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Chong

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[54] **ELECTROLYTIC SEPARATION OF OXYGEN FROM AIR**

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[52] **U.S. Cl.** **204/129;** 204/248; 204/DIG. 3

[51] **Int. Cl.** **C01b 13/04;** B01k 1/00

[58] **Field of Search** .... 204/248, 249, 129, DIG. 3

[56] **References Cited**

UNITED STATES PATENTS

2,390,591	12/1945	Janes	204/129
3,401,099	9/1968	McEvoy	204/129
3,630,879	12/1971	Spacil et al.	204/248

FOREIGN PATENTS OR APPLICATIONS

303,027	10/1929	United Kingdom	204/DIG. 3

OTHER PUBLICATIONS

Electroanalytical Chemistry–James Lingane (1958) 2nd Edition, pgs. 52 and 53.

Physical Chemistry–Walter Moore, 4th Edition, 1962, pg. 396.

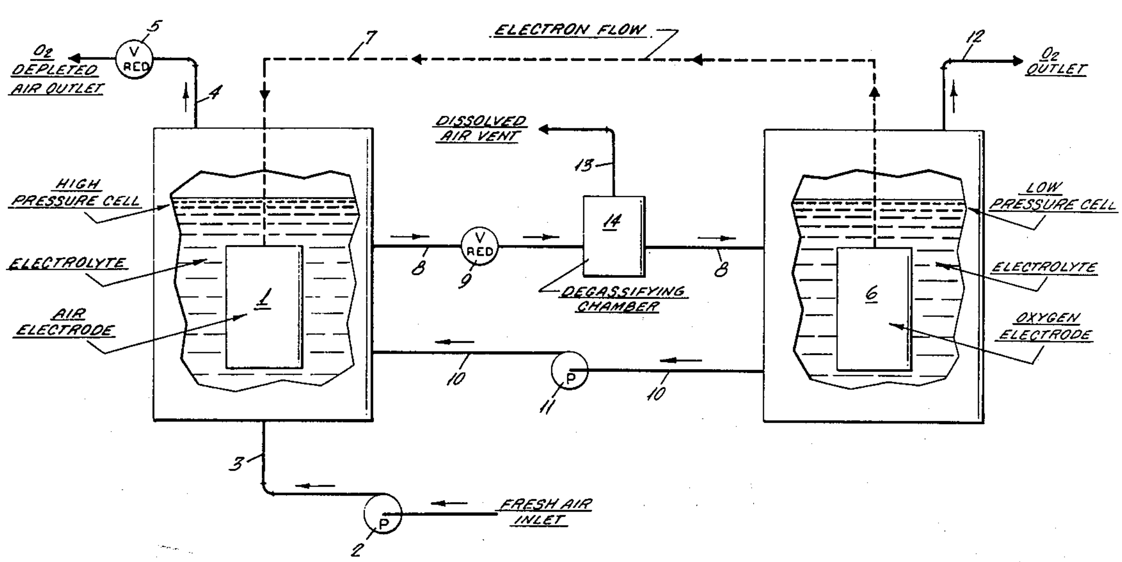
Primary Examiner—T. M. Tufariello

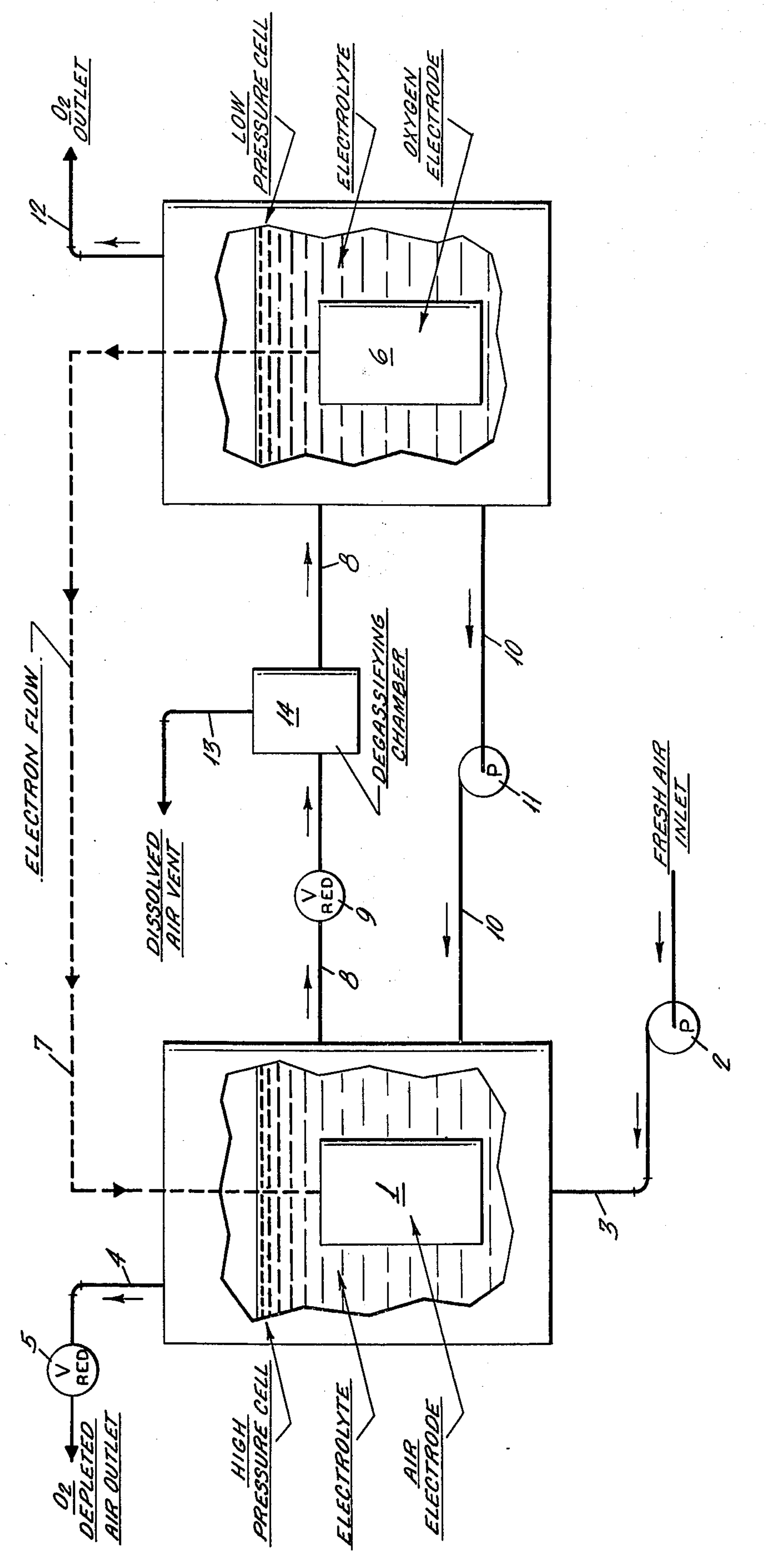
Attorney, Agent, or Firm—George L. Church; Donald R. Johnson; Anthony J. Dixon

[57] **ABSTRACT**

An electrolytic process for the separation of oxygen from air wherein compressed air is charged to a system of two cells, with an electrolyte being circulated between said cells and differing oxygen partial pressures over said cells, connected to produce an emf between the low pressure and high pressure cells, resulting in oxygen being separated from air at the high pressure cell, carried by the electrolyte to the low pressure cell and liberated.

4 Claims, 1 Drawing Figure




O2 OUTLET
LOW PRESSURE CELL
ELECTROLYTE
OXYGEN ELECTRODE
12
6
8
10
11
ELECTRON FLOW
7
DEGASSIFYING CHAMBER
14
13
DISSOLVED AIR VENT
V RED
9
FRESH AIR INLET
P
2
3
1
4
5
O2 DEPLETED AIR OUTLET
HIGH PRESSURE CELL
ELECTROLYTE
AIR ELECTRODE

ELECTROLYTIC SEPARATION OF OXYGEN FROM AIR

