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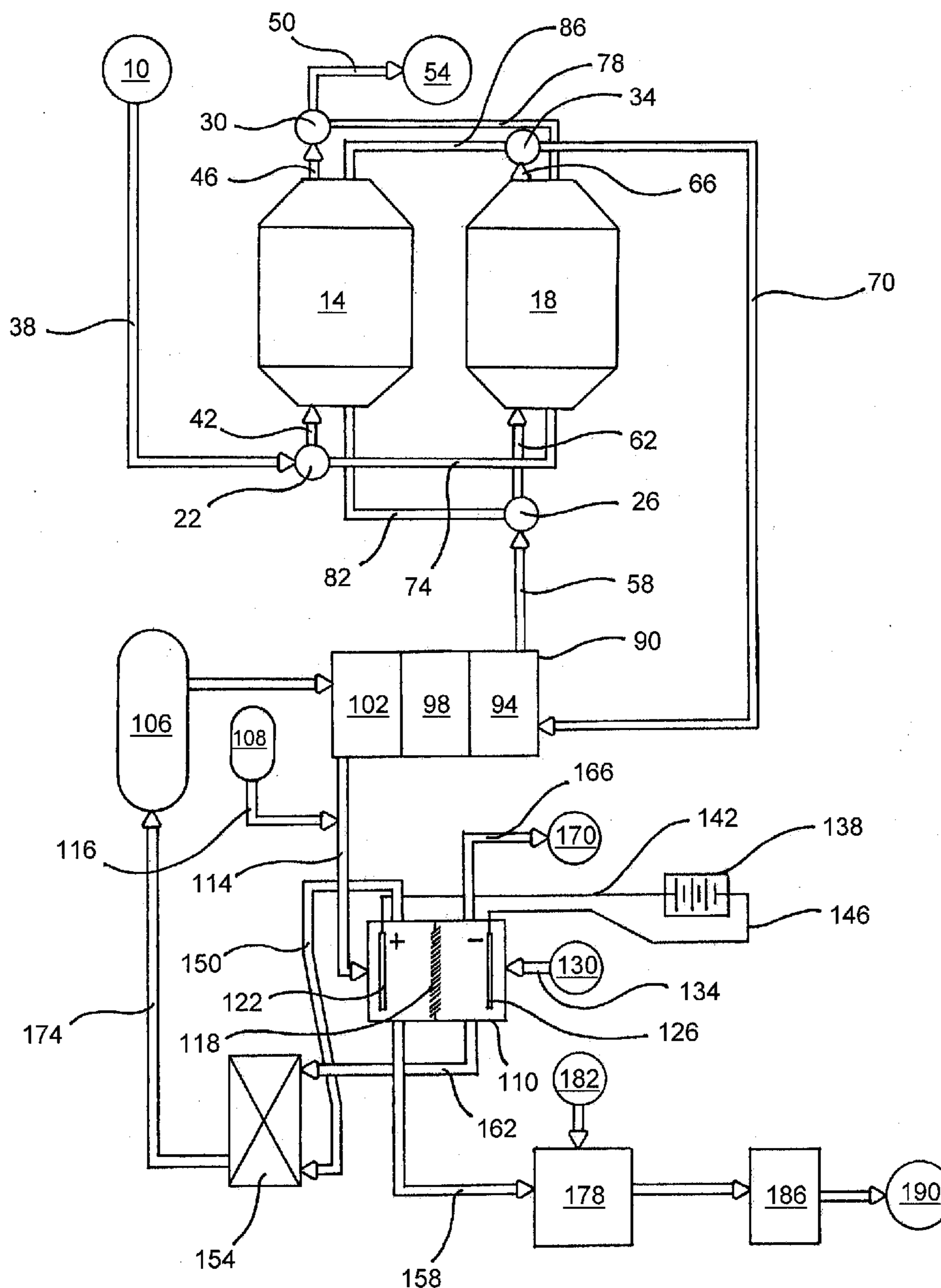
(19) **United States**(12) **Patent Application Publication**
Malhotra(10) **Pub. No.: US 2009/0032403 A1**(43) **Pub. Date: Feb. 5, 2009**(54) **URANIUM RECOVERY USING
ELECTROLYSIS****Related U.S. Application Data**

(60) Provisional application No. 60/953,763, filed on Aug. 3, 2007.

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(US)**Publication Classification**(51) **Int. Cl.**
C25C 1/22 (2006.01)(52) **U.S. Cl.** **205/46**(57) **ABSTRACT**

An electrolytic process for recovering uranium produces high quality uranium while reducing the processing necessary as well as the chemicals consumed. The process is environmentally friendly as it significantly reduces the emission of carbon dioxide from the processing system.

