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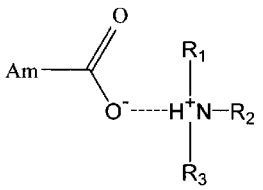
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(54) **Title**: ABSORBENT SYSTEM FOR CARBON DIOXIDE CAPTURE




(1)

(57) **Abstract**: This invention relates to a liquid absorbent system for capture of carbon dioxide present in gases which comprises of contacting a CO2-containing gas with an aqueous solution containing an amine salt of an amino acid of the general formula [1]. wherein Am is an amino acid backbone containing 1 to 4 carbon atoms and at least one amine group. The amino acid is reacted with an amine with at least one amine functionality and where at least one of R1, R2 and R3 is an alkyl, alkanol, or amine group. The absorbent system is the product of neutralizing stoichiometric proportions of an amino acid with an organic base, the amine; wherein excess amine could be used as promoter. This absorbent system improves carbon dioxide removal efficiency due to its higher CO2 removal ability per cycle when compared with conventional amine and absorbent from organic acid neutralized with inorganic base. It also does not exhibit solvent vaporisation loss because the absorbent is in salt form, thus its ionic nature practically does not allow solvent vapour pressure.

# Absorbent system for carbon dioxide capture

The present invention relates to a liquid solvent composition for use in the capture of carbon dioxide ($CO_2$) for purification of acidic gases such as combustion exhaust gases, blast oven gases, and cement kiln off-gases.

It is known that it is possible to remove undesirable acidic gaseous compounds or acidic gases, especially $CO_2$, $H_2S$ and COS from gas streams by scrubbing with regenerable absorbent liquid. Use of a regenerable absorbent liquid of organic bases such as alkanolamines for this purpose has been an active area of research. Several alkanolamines and the mixtures thereof, have also been proposed for this purpose. Examples of such alkanolamines include monoethanolamine, diethanolamine, triethanolamine, dimethyldiethanolamine, diisopropanolamine and diglycolamine, and in general, monoethanolamine is preferably used. These absorbents react with $CO_2$, $H_2S$ and COS forming compounds which are capable of being decomposed by heating, thus allowing the liquid absorbent to be regenerated. However, these amines have the disadvantage of requiring large amounts of energy for regeneration. Also, due to high vapour pressure of the solution enriched with $CO_2$, $H_2S$ and COS, a complete wash out of the acid gas is very difficult. Equally the organic bases are volatile and thus considerable solvent loss is incurred both during the absorption of the acid gases and stripping of same from the absorbent.

U.S. Pat. No. 1,990,217 discloses a solvent system for washing of gaseous weak acids from gases containing the same by aqueous liquids which contain organic acids in combination with inorganic bases. As such bases alkalies or alkaline earths may be used. They may initially be present in the form of their salts with said organic acids. The alkaline-reacting salts of the organic acids, especially salts of aminocarboxylic acids, were disclosed to be practically non-volatile and have stronger absorption power than organic bases and alkali metal salts of weak inorganic acids which have also been proposed for gas purification. A drawback of these alkaline-reacting salts is their tendency to form solid deposits when they absorb large amounts of gaseous weak acids, in particular carbon dioxide.

US. Pat. No. 2,176,441 describes that in the purification of gases by means of alkaline-reacting washing liquids especially good results are obtained by employing solutions of salts of amino or imino acids or tertiary N-acids which are derived from a primary, secondary, or tertiary amine which contains at least two nitrogen atoms. The

scrubbing solution is composed of a salt of a base selected from the group consisting of the alkalies, alkaline earths and the strong organic bases together with an amino carboxylic acid containing at least two nitrogen atoms and derived from an amine selected from the group consisting of ethylene diamine and its polymers. The advantage of this process resides in the fact that deposits of solid substances do not form, or only form to a very slight extent, during the washing of the gas or during regeneration. Lower viscosity and high absorption capacity are mentioned as additional advantages.

U.S. Pat. No. 1,990,217 teaches the use of a salt of an organic acid and an inorganic base for gas purification while US. Pat. No. 2,176,441 teaches the use of a salt of amino acids and inorganic or organic bases whereby the amino acid should be derived from a primary, secondary or tertiary amine having at least two nitrogen atoms. However none of the patents recognize the advantage of using amino acids derived from primary, secondary or tertiary amines and no mention was made of the use of an amine-amino acid salt of such composition.