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a process for separation of oxygen from air. More particularly, the present invention relates to electrolytic separation of oxygen from air by use of an electrode concentration cell comprising two electrodes with identical electrolyte compositions but differing oxygen partial pressures connected to produce an emf. Electrode-concentration cells are disclosed by W. J. Moore in Physical Chemistry, third ed., second printing, Prentice-Hall (May 1963) at page 396.

2. Description of the Prior Art

Electrolysis for the production of oxygen is known but the process as presently practiced uses water as the oxygen source. In the electrolysis of water, a direct current is passed through an aqueous alkaline electrolyte. Hydrogen is deposited at the cathode or negative electrode and oxygen is deposited at the anode or positive electrode. Commercial electrolytic cells are usually iron or steel with the anodes having a nickel plating. The amount of hydrogen and oxygen produced is directly proportional to the density of the current flowing through the electrolyte in the cell. An electrolytic gas generator capable of supplying oxygen in a nearly continuous manner by the electrolysis of water is described in U.S. Pat. No. 2,951,802 granted to White et al, Sept. 6, 1960.

Oxygen is also produced commercially by cryogenic processes; however, the apparatus needed for such production is complex and the energy requirements are substantial.

SUMMARY OF THE INVENTION

The present invention enables oxygen to be produced from air by use of an electrolytic process comprising:

a. introducing air into a first electrolytic cell comprising a first electrode and an electrolyte,

b. circulating electrolyte between said first cell and a second electrolytic cell comprising a second electrode and an electrolyte, said first electrode and said second electrode being electrically connected to allow flow of current from said second electrode to said first electrode,

c. maintaining the partial pressure oxygen in said first cell higher than the partial pressure of oxygen in said second cell,

d. withdrawing oxygen-depleted air from said first cell and,

e. withdrawing oxygen from said second cell.