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BATEMAN IP LAW GROUP**P.O. BOX 1319****SALT LAKE CITY, UT 84110 (US)**(21) Appl. No.: **12/183,907**(22) Filed: **Jul. 31, 2008**

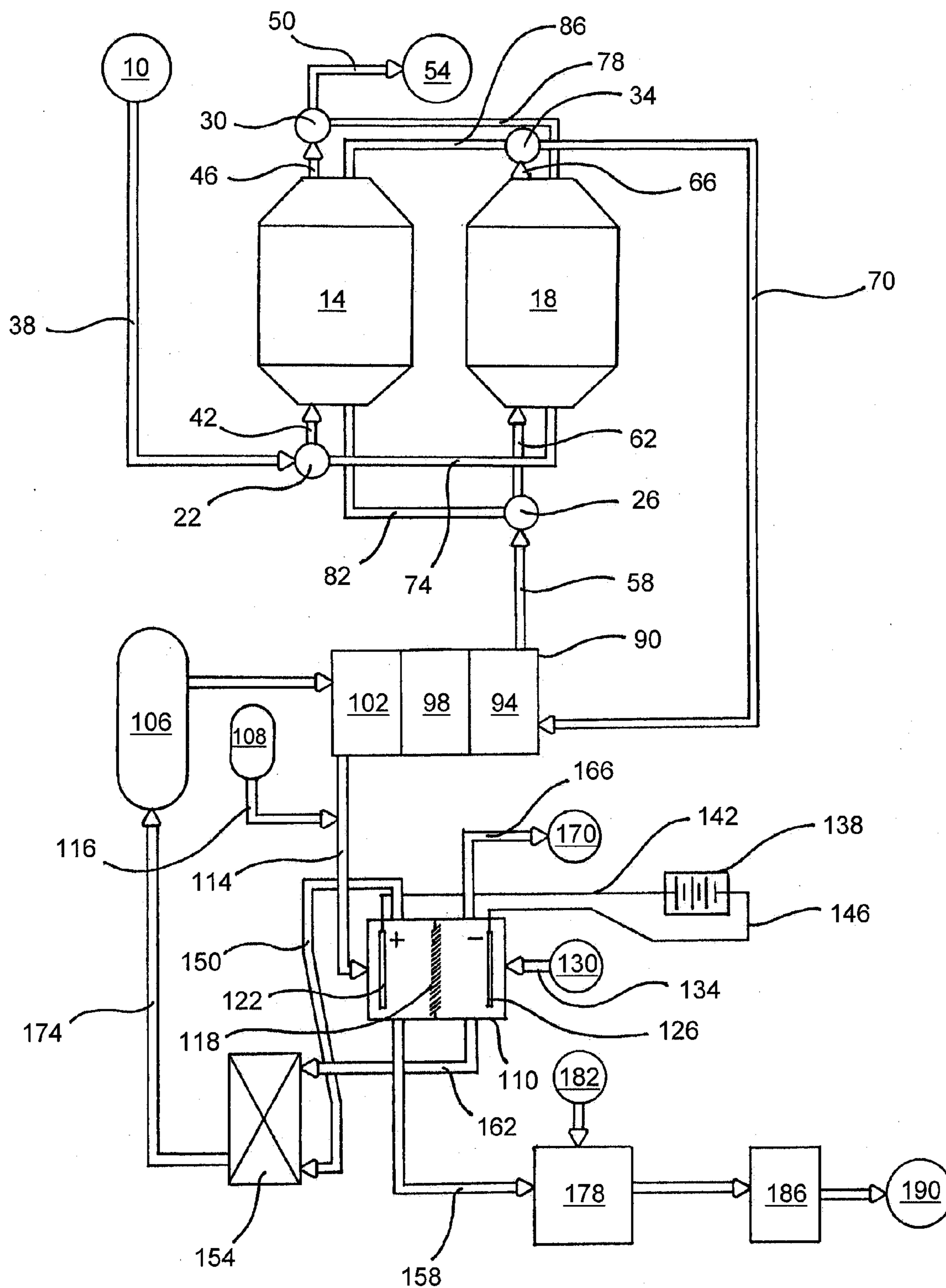


FIG. 1

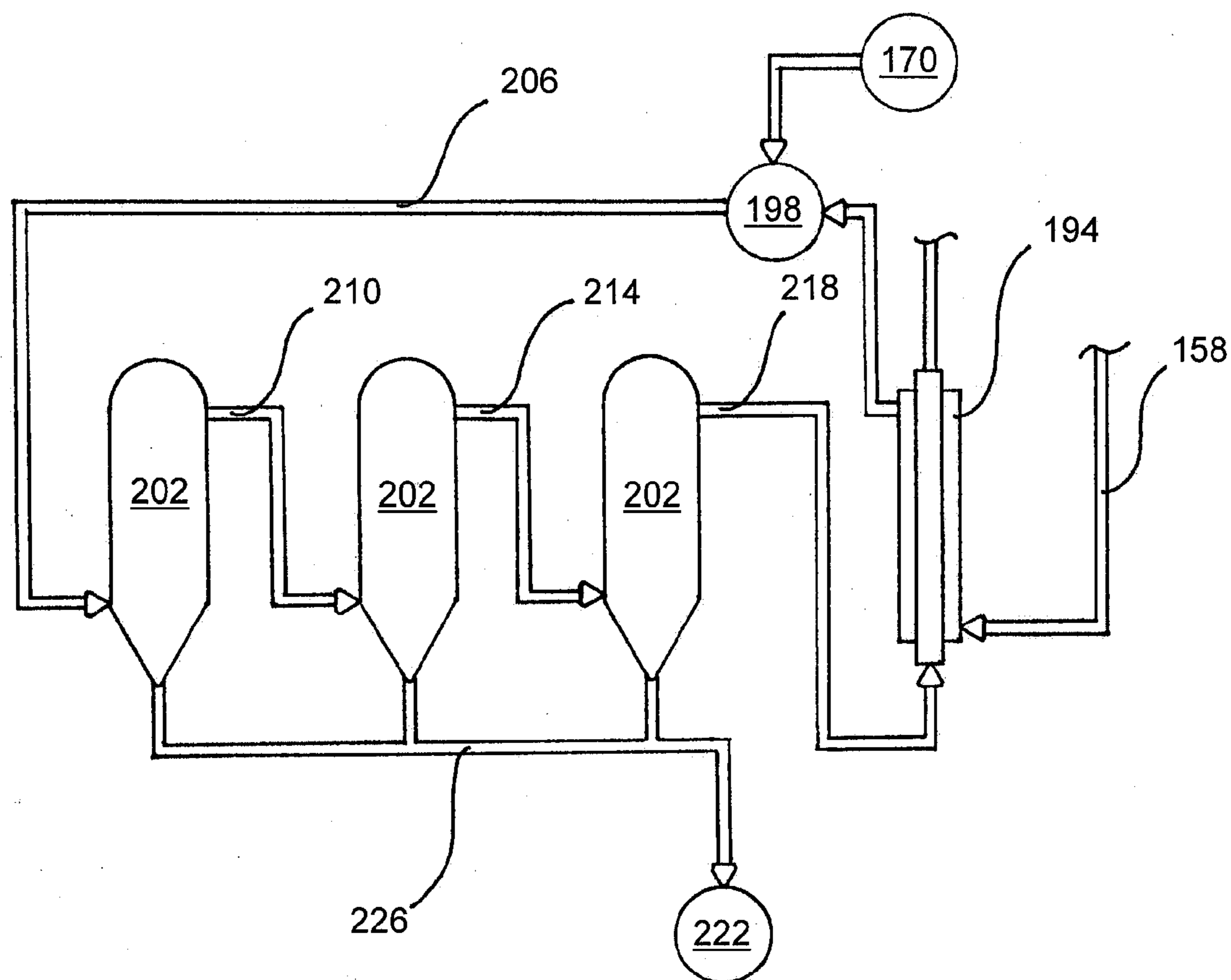


FIG. 2

URANIUM RECOVERY USING ELECTROLYSIS

RELATED APPLICATIONS

[0001] The present application claims the benefit of U.S. Provisional Application Ser. No. 60/953,763, filed Aug. 3, 2007, which is expressly incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] 1. The Field of the Invention

[0003] The present invention relates to uranium recovery. More specifically, the present invention relates to a method for recovering uranium from solutions utilizing electrolysis.

[0004] 2. State of the Art

[0005] Uranium occurs naturally in many different types of rock at some level. Often, rock will naturally contain a small quantity of uranium, such as a few parts per million (ppm) to ten ppm or more. Uranium may be naturally found in many types of rocks including coal, shale, sandstone, granite, etc. Naturally occurring uranium typically occurs with a reducing agent such as pyrite or hydrogen sulfide which fixes the uranium and prevents solubilization of the uranium. Thus, this naturally occurring uranium is typically insoluble, and thus stable, but is often easily solubilized by oxidation and complexing with carbonate or sulfate ions. Such ions may be present in ground waters, or may be introduced by mining or other human activities.

[0006] By way of example, copper mining typically involves the leaching of copper from rocks with solutions that will also dissolve the uranium and leach the uranium from the rocks. Thus, copper leach solutions will typically contain uranium. These leach solutions often contain uranium levels between one and forty ppm. If the leach solutions are recycled or recirculated, the uranium concentration is increased. Recovery of the uranium from the leach solutions is desirable for multiple reasons. It is desirable to remove the uranium from the water from an environmental standpoint so as to not contaminate the groundwater or cause pollution. It is also desirable to remove the uranium from a commercial standpoint, as the uranium has value as a product.