AU-B-67247/81 describes the use of an aqueous scrubbing solution comprising a mixture of a basic salt, potassium carbonate, and an activator for the said basic salt comprising at least one, sterically hindered amine and a sterically hindered amino acid as a cosolvent for the sterically hindered amine. The amino acid here serves to prevent two phase separation of the aqueous solution at high temperatures.

US 2007/0264180 A1 discloses use of an absorbent solution comprising compounds having the property of forming two separable phases by addition of an acid that is stronger than the acid compounds of the gaseous effluent to be treated: a first phase rich in acid compounds and a second phase poor in acid compounds wherein amine, amino acids or amino-acid alkaline salts are used as activators to favour absorption of compounds to be eliminated. The invention describes acid neutralization of multiamines to form two phase liquid and a process for separation of the two phase liquid.

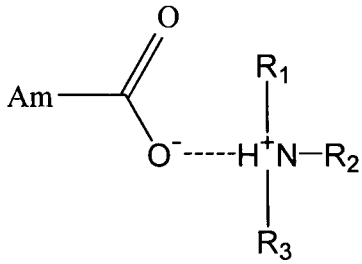
Different researchers including, Jensen and Faurholt, Acta Chemica Scandinavica (1952), 6 385-94; Jensen et al., Acta Chemica Scandinavica (1952), 6 395-7; Caplow, Journal of the American Chemical Society (1968), 90(24), 6795-803; Penny and Ritter, Journal of the Chemical Society, Faraday Transactions 1: Physical Chemistry in Condensed Phases (1983), 79(9), 2103-9; Hook, Industrial &

Engineering Chemistry Research (1997), 36(5), 1779-1790; Kumar et al., AIChE Journal (2003), 49(1), 203-213 and Hamborg et al., Journal of Chemical & Engineering Data (2007), 52(6), 2491-2502 have all investigated the reactions of amino acids or amino acid salts with $CO_2$, but they only investigated the amino acid salts of a strong inorganic base (either potassium or sodium hydroxide) with a weak acid.

We have now found that a solvent composition formed by full or partial neutralization of amino acids with essentially stoichiometric proportion of an organic base gives an especially good result for purification of gases containing $CO_2$, $H_2S$ and COS and as such is very suitable for $CO_2$ capture. The amino acid in this case has at least one amine group while the organic base is preferably amine(s). This amine salt of amino acid composition was found to have unique advantages which include; no precipitate or deposit formation during absorption or regeneration stages of the absorbent. It is practically non-volatile since the reacting salt formed is ionic in nature thus the absorbent does allows only low solvent evaporation losses because it has low vapour pressure. The amine salt of amino acid formed does not show signs of foaming or discolouration during absorption or regeneration which gives indications of good stability properties of the solvent composition. It has high absorption capacity and reactivity since the salt formed is comparable to alkanol amines of related class. It also has low viscosity indicating that the solvent composition could be used at higher concentrations if desired.

**Brief Summary of Invention**

The present invention provides a liquid absorbent for removing carbon dioxide from a gas stream, essentially comprising an aqueous solution of an amine salt of an amino acid of the general formula [1]

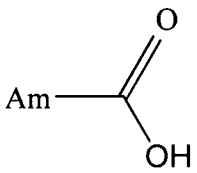



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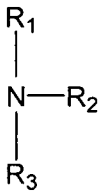
wherein Am is an amino acid backbone containing 1 to 4 carbon atoms and at least one amine group; and $R_1$, $R_2$ and $R_3$ are selected from hydrogen, $C_{1-4}$ alkyl, $C_{1-4}$ alkanol, or a straight chain, cyclic or aromatic amine groups, wherein at least one of $R_1$, $R_2$ and $R_3$ is an $C_{1-4}$ alkyl, $C_{1-4}$ alkanol or a straight chain, cyclic or aromatic amine group.

The present invention relates to an absorbent liquid where the aqueous solution of the salt is the main component of the liquid absorbent. The reacting salt is formed from a mixture of amino acid and organic base, preferably amine(s), in essentially stoichiometric proportions. The amino acid is represent by the general formula [2] wherein Am is an amino acid backbone containing 1 to 4 carbon atoms and at least one amine group.