Although the invention is not to be limited to any theory of operation, it is believed that the principles involved in the operation are as described hereinafter. The nitrogen in air is inert whereas the oxygen is active to a level which corresponds to its partial pressure and is capable of taking part in an electrode equilibrium of the following kind:

$$2\ e^- + \frac{1}{2}O_2 + x^n \rightleftarrows xO^{n-2}$$

where,

x = electrolyte species

n = charge of electrolyte

When two such electrodes are connected with similar electrolyte compositions but differing oxygen partial pressures, an emf is produced which flows from the low pressure electrode to the high pressure electrode. At the high pressure electrode, equation (1) proceeds left to right and oxygen from the air combines with the electrolyte which then becomes oxygen-rich. At the low pressure electrode, equation (1) proceeds right to left liberating oxygen from the electrolyte which has been circulated by (*d*) above.

The advantages of this process are twofold. The apparatus required is simple compared to the cryogenic process and the energy required is lower than that of the conventional electrolytic process.

From an energy standpoint, the process of the invention can be made almost indentical to an ideal separation using a membrane permeable to oxygen only. Thus, the work required to run the process can be reduced to very near the theoretical minimum. The process of the invention can be operated without external direct current electrical power as needed for electrolytic decomposition of water, the only power requirement being for pumps and compressors. It is clear to the skilled practitioner that ideally, the energy required to break water into its component parts is greater than the energy required to separate the oxygen from air.

A better understanding of the process of the invention and its advantages will be had by referring to the drawing in light of the description which follows.

DESCRIPTION OF THE DRAWING AND THE PREFERRED EMBODIMENT

The drawing shows schematically how the electrolytic cell is used for air separation.

Fresh air is pumped to the air electrode cell, **1,** via compressor **2** and line **3.** Cell **1** contains a suitable electrolyte such as an acidic or basic water solution. An example may be a 20 percent solution of NaOH. Outlet line **4** is provided to allow oxygen depleted air to exit via reducing valve **5.** The cell is connected to the oxygen electrode cell **6** in two ways. First, cable **7** is provided to allow a flow of electrons from the oxygen electrode to the air electrode. Second, line **8** and reducing valve **9** act in concert with line **10** and circulating pump **11** to allow a constant circulation of electrolyte to maintain similar concentrations around both cells. The electrolyte leaving cell **1** is rich in oxygen which passes to cell **6** and is withdrawn via line **12.**

A degassifying chamber, **14,** is supplied in line **8** on the low pressure side of valve **9** to allow dissolved air to be vented off via line **13** prior to entering cell **6.**

The partial pressure of oxygen over the air electrode, **1,** is maintained higher than the partial pressure of oxygen over the oxygen electrode **6.** That is

$$(PO_2)_A > PO_2 \quad (1)$$

where

$(PO_2)_A$ = partial pressure of O_2 over air electrode

(PO_2) = partial pressure of O_2 over oxygen electrode

also, assuming ideal behavior, PO_2 = total pressure over oxygen electrode.

The coupling of the differential partial pressure electrodes produces an emf flowing from the oxygen electrode to the air electrode.

Since the gas over the air electrode can not contain more than about 21 percent oxygen, equation (1) can be reduced to:

$$P_A > \sim 5PO_2$$

where P_A = total pressure over the air electrode. Thus, for example, the low pressure cell may be at 1.5 atmospheres and the high pressure cell at 10 atmospheres.

With this pressure arrangement, the electrode equilibrium equation (1) disclosed above,

$$2e^- + \frac{1}{2} O_2 + X^n \rightleftharpoons XO^{n-2}$$

where X = electrolyte
n = charge on X,

proceeds left to right at the air electrode, that is at higher pressure, and right to left at the oxygen electrode, that is of lower pressure, thus liberating oxygen from the electrolyte.

The simplest examples of this type of equilibria are the oxygen electrode reactions for electrolytic decompositions of acidic or basic water solutions:

$$2^{e-} + \frac{1}{2}O_2 + 2H^+ \rightleftharpoons H_2O$$

$$2^{e-} + \frac{1}{2}O_2 + H_2O \rightleftharpoons 2OH^-$$

Other reactions are possible but these are probably the least expensive.

Other features may be added to the process such as turbines to replace reducing valves. These would be desirable for energy recovery.

Any combination of the above can be assembled by the reasonably skilled practitioner with minimum experimentation to gain the advantages of the invention in a given situation.

I claim as my invention:

1. A process for the electrolytic separation of oxygen from air without application of external current comprising:
   a. introducing air into a first electrolytic cell comprising a first electrode and an electrolyte,
   b. circulating electrolyte between said first cell and a second electrolytic cell comprising a second electrode and an electrolyte, said first electrode and said second electrode being electrically connected to allow flow of current from said second electrode to said first electrode,
   c. maintaining the partial pressure of oxygen in said first cell higher than the partial pressure of oxygen in said second cell,
   d. withdrawing oxygen-depleted air from said first cell and
   e. withdrawing oxygen from said second cell.

2. The process of claim 1 wherein said electrolyte is an acidic water solution.

3. The process of claim 1 wherein said electrolyte is a basic water solution.

4. The process of claim 1 wherein circulating electrolyte between said first electrolytic cell and said second electrolytic cell further comprises removing dissolved air from said electrolyte in a degassifying zone positioned after the outlet of said first electrolytic cell and before the inlet of said second electrolytic cell.

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