[0007] Uranium may be recovered in a cost effective manner. It may be particularly cost effective to recover uranium from the leach solutions of a copper mine or other plant utilizing leach solutions as the uranium has already been solubilized and removed from the rock, and only the marginal costs of recovering the uranium from the solution must be considered.

[0008] Attempts have been previously made to recover uranium from copper leach solutions. The Eluex process has been previously used to recover uranium. This process involves the use of ion-exchange resins and solvent extraction to extract the uranium from the leach solution and achieve a uranium solution having a concentration of approximately 10 g/L. In the ion-exchange portion of the Eluex process, the resin is moved through a Higgins loop where the ion-exchange resin is moved between a loading chamber and a stripping chamber. The leach solution (weak sulfuric acid) is pumped through the resin in the loading chamber in a down flow condition for five to ten minutes to allow the resin to absorb the uranium from the solution. At the same time, resin loaded with uranium is stripped with a concentrated solution of (typically) sulfuric acid in a stripping chamber. After the

desired contact time, flow of the leach solution and stripping solution is discontinued and a water pulse is used to quickly move the loaded resin from the loading chamber to the stripping chamber and resin from the stripping chamber to the loading chamber. About thirty seconds are required to circulate the resin.

[0009] The Higgins loop resin exchange process is disadvantageous as it results in significant attrition of the resin. The flow system used to load and strip the resin of uranium generates a significant back pressure. The back pressure results in excessive compressive forces on the resin itself and results in damage to the resin particles. The damage resin particles will often increase the back pressure in the system, resulting in accelerated damage to the resin. Additionally, the cycling of the resin between the loading chamber and the stripping chamber results in damage to the resin as the resin particles experience significant physical impact with other resin particles, the chamber walls and plumbing, valves, etc. The damage to and loss of the resin results in significant additional costs for replacement resin.

