250 mm Hg. It is preferred to operate at temperatures such that the vapor pressure of the electrolyte is less than about 50 mm Hg. As will be understood by those skilled in the art, the vapor pressure of the electrolyte at a given temperature will be dependent upon the composition of said electrolyte. It is well known that additives such as potassium fluoride cause the vapor pressure of liquid hydrogen fluoride to be decreased an unusually great amount. A presently preferred range of temperature is from about 60 to about 105°C. Higher temperatures sometimes tend to promote fragmentation of the product molecules.

Pressures substantially above or below atmospheric can be employed if desired, depending upon the vapor pressure of the electrolyte as discussed above. In all instances, the cell pressure will be sufficient to maintain the electrolyte in liquid phase. Generally speaking, the process is conveniently carried out at substantially atmospheric pressure. It should be pointed out that a valuable feature of the process is that the operating conditions of temperature and pressure within the limitations discussed above are not critical and are essentially independent of the type of feed employed in the process.

For purposes of efficiency and economy, the rate of direct current flow through the cell is maintained at a rate which will give the highest practical current densities for the electrodes employed. Generally speaking, the current density will be high enough so that anodes of moderate size can be employed, yet low enough so that the anode is not corroded or disintegrated under the given current flow. Current densities within the range of from 30 to 1,000, or more, preferably 50 to 500, milliamps per square centimeter of anode geometric surface area can be used. Current densities less than 30 milliamps per square centimeter of anode geometric surface area are not generally practical because the rate of fluorination is too slow. The voltage which is employed will vary depending upon the particular cell configuration employed and the current density employed. In all cases, under normal operating conditions, however, free or elemental fluorine will not accumulate in significant quantities. Voltages in the range of from 4 to 12 volts are typical. The maximum voltage will not exceed 20 volts per unit cell. Thus, as a guide, voltages in the range of 4 to 20 volts per unit cell can be used.

The rate of the fluorinatable material being introduced into the pores of the porous carbon element of the anode can be an important process variable in that, for a given current flow or current density, the feed rate controls the degree of conversion. Similarly, for a given feed rate, the amount of current flow or current density can be employed to control the degree of conversion. Gaseous feed rates which can be employed will preferably be in the range of from 0.5 to 10 milliliters per minute per square centimeter of anode geometric surface area. As used herein the term "anode geometric surface" refers to the outer geometric surface area of the porous carbon element of the anode which is exposed to electrolyte and does not include the pore surfaces of said porous element. With the higher feed rates, higher current density and current rates are employed. Since the anode can have a wide variety of geometrical shapes, which will affect the geometrical surface area, a sometimes more useful way of expressing the feed rate is in terms of anode cross-sectional area (taken perpendicular to the direction of flow). On this basis, for a typical anode the above range would be 25 to 500 milliliters per minute per square centimeter of cross-sectional area.

The actual feed rate employed will depend upon whether the anode is porous and the type of carbon used in fabricating the element of the anode as well as several other factors including the nature of the feedstock, the conversion desired, current density, etc., because all of these factors are interrelated and a change in one will affect the others.

In using porous anode the feed rate will be such that the feedstock is passed into the pores of the anode, and into contact with the fluorinating species therein, at a flow rate such that the inlet pressure of said feedstock into said pores is essentially less than the sum of (a) the hydrostatic pressure of the electrolyte at the level of entry of the feedstock into said pores and (b) the exit pressure of any unreacted feedstock and fluorinated products from said pores into the electrolyte. Said exit pressure is defined as the pressure required to form a bubble on the outer surface of the anode and break said bubble away from said surface. Said exit pressure is independent of hydrostatic pressure. Under these flow rate conditions there is established a pressure balance between the feedstock entering the pores of the anode from one direction and electrolyte attempting to enter the pores from another and opposing direction. This pressure balance provides an important feature in that essentially none of the feed leaves the anode to form bubbles which escape into the main body of the electrolyte. Essentially all of the feedstock and/or reaction product travels within the carbon anode via the pores therein until it reaches a collection zone within the anode from which it is removed via a conduit, or unit it exits from the anode at a point above the surface of the electrolyte.

In porous anodes the more permeable carbons will permit higher flow rates than the less permeable carbons. Similarly, electrode shapes, electrode dimensions, and manner of disposition of the electrode in the electrolyte will also have a bearing on the flow rate. Thus, owing to the many different types of carbon which can be employed and the almost infinite number of combinations of electrode shapes, dimensions, and methods of disposition of the electrode in the electrolyte, there are no really fixed numerical limits on the flow rates which can be used. Broadly speaking, the upper limit on the flow rate will be that at which "breakout" of feedstock and/or fluorinated product

begins along the immersed portion of the electrode element. Unless otherwise specified, "breakout" is defined as the formation of bubbles of feedstock and/or fluorinated product on the outer immersed surface of the electrode element with subsequent detachment of said bubbles wherein they pass into the main body of the electrolyte. Broadly speaking, the lower limit of the feed rate will be determined by the requirement to supply the minimum amount of feedstock sufficient to prevent evolution of free fluorine. As a practical guide to those skilled in the art, the gaseous flow rates can be within the range of from 3 to 600, preferably 12 to 240, cc (STP) per minute per square centimeter of cross-sectional area (taken perpendicular to the direction of flow).