The amine used is of the general formula [3], wherein $R_1$, $R_2$ and $R_3$ are selected from hydrogen, $C_{1-4}$ alkyl, $C_{1-4}$ alkanol, or a straight chain, cyclic or aromatic amine groups, wherein at least one of $R_1$, $R_2$ and $R_3$ is an $C_{1-4}$ alkyl, $C_{1-4}$ alkanol or a straight chain, cyclic or aromatic amine group wherein the straight chain contains up to 7 carbon atoms while cyclic or aromatic amine groups contain 3 to 6 carbon atoms. It could be a primary amine wherein $R_1$ and $R_2$ are hydrogen atoms, a secondary amine wherein only $R_1$ is a hydrogen atom or a tertiary amine wherein none is hydrogen atom. The amine [3] could be a mono, di or polyamine molecule. [3] could also have a ring structure.

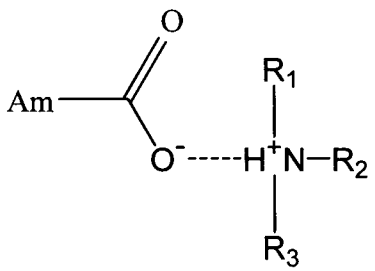



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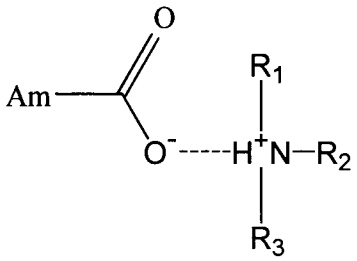
The reacting amine salt of amino acid formed by the mixture of essentially stoichiometric composition of [2] and [3] is as shown in formula[1]. This is the salt that reacts with acidic gas during gas purification. To further enhance the performance of [1], excess amine could be added to the salt formed. The excess amine could be the same as [3] or a different amine group having desired properties. It should however be noted that addition of excess amine could increase volatility since the excess amine is not present in salt form.




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Another aspect of the present invention is a process for removing carbon dioxide from a gas stream, having the following steps

- absorbing carbon dioxide gas from a gas stream by contacting and scrubbing said gas with an absorbent liquid comprising essentially of an amine salt of amino acid with the general formula [1]



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wherein Am is an amino acid backbone containing 1 to 4 carbon atoms and at least one amine group; and $R_1$, $R_2$ and $R_3$ are selected from hydrogen, $C_{1-4}$ alkyl, $C_{1-4}$ alkanol, or a straight chain, cyclic or aromatic amine groups, wherein at least one of $R_1$, $R_2$ and $R_3$ is an $C_{1-4}$ alkyl, $C_{1-4}$ alkanol or a straight chain, cyclic or aromatic amine group wherein the straight chain contains up to 7 carbon atoms while cyclic or aromatic amine group contain 3 to 6 carbon atoms ; and

- regenerating the rich absorbent liquid.

The present invention also relates to a process which utilizes the absorbent liquid of the present invention to remove acidic gases such as $CO_2$, from a gas stream using amine salt of amino acid. The steps of the process comprise absorbing $CO_2$ from an acidic gas stream by contacting and scrubbing said gas with an absorbent liquid composed of amine salt of amino acid and regenerating the $CO_2$ rich absorbent liquid for further contacting with, and absorption of $CO_2$ from, the gas stream.

When a salt solution comprised of general formula [1] is used as an absorbing solution according to the present invention, the amount of $CO_2$ captured per mole of absorbent, as well as per litre of absorbent, is increased compared to the amount captured by inorganic salts of amino acids and other conventional absorbing solutions used. Moreover, since this absorbent is in salt form it is less volatile, and thus, there is reduced solvent loss through evaporation. In addition, this absorbent does not form solid precipitates, foam or discolouration during the absorption or regeneration process, and thus, has good stability. Hence reduced solvent loss by degradation is achieved, and the absorbent system removes $CO_2$ more efficiently.

**Figures**

Figure 1 shows equilibrium measurement results of $CO_2$ partial pressure versus loading for potassium salt of 2-(methylamino)acetic acid (KSAR) and 3-(methylamino)propylamine salt of 2-(methylamino)acetic acid (SARMAPA)

Figure 2 shows pilot plant result in terms of energy input as function of loading into stripper for potassium salt of 2-(methylamino)acetic acid (KSAR) and 3-(methylamino)propylamine salt of 2-(methylamino)acetic acid (SARMAPA).