[0010] The solvent extraction step of the Eluex process then removes the uranium from the sulfuric acid stripping solution to further concentrate the uranium. An organic solvent solution, such as D2EHPA/TOPO in kerosene, is used to extract the uranium from the strip solution. The strip solution and the organic solvent solution are mixed and then separated. The dissolved uranium is collected into the organic solvent solution. The uranium is then extracted from the organic solvent solution with a solution of sodium carbonate. In this process, the uranium is further concentrated, and may result in a uranium concentration of about 10 g/L.

[0011] Following the solvent extraction, the uranium is precipitated from the sodium carbonate solution. The precipitation is typically achieved by adding sulfuric acid to the carbonate solution, lowering the pH and destroying the carbonate while releasing carbon dioxide gas. Ammonia is added to the solution to precipitate the uranium as ammonium diuranate, which is insoluble in water. The ammonium diuranate is thickened and washed to remove sodium, and then calcined to produce uranium oxide (U_3O_8).

[0012] The precipitation process has several disadvantages. Significant amounts of sodium carbonate are consumed to produce the uranium. The process requires over ten pounds of sodium carbonate to produce one pound of uranium oxide. The consumption of such an amount of sodium carbonate increases the cost of producing the uranium and makes the process less economically feasible. Additionally, the sulfuric acid used to neutralize the sodium carbonate before precipitation with the ammonia is consumed, adding to the cost and the amount of chemicals consumed in the process. Thus, a significant amount of chemicals are consumed during the production of the uranium oxide.

[0013] Additionally, impurities are introduced into the solution, and into the resulting uranium product, due to the use of commercial grade sodium carbonate. Grades of sodium carbonate having less impurities are simply too expensive to use in such a process having such high consumption of the carbonate. Another drawback of the precipitation process is that the sodium from the sodium carbonate remains in the solution after decarbonation and remains as an impurity in the ammonium diuranate, and must be washed from the diuranate in order to achieve the desired level of purity.

[0014] A further disadvantage is the release of significant amounts of carbon dioxide. The release or production of

carbon dioxide is undesirable as it has been shown to have a damaging effect on the environment.

SUMMARY OF THE INVENTION

[0015] It is an object of the present invention to provide an improved method for recovering uranium using electrolytic processes. It is desirable to produce high purity uranium from leach solutions or the like in a more cost effective manner. Additionally, it is desirable to provide an improved process for producing uranium which has less of an adverse impact on the environment and which utilizes fewer resources, such as by consuming fewer chemicals.

[0016] According to one aspect of the invention, an improved ion-exchange resin bed and method of using the same are provided. The present invention provides for a method of using the ion-exchange resin which results in significantly less damage to the resin and thus reduces the amount of replacement resin which is necessary.

[0017] According to another aspect of the invention, electrolysis is used for precipitation of the uranium from the sodium carbonate solution. The electrolysis produces uranium which contains significantly less impurity. Additionally, the use of electrolysis results in a process which consumes significantly less chemicals, and which allows for greater recycling of the chemicals within the uranium processing system. The use of electrolysis also allows for the processing of uranium without release of significant amounts of carbon dioxide to the atmosphere.

[0018] These and other aspects of the present invention are realized in a method and system for uranium recovery as shown and described in the following figures and related description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] Various embodiments of the present invention are shown and described in reference to the numbered drawings wherein:

[0020] FIG. 1 shows a process diagram for the method and apparatus for processing uranium according to the present invention; and

[0021] FIG. 2 shows a process diagram for another precipitation system as may be used with the present electrolytic process.

[0022] It will be appreciated that the drawings are illustrative and not limiting of the scope of the invention which is defined by the appended claims. The embodiments shown accomplish various aspects and objects of the invention. It will be appreciated that not every embodiment of the invention need accomplish all advantages of the present invention.

DETAILED DESCRIPTION

[0023] The invention and accompanying drawing will now be discussed in reference to the numerals provided therein so as to enable one skilled in the art to practice the present invention. The drawing and descriptions thereof are exemplary of various aspects of the invention and are not intended to narrow the scope of the appended claims.

[0024] Turning now to FIG. 1, a process diagram illustrating the uranium recovery processes of the present invention is shown. In describing the process, the process diagram does not include many incidental pieces of equipment such as pumps, heaters, coolers, holding tanks, etc. which may be necessary to maintain the desired flows and conditions within

the system. These pieces of equipment are within the ability of a skilled engineer to adapt to the present system as may be necessary. The diagram uses double lines to illustrate piping and flow between equipment, illustrating the direction of flow with triangular arrow heads. Single lines are used to denote electrical power.

[0025] The process is designed to remove uranium from a leach solution 10. The leach solution 10 may often be a leach solution from a copper mine, as copper mines will use these leach solutions to extract copper from the ore and will, in most cases, generate a leach solution containing uranium which has been solubilized and extracted from the ore. It will be appreciated, however, that the leach solution need not come from a copper mine. Uranium may be present in other solutions which may be advantageously process with the methods of the present invention.