Although the electrolyte used with porous anodes is non-wetting, there will be some penetration of the larger pores of the electrode element by the hydrogen fluoride electrolyte as previously noted. The amount of said penetration will depend upon the pore size and other factors. The larger size pores are more readily penentrated. It has been found that porous carbon anodes as described herein can be successfully operated when up to about 40 or 50 per cent of the pores have been filled by liquid HF electrolyte.

The feed material and the products obtained therefrom are retained in the cell for a period of time which is generally less than one minute. Because the residence time is comparatively short and is especially uniform, the production of the desired products is facilitated. The fluorinated products and the unconverted feed are passed from the cell and then are subjected to conventional separation techniques such as fractionation, solvent extraction, adsorption, and the like, for separation of unconverted feed and reaction products. Unconverted or insufficiently converted feed materials can be recycled to the cell for the production of more highly fluorinated products, if desired. Perfluorinated products, or other products which have been too highly fluorinated, can be burned to recover hydrogen fluoride which can be returned to the cell, if desired. By-product hydrogen, produced at the cathode, can be burned to provide heat energy or can be utilized in hydrogen-consumiong processes such as hydrogenation, etc.

Referring now to the drawings, FIG. 1 shows the top view of the anode plate of the electrolysis cell of this invention. In this view the containing walls of the plate 1 are shown surrounding the dished area for containing the electrolyte 2 and the outlet ports 3 which are cut-outs in the wall of the plate allowing the outflow of the electrolyte to maintain a low level of electrolyte over the anode plate.

The relationship of the electrolyte and the anode plate are better seen in FIG. 2 which is a view of section 2—2 of FIG. 1. In this figure the anode plate 4 with its sidewalls 1, central dished area 2 and overflow port 3 are better visualized. Here the depth of the electrolyte 5 is controlled by the distance of the bottom of the overflow port 3 from the dished bottom of the anode plate. Cathode plate 6 is shown submerged in the electrolyte removed a minimal gap distance from the anode plate. Using a porous electrode, a feed passageway 7 beneath the porous anode is employed.

FIGS. 3 and 4 show various configurations for using an electrolysis cell of this invention in an electrochemical fluorination process. Here, in both embodiments shown, a porous carbon anode 4 is employed. The feedstock is supplied in feed header 7 passing through the porous anode 4. Electrolyte is fed to the top cell and overflows through the outlet port 3 to provide electrolyte for the cell below. The overflow is so arranged that the depth of the electrolyte does not exceed 6 inches. The cathode 6 is submerged in the electrolyte and is spaced at a distance about one-sixteenth inch to about 3 inches from the anode. This arrangement provides for economy both in construction, allowing the use of less material for containing the electrolyte, and also is more economical in operation, allowing the use of less electrolyte. The containing walls for the multiple cell unit and interior surfaces in contact with the reaction material and products are constructed of materials that are impervious to the reaction materials and products. Collection points for removal of product are shown at 8 in both FIGS. 3 and 4 where the surfaces of the collection headers can be coated with impervious material as in FIG. 3 or direct contact may be had with the porous carbon anode as in FIG. 4 for further reaction of the product and/or unreacted feed passing through the next higher cell in the reaction system.

The examples that follow are intended to be illustrative and not exclusive.

EXAMPLE I

In an electrolysis cell constructed with an anode of dished configuration 4 inches × 4 inches × 2 inches deep made of B303 carbon, which is a porous carbon, and with a cathode of ⅛ inch steel plate with ¼ inch perforations of ½ inch centers maintained with a gap ½ inch between anode and cathode plate in a 1½ inch deep electrolyte comprising hydrogen fluoride, perfluorination of isobutane was carried out. Isobutane was fed through the porous anode at a feed rate of 0.057 mols per hour (1.28 liters per hour STP). A current of 25 amps was maintained with a voltage of 7.0 to 7.5 volts per unit supplied from a rheostat controlled source.

Using an internal standard, the effluent from the cell was determined to contain 15 mole percent perfluoroisobutane, 4 mole percent isobutane, less than 2 percent lights, with the remainder of the effluent comprising a large number of partially fluorinated isobutanes. There were essentially no heavies.

The example above shows that the electrolysis cell of this invention is useful in producing fluorinated hydrocarbons by electrofluorination process.