**Detailed Description of the Invention**

According to the present invention, a gas containing carbon dioxide is brought into contact with an aqueous solution containing, as an absorbent, at least one amine salt of amino acid of the general formula [1]. Said amine salt of amino acid is formed by mixing equimolar amounts of amino acid [2] with organic base, preferably amine [3]. In this formula, Am is an amine or aminoethanol group. Am is an amino acid backbone containing 1 to 4 carbon atoms and at least one amine group. Specific examples of the amine group include monomethyl, dimethyl, ethyl, diethyl, propyl, isopropyl, butyl, isobutyl, sec-butyl and tert-butyl amine or aminoethanol groups. Examples of such amino acid include, but are not limited to, 2-aminoacetic acid, 2-aminopropanoic, 3-aminopropanoic acid, 2-(methylamino)acetic acid, 2-amino-3-methyl-butanoic acid. It is preferred to use the amino acid [2] wherein Am is monomethyl or dimethyl amine.

An amine of the general formula [3], wherein $R_1$, $R_2$ and $R_3$ are selected from hydrogen, $C_{1-4}$ alkyl, $C_{1-4}$ alkanol, or a straight chain, cyclic or aromatic amine groups, wherein at least one of $R_1$, $R_2$ and $R_3$ is an $C_{1-4}$ alkyl, $C_{1-4}$ alkanol or a straight chain, cyclic or aromatic amine group, wherein the straight chain is up to 7 carbon atoms while cyclic or aromatic amine group contain 3 to 6 carbon atoms. This could be primary amine wherein $R_1$ and $R_2$ are hydrogen atoms, secondary amine wherein only $R_1$ is a hydrogen atom or tertiary amine wherein there are no hydrogen atoms. The amine [3] could be mono, di or polyamine molecule. [3] could also be a cyclic or aromatic amine. Examples of amine compounds that can be used include monoethanolamine (MEA), diethylenetriamine (DETA), N-aminoethylethanol-amine(AEEA), tetraethylenepentamine(TEPA), piperazine(PZ), 3-(methylamino)propyl-amine (MAPA), ethylenediamine (EDA), triethylenetetramine (TETA), hexamethylene-diamine (HMDA), N,N-dimethylpropane-1,3-diamine (DMAPA), 1,2 diaminocyclo-hexane (DACH), 3,3' diaminodipropylamine(DADPA), N-(2-aminoethyl)-1,3-propane-diamine(AEPDA), 2-(1-piperazinyl)ethylamine(AEP), 3-dimethylaminopropylamine (DMPDA), monomethylethanolamine(MMEA), 2-ethylaminoethanol, 2-methyl-piperazine, 2,5-dimethylpiperazine.

In the aqueous solution composed of a mixture of at least one of [2] and [3], the amine salt of amino acid formed [1] (hereinafter also referred to as absorbing solution) could be monoethanolamine salt of 2-aminoacetic acid, diethylenetriamine

salt of 2-aminopropanoic, N-aminoethylethanolamine salt of 3-aminopropanoic acid , 3-(methylamino)propylamine salt of 2-(methylamino)acetic acid, 3-(methylamino)-propylamine salt of 2-aminoacetic acid, 3-(methylamino)propylamine salt of 2-aminopropanoic, piperazine salt of 2-(methylamino)acetic acid, piperazine salt of 2-aminoacetic acid, piperazine salt of 2-aminopropanoic acid, to mention but a few. Whereby 3-(methylamino)propylamine salt of 2-(methylamino)acetic acid and piperazine salt of 2-(methylamino)acetic acid are one preferred composition of [1].

The concentration of the absorbing solution which is used for contact with the $CO_2$-containing gas according to the present invention may be between about 1 mole/litre and about 7 mole/litre. Preferably, the concentration is between about 2.5 mole/litre and 5 mole/litre. The temperature at which the absorbing solution is brought into contact with a $CO_2$-containing gas is usually in the range 30 to 70°C.

In order to further enhance the $CO_2$-absorbing power (the amount of $CO_2$ absorbed and the absorption rate) of the absorbing solution, excess amine could be added wherein same amine as [3] or any other amine selected from the suggested examples for [3], provided that it is soluble in the absorbing solution. Excess amine is to be used at the concentration of 1.5 to 50% by weight but preferably 5 to 40% by weight.