[0026] In a first stage of the inventive process, the uranium is removed from the leach solution 10 using an ion-exchange resin which is selective for uranium. Typically, the leach solution is a weak sulfuric acid solution, so a resin is selected which selectively adsorbs uranium from the acidic solution. Such a resin is known in the art and has been used historically in the Eluex process used by the Wyoming Mineral Corp., although with a different system which disadvantageously caused excessive attrition of the resin. The resin will adsorb the uranium from a weak sulfuric acid solution, such as the leach solution, but will release the uranium to a stronger acidic solution such as a strong sulfuric acid solution. The leach solution may also be a basic solution, such as a carbonate/bicarbonate solution used for in-situ leaching. In such a case, the same resin may often be used, and the solvent extraction step may not be necessary if the uranium concentration is high enough in the leach solution. If the leach solution contains a sufficiently high concentration of uranium, the leach solution may pass directly to the electrolytic decarbonation step and not require ion extraction or solvent extraction.

[0027] According to the present invention, multiple packed columns 14, 18 are filled with the ion-exchange resin. Valves 22, 26, 30, 34 are used to control the flow through the packed columns 14. Three way valves 22, 26, 30, 34 are illustrated as convenient control valves for directing flow through two packed columns 14, 18. As shown, valves 22 and 30 are positioned to direct flow of the leach solution 10 through the first packed column 14, allowing the resin in the packed column to adsorb the uranium from the leach solution. The leach solution 10 is carried through pipes 38, 42, 46, and 50, placing the processed leach solution (largely free of uranium and ready for reuse as a leach solution) to a storage tank 54. Valves 26 and 34 are positioned to direct flow of a stripping solution through the second packed column 18 (which has been previously loaded with uranium). The stripping solution is typically a strong sulfuric acid solution.

[0028] As shown, pipes 58, 62, 66, 70 carry the stripping solution through the packed column 18. As packed column 14 is loaded with uranium from the leach solution 10, packed column 18 is unloaded of uranium by the stripping solution. Once the columns are loaded or unloaded with uranium as is desired for each particular column, the valves are changed to unload the loaded column and vice versa. Changing the position of valves 22, 26, 30, 34 will direct the leach solution through pipes 38, 74, 78, 50 so as to flow through packed column 18, and will direct the stripping solution through pipes 58, 82, 86, 70 and through packed column 14.

[0029] Although the operation of the system is described herein with two packed columns **14**, **18** to illustrate the loading and unloading cycles of the resin, it will be appreciated that multiple columns may be used to accommodate the desired processing rates and to accommodate the differing times or flows necessary for loading or unloading the resin in the packed columns. As such, the system may typically operate with manifolds to control flow of the leach solution **10** and the stripping solution through a number of packed columns.

[0030] Different numbers of packed columns may accommodate different loading or unloading times. For example, if it is desirable to have a loading time of five minutes and an unloading time of 10 minutes, three packed columns may be used. One of the packed columns may be loaded with uranium while the other two columns may be unloaded of uranium by the stripping solution. Such a configuration allows for an unloading time of approximately twice the loading time. Additionally, larger numbers of packed columns may be used to increase the processing capacity of the system.

[0031] The use of multiple packed columns and the selectively directing the solution flows therethrough inhibits attrition of the ion-exchange resin by keeping the resin bed stationary and minimizing trauma to the resin bed. The packed columns **14**, **18** filled with ion-exchange resin may thus be used to concentrate the low uranium concentration in the leach solution (often around 5 ppm) to as high as 1000 ppm in the stripping solution.

[0032] The ion-exchange stripping solution which is laden with uranium is passed through a solvent extractor **90**. The solvent extractor **90** is a liquid/liquid extractor and may include a first extraction section **94** which uses a solvent such as D2EHPA/TOPO in kerosene to extract the uranium from the ion-exchange stripping solution. Other suitable stripping solvents may be used. This and other extractions may be achieved by mixing and settling the liquids as is known in the art. The ion-exchange stripping solution is then recycled and passed through the packed columns **14**, **18** as desired to strip uranium from loaded columns.

[0033] The solvent extractor **90** may include a washing stage **98** where water is used to remove impurities, such as acid, from the extraction solvent. A final stage **102** in the solvent extractor **90** uses a solution of sodium carbonate **106** (Na_2CO_3) to extract the uranium from the solvent (such as D2EHPA/TOPO in kerosene). The sodium carbonate solution may have a one molar concentration of sodium carbonate, although somewhat higher or lower concentrations may be used.

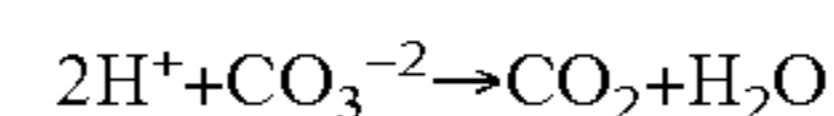
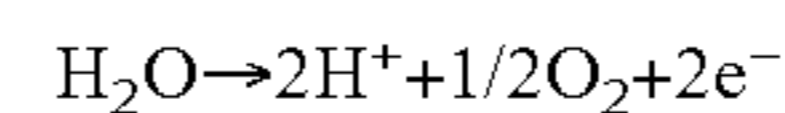
[0034] In some circumstances, uranium is present in a phosphoric acid solution. This may be a leach solution or an impurity found in phosphoric acid while producing phosphoric acid. Where uranium is present in a phosphoric acid solution, the ion exchange resin is typically not used, and the phosphoric acid solution is passed directly into the solvent extractor **90** where an extraction solvent such as the D2EHPA/TOPO is used to remove the uranium from the phosphoric acid. The uranium is then transferred into a carbonate solution in the solvent extractor **90** as discussed. The uranium bearing carbonate solution is then processed in the electrolytic cell in the manner discussed herein.