EXAMPLE II

Electrode invasion or flooding was measured by immersing porous carbon electrodes in an electrolyte under controlled test conditions including time, current flow, removal of the electrode from the electrolyte, removal of excess electrolyte from the exterior of the electrode, cooling of the electrode so that electrolyte within the pores thereof would solidify, cutting the electrode horizontally into a number of vertically oriented segments (classifiable by depth of immersion) and, by means of volume and weight meaurements, determining the density of the electrode segments. The carbon electrodes, generally of circular or square cross section, had an initial apparent density of about 1.05 grams per cubic centimeter, and a true density of about2.2 grams per centimeter. Therefore, the extent of pore invasion was readily evaluated by interpolation

of the measured density of the electrode section between these values by means of the equation

$$X=d-1.05/1.15$$

where X equals fraction of pores filled by electrolyte, and d equals density, grams per centimeter, of anode section.

For example, two identical porous carbon electrodes having rectangular dimensions of 12 × ¾ × ½ inch were immersed overnight in an essentially anhydrous hydrogen fluoride-containing electrolyte having an approximate molar composition of K F.2HF at a typical cell-operating temperature of 95° to 100° C. with no electrical current flowing. One electrode was then removed, wiped clean, cooled, and cut into sections on which densities were determined. The other electrode was then connected to serve as an anode in the cell. A low-voltage direct current capable of causing a low current flow of 1 to 2 milliamps per cm^2 of anode geometric surface was applied to the anode in the cell for about 48 hours. The anode was then removed from the cell, wiped clean, cooled, and cut into sections on which densities were determined. The electrodes were made from National Carbon Company grade-45 carbon (NC-45) having a pore volume of about 0.5 centimeter per gram with pore diameters ranging from about 10 to 100 microns, and an average pore diameter of about 58 microns. The results of the test runs are tabulated below:

Section:	Depth of immersion, inches	CURRENT FLOW: None d	None X	0.15 milliamps d	0.15 milliamps X	1–2 milliamps d	1–2 milliamps X
A	0–0.5	1.03	0	1.11	0.05	1.09	0.03
B	0.5–1.5	1.06	0.01	1.14	0.08	1.13	0.07
C	1.5–2.5	1.06	0.01	1.16	0.10	1.18	0.11
D	2.5–3.5	1.08	0.03	1.20	0.13	1.19	0.12
E	3.5–4.5	1.10	0.04	1.24	0.17	1.19	0.12
F	4.5–5.5	1.30	0.22	1.21	0.14	1.21	0.14
G	5.5–6.5	1.74	0.60	1.24	0.17	1.34	0.25
H	6.5–7.5	1.80	0.65	1.34	0.25	1.42	0.32
I	7.5–8.5	1.85	0.70	1.43	0.33	1.49	0.38
J	8.5–9.5	1.84	0.69	1.46	0.36	1.51	0.40
K	9.5–10.5	1.82	0.67	1.51	0.40	1.54	0.43
L	10.5–11.5	1.78	0.63	1.44	0.34	1.47	0.37

The above data show the increase of invasion or flooding of electrode pores with electrolyte at deeper immersions at conditions of no current flow and varied conditions of current flow. The invasion of electrode pores would be analogous at a certain depth of electrolyte whether the electrode were immersed in the electrolyte as shown in the example above or formed a dish container for the electrolyte as in this invention. It is therefore important to build an electrolysis cell with a smaller immersion of the porous electrode if possible to prevent flooding of the electrode pores.

Reasonable variation and modification are possible within the scope of the foregoing disclosure, drawings, and the appended claims to the invention, the essence of which is that an electrolysis cell with reduced tendency to flood the porous electrode can be constructed with the electrolyte trough requiring a minimal amount of electrolyte and the cathode removed a minimal distance from the anode.

I claim:

1. An electrolysis cell comprising:

a. an impervious jacket provided with openings for inlet and egress of electrolyte, feed and product,

b. a porous electrode plate of dished configuration to hold a level of electrolyte not exceeding 6 inches in depth, said porous electrode plate being positioned within said jacket, means defining a feed inlet passageway at the bottom surface of said porous electrode to pass the feed into the pores of said porous electrode,

c. an electrode plate situated within the dished configuration of the dished electrode plate removed from said dished electrode plate a distance not exceeding 3 inches so as to be submerged in the electrolyte contained by the dished configuration of said porous electrode plate, and

d. terminals for connecting said electrode plates with an electrical source.

2. The electrolysis cell of claim **1** wherein the depth of the dished electrode plate does not exceed 2 inches and the electrode plates are removed from each other by a distance that does not exceed one-sixteenth inch.

3. The electrolysis cell of claim **1** wherein the dished electrode plate is constructed of porous carbon.

4. The electrolysis cell of claim **3** wherein the electrode plate within the dished configuration is a nickel screen.

5. The electrolysis cell of claim **3** wherein the electrode plate within the dished configuration is steel perforated plate.

6. A system of electrolysis cells wherein a plurality of electrolysis cells of claim **1** are stacked with headers provided for collection of product and distribution of electroyte and feedstock at the points of ingress and egress.

7. A system of electrolysis wherein a plurality of electrolysis cells of claim **1** are arranged so that electrolyte is cascaded from one cell to another seriatim and headers are provided for collection of product and distribution of electrolyte and feedstock at the points of ingress and egress.

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