The acidic gases which can be treated by the present invention include natural gas, various industrial gases (e.g. synthesis gas) produced in chemical plants, combustion exhaust gases such as originating from coal gasification, blast and coke oven gases, refinery gases and the like.

The steps of the process that uses the absorbent of said invention comprise absorbing $CO_2$ from an acidic gas stream by contacting and scrubbing the said gas with an absorbent liquid of the said invention and regenerating the $CO_2$ rich absorbent liquid for further contacting with and absorption of $CO_2$ from the gas stream. During the absorption stage, the gas to be treated and the absorbent liquid are contacted with each other, preferably in counter current flow, in an absorber under suitable conditions to produce treated gas with reduced content of acidic gaseous compounds which generally correspond to the specifications provided for the treated gas. The rich absorbent liquid comprising $CO_2$ and other acidic gaseous compounds is then subjected to regeneration treatment under suitable conditions to release the acidic gaseous compounds absorbed by the liquid, and thus, producing at least two streams, one of which is the released acidic gaseous compounds and the other a regenerated

absorbent liquid which is recycled to the absorber. No particular restriction is placed on a process which can be employed in a method for removing $CO_2$ from combustion exhaust gas according to the present invention. Methods described in US. Pat. No. 6,051,161 and 6,500,397 could be used.

One advantage found in the use of the present invention for $CO_2$ absorption includes no precipitate or deposit formation during the absorption or regeneration stages of the absorbent, thus no stoppage or mechanical problem is envisaged during the use of said absorbent for $CO_2$ absorption even at high loadings and absorbent system concentrations. Absorbent solution of the said invention is practically nonvolatile since the reacting salt formed is ionic in nature, and thus, the absorbent minimizes solvent vaporisation losses since it has low vapour pressure. This will also result in reduced water wash of the purified gas. The amine salt of amino acid formed does not show signs of foaming or discolouration during absorption or regeneration which gives indication of good stability properties of the solvent composition, and thus, solvent loss by degradation is also reduced. The absorbent of the invention has high $CO_2$ removing power compared with alkanolamines of related class as well as organic acid salt of inorganic base. It also has low viscosity indicating that the solvent composition could be used at higher concentrations if desired. The following examples will illustrate the nature of the invention, but the invention is not restricted to these examples.

**Example 1**

Absorption and desorption test experiments were carried out on 2.5mole/liter potassium salt of 2-(methylamino)acetic acid (KSAR) charged in a glass reactor placed in a thermostatic bath. Absorption at 40°C starts after automatic calibration of $CO_2$ analyser with $CO_2$-$N_2$ gas mixture containing 10 vol% $CO_2$ with flow rate 5NL.min$^{-1}$. Same gas mixture is then bubbled through a 750mL of the absorbing solution using sinter glass. The gas phase leaving the reactor is cooled and $CO_2$ content is analysed online by IR. The apparatus is designed to operate at atmospheric conditions and up to 80°C. It gives fast relative comparison of absorption rate and absorption capacity as well as the stripping rate for each absorbent, thus an estimate of the relative cyclic capacity of each system could be deduced. Apart from these factors, other properties such as foaming, precipitation and possible discolouration upon $CO_2$ loading, could be observed. The absorption process terminates automatically when the concentration of $CO_2$ in the effluent reaches 9.5 vol% representing about 9.5 kPa partial pressure of $CO_2$. A liquid sample is collected for analysis and the solvent is ready for stripping. The desorption process starts by heating up the solvent from 40°C to 80°C, this takes

about 40 minutes and stripping starts automatically at 80°C by introduction of pure $N_2$ gas into the desorber bottle. The $CO_2$ content of the effluent gas decreases as $N_2$ bubbles through the solution. This is measured and logged every minute. Stripping terminates automatically when the effluent gas records 1.0 vol% representing 1.0 kPa partial pressure of $CO_2$. The liquid sample from stripping is collected for analysis of $CO_2$ content. Collected absorption and stripping liquid samples were analysed by the barium chloride method and excess HCl titrated with 0.1M ($molL^{-1}$) NaOH using an automatic titrator (Metrohm 702 SM Titrino) with end point pH 5.2.

**Examples 2-4**

An absorption/desorption experiment was carried out in the same manner as in Example 1, except that an aqueous solution containing 2.5 mole/litre 3-(methylamino)propylamine salt of 2-(methylamino)acetic acid (SARMAPA) as an absorbent was used as an absorbing