[0035] The sodium carbonate solution is carried to an electrolytic cell **110** via pipe **114** for removal of the sodium carbonate. The electrolytic cell **110** includes an ion-permeable cationic membrane **118** which divides the cell **110** and separates the anode **122** and the cathode **126**. The anode **122**

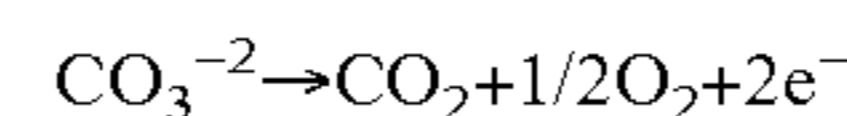
and cathode **126** may be selected so as to minimize degradation of the anode and cathode and to encourage the desired electrolytic reactions. For example, the anode **122** may be made from stainless steel, platinum, platinum coated titanium or nickel, metal oxides on titanium, etc. The cathode **126** may be a gas diffusing cathode, and may be made from materials such as stainless steel, copper, iron, nickel, etc. The membrane **118** may be constructed of organic, ceramic, composite, or other suitable materials. One of skill in the art will be able to select a desirable membrane construction and electrode materials from those which are suitable.

[0036] In operation, the electrolytic cell will function as follows. The carbonate solution bearing the dissolved uranium is introduced into the electrolytic cell **110** via pipe **114** as the anolyte solution. A catholyte solution **130**, which may be water or dilute sodium hydroxide, is introduced into the electrolytic cell via pipe **134**. The anode **122** and cathode **126** are connected to a DC power source **138** via wires **142**, **146** and a voltage is applied to the anode and cathode. As DC voltage is applied to the anode **122** and cathode **126**, the following electrolytic reactions will occur.

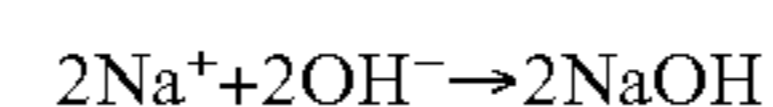
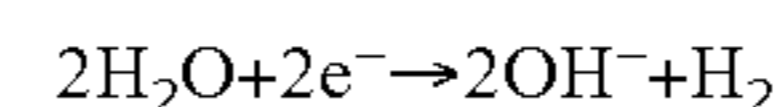
[0037] Anodic Reactions:



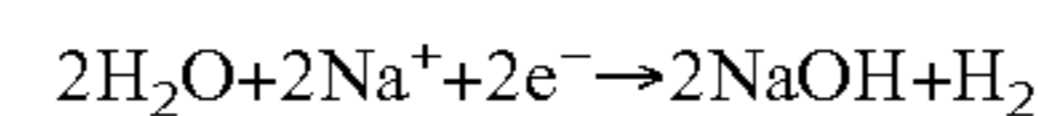
[0038] Net Reaction:



[0039] Cathodic Reactions:



[0040] Net Reaction:



[0041] The uranium bearing sodium carbonate anolyte solution is thus processed in the electrolytic cell to remove the sodium carbonate. A sulfate bearing solution **108**, such as Na_2SO_4 or H_2SO_4 , is mixed into the uranium bearing carbonate solution **106**, either before introduction of the carbonate solution **106** into the electrolytic cell **110**, directly into the electrolytic cell, or into another fluid stream which enters the electrolytic cell such as the recycle stream **174** such that the sulfate solution is mixed with the uranium bearing solution. The sulfate ions in the sulfate solution **108** complexes with the uranium (here, UO_2^{2+}) to prevent migration of the uranium across the membrane **118** and to prevent precipitation of the uranium in the electrolytic cell (which may result in uranium precipitation on the membrane or clogging of the membrane). As shown, the sulfate solution **108** is mixed, via pipe **116**, with the uranium bearing carbonate solution carried by pipe **114**.

[0042] Carbon dioxide and oxygen is liberated in the anode chamber of the cell **110** and is transported via pipe to a scrubber **154** for reuse. The sodium ions remaining will pass through the ion-permeable membrane **118** into the cathode chamber. A uranium bearing solution which is substantially free of both sodium and carbonate ions will exit the anode chamber via pipe **158** for further processing.

[0043] The catholyte solution **130** (typically dilute NaOH or water which may be recycled from other parts of the system) is introduced into the cathode chamber and will accumulate sodium ions from the anode chamber (as these ions

will flow across the cationic membrane **118**). Hydroxide ions are produced in the cathode chamber which contribute to the formation of the concentrated sodium hydroxide solution which exits the cathode chamber via pipe **162**. The hydrogen gas produced is transported via pipe **166** to storage **170** (which may include compressing, use as a fuel, etc.).

[0044] The concentrated sodium hydroxide solution is moved via pipe **162** to scrubber **154** where it is contacted with the gasses from the anode chamber, which is the carbon dioxide and oxygen gasses transported via pipe **150**. The sodium hydroxide and carbon dioxide react in the scrubber to produce sodium carbonate solution (**106**) which is reused in the process as shown by pipe **174**.

[0045] The system is thus advantageous as it recycles the sodium carbonate. This is advantageous as it eliminates the consumption of the sodium carbonate as occurs in prior art systems and saves considerable money. This is also advantageous as the sodium carbonate produced from the electrolytic products is quite pure and thus does not introduce impurities into the system as occurs with the prior art systems. Additionally, the recycling of the sodium carbonate removes the sodium from the precipitated uranium and produces a uranium product with a higher purity and which requires less washing and processing. It will be appreciated that the electrolytic process may be performed in other types of electrolytic cells, such as three compartment cells. One skilled in the art of electrolysis will understand how to adapt the present electrolytic process to other types of electrolytic cells.

[0046] The uranium bearing solution produced in the anode chamber of the electrolytic cell **110** is moved via pipe **158** to a precipitation chamber **178** where ammonia **182** is added to precipitate the uranium as ammonium diuranate. Alternatively, hydrogen peroxide may be used to precipitate the uranium. The precipitate is removed from the solution and requires very little washing or processing as it is substantially free of impurities, such as the residual sodium or the impurities introduced via the commercial grades of sodium carbonate used in the prior art processes. The uranium precipitate is then typically calcined in a kiln **186** to produce uranium oxide **190**.

[0047] Alternative processes for precipitating uranium are known. For example, it is known to precipitate uranium using hydrogen gas. In such a system, hydrogen gas is mixed with the uranium bearing solution under elevated pressure and increased temperature to precipitate the uranium. Typically, the hydrogen and uranium bearing solution are mixed and passed through a series of reaction vessels. The precipitated uranium acts as a catalyst for further precipitation. The uranium depleted solution and the uranium rich feed solution are typically passed through a heat exchanger to cool the depleted solution and heat the rich feed solution and thereby recover heat from the system.

[0048] Previously, this system was disadvantageous as it required a supply of hydrogen gas to achieve the precipitation. The present electrolytic process may be advantageously combined with the hydrogen precipitation process as it provides a source of pure hydrogen gas. The hydrogen gas produced at the cathode **126** may be collected and mixed with the uranium bearing solution in pipe **158** to precipitate the uranium under applied heat and pressure.

[0049] FIG. 2 shows such a precipitation system as utilized with the present invention. The uranium bearing solution in pipe **158** is passed through a heat exchanger **194** and then mixed with the hydrogen gas **170**. The resulting heated mix-

ture **198** (also typically at an elevated pressure) is moved through precipitation vessels **202** as shown by pipes **206**, **210**, **214**. The uranium depleted solution exiting the final precipitation vessel is moved through the heat exchanger **194** via pipe **218** to heat the incoming uranium bearing solution in pipe **158**. The depleted solution may be reused as may be appropriate. The precipitated uranium **222** is collected from the precipitation vessels **202** by manifold pipe **226**, and may be thereafter process as necessary, such as by additional washing or calcining.

[0050] The inventive process for recovering uranium is advantageous over the prior art processes for many reasons. As discussed, the process initially addresses the significant attrition of ion-exchange resin caused by the prior art process, and which leads to costly resin replacement. The process is further advantageous as it recycles the sodium carbonate instead of destroying the same with acid, reducing the amounts of sodium carbonate and acid consumed by the process. The process produces very pure sodium carbonate solution which does not introduce impurities into the product as the use of commercial grade sodium carbonate does. It is thus appreciated that the inventive process is an improvement over the prior art as it produces a highly pure uranium product while requiring less processing, consuming fewer chemicals, and releasing less chemicals into the environment.

[0051] There is thus disclosed an improved method and system for recovering uranium using electrolysis. It will be appreciated that numerous changes may be made to the present invention without departing from the scope of the claims.

What is claimed is:

1. A method for recovering uranium comprising:

passing a solution containing soluble uranium and basic salt consisting of at least one of the group consisting of alkali metal carbonate and alkali metal bicarbonate into the anode chamber of an electrolytic cell, said electrolytic cell comprising an anode chamber, a cathode chamber, and an ion-permeable membrane therebetween so as to selectively isolate the anode chamber from the cathode chamber;

passing a catholyte into the cathode chamber of the electrolytic cell; and

operating the electrolytic cell so as to produce carbon dioxide gas from the anode chamber, transfer alkali metal ions through the ion-permeable membrane from the anode chamber to the cathode chamber, produce a solution containing soluble uranium and being substantially free of alkali metal and carbonate/bicarbonate ions from the anode chamber; and producing a alkali metal hydroxide solution from the cathode chamber.

2. The method of claim 1, wherein the method further comprises precipitating the uranium from the solution containing soluble uranium to produce uranium which is substantially free of alkali metal.

3. The method of claim 2, wherein the method comprises precipitating the uranium with at least one of the group consisting of hydrogen peroxide and ammonia.

4. The method of claim 1, wherein the method further comprises producing a hydrogen gas from the cathode chamber of the electrolytic cell and mixing the hydrogen gas with the solution containing soluble uranium to thereby precipitate the uranium.

5. The method of claim 1, wherein the method further comprises contacting the carbon dioxide gas with the alkali

metal hydroxide solution produced by the electrolytic cell to form an alkali metal carbonate solution.

6. The method of claim 5, wherein the method further comprises utilizing the alkali metal carbonate solution to extract soluble uranium in a solvent extractor and passing said solution of alkali metal carbonate and soluble uranium into the electrolytic cell to thereby recycle the alkali metal carbonate.

7. The method of claim 6, wherein the method comprises passing a solution containing acid and soluble uranium through a solvent extractor to thereby transfer the soluble uranium to said solution of alkali metal carbonate.

8. The method of claim 7, wherein the method comprises utilizing an ion-exchange resin to concentrate the soluble uranium.

9. A method for recovering uranium comprising:
selecting a first solution containing soluble uranium;
passing the first solution containing soluble uranium through a solvent extractor to thereby transfer the soluble uranium into a second alkali metal salt solution comprising at least one of the group consisting of alkali metal carbonate and alkali metal bicarbonate to thereby generate a third alkali metal salt solution containing soluble uranium;
passing the third alkali metal salt solution having soluble uranium into an electrolytic cell to thereby remove the alkali metal carbonate or alkali metal bicarbonate from the alkali metal salt solution to produce a fourth solution containing soluble uranium; and
precipitating the soluble uranium from the fourth solution of soluble uranium.

10. The method of claim 9, wherein the method further comprises using a mixture of kerosene and D2EHPA/TOPO as an extraction solvent to transfer the soluble uranium from the first solution to the second alkali metal salt solution.

11. The method of claim 9, wherein the method further comprises passing the first solution through an ion-exchange resin to generate a solution having a higher concentration of uranium and passing said solution of higher concentration through said solvent extractor.

12. The method of claim 9, wherein the method further comprises, in the electrolytic cell, passing the third solution having alkali metal salt and soluble uranium into the anode chamber of the cell, electrolytically converting the alkali metal salt to alkali metal ions and carbon dioxide gas, passing the alkali metal ions through an ion-permeable membrane into the cathode chamber; and producing from the anode chamber said fourth solution containing soluble uranium and having a significantly reduced concentration of alkali metal salt.

13. The method of claim 10, wherein the fourth solution is substantially free of alkali metal salt.

14. The method of claim 10, wherein the method further comprises, in the electrolytic cell, passing an aqueous catholyte solution into the cathode chamber, electrolytically converting water to hydrogen gas and hydroxide ions so as to form a alkali metal hydroxide solution, and producing from the cathode chamber, said alkali metal hydroxide solution.

15. The method of claim 14, wherein the method further comprises mixing the carbon dioxide and alkali metal hydroxide solution produced in the electrolytic cell to thereby produce an alkali metal carbonate solution.

16. The method of claim 15, wherein the method further comprises passing the carbon dioxide and alkali metal

hydroxide solution through a scrubber to thereby for the alkali metal carbonate solution.

17. The method of claim 15, wherein the method further comprises passing the alkali metal carbonate solution through the solvent extractor to receive soluble uranium and thereby form the third solution containing alkali metal carbonate and soluble uranium.

18. The method of claim 12, wherein the method further comprises adding sulfate ions to the third solution.

19. The method of claim 9, wherein the method further comprises precipitating the soluble uranium with at least one of the group consisting of ammonia and hydrogen peroxide.

20. A method for recovering uranium comprising:
selecting an acid solution containing soluble uranium;
passing the acid and uranium through a solvent extractor to thereby transfer the uranium to a solution of sodium carbonate;
passing the solution of sodium carbonate and uranium through an electrolytic cell to thereby remove the sodium carbonate from the sodium carbonate and uranium solution to produce a uranium solution substantially free of sodium carbonate; and
precipitating and collecting the uranium.

21. The method of claim 20, wherein the method further comprises passing the acid solution through an ion-exchange resin to thereby adsorb the uranium onto the resin;

passing a strong acid stripping solution through the ion-exchange resin to thereby desorb the uranium and create a solution of strong acid and uranium which has a higher concentration of uranium than the leach solution;

passing the solution of strong acid and uranium through the solvent extractor.

22. The method of claim 20, wherein the method further comprises selecting a leach solution which is an acidic solution containing soluble uranium.

23. The method of claim 20, wherein the method further comprises passing the leach solution through a first packed column of ion-exchange resin to load the first packed column while passing the strong sulfuric acid stripping solution through a second packed column which has been previously loaded with uranium to thereby remove the uranium.

24. The method of claim 23, wherein the method comprises selective alternating, for a plurality of packed columns, between loading a packed column with uranium contained in the leach solution and unloading another packed column of uranium via the stripping solution to thereby allow for substantially continuous flow of the leach solution stripping solution through the plurality of packed columns.

25. The method of claim 20, wherein the method further comprises utilizing a mixture of kerosene and D2EHPA/TOPO in the solvent extractor to extract the uranium from the sulfuric acid stripping solution and using the sodium carbonate solution to extract the uranium from the kerosene mixture.

26. The method of claim 20, wherein the method further comprises, in an anode chamber of the electrolytic cell, removing the sodium carbonate from the sodium carbonate and uranium solution, generating carbon dioxide gas, and releasing a uranium solution which is substantially free of sodium carbonate, transferring sodium ions through the ion-permeable membrane from the anode chamber to a cathode chamber of the electrolytic cell, and, in the cathode chamber, generating hydrogen gas, producing hydroxide ions to

thereby produce a sodium hydroxide solution, and releasing a sodium hydroxide solution.

27. The method of claim **26**, wherein the method further comprises mixing the carbon dioxide gas from the anode chamber and the sodium hydroxide solution from the cathode chamber to thereby form a sodium carbonate solution.

28. The method of claim **27**, wherein the method further comprises using the sodium carbonate solution formed from

the electrolytic cell products as the feed solution of sodium carbonate to the solvent extractor to thereby recycle the sodium carbonate.

29. The method of claim **20**, wherein the method further comprises precipitating the uranium with one of the group consisting of hydrogen peroxide and ammonia and calcining the uranium to form uranium oxide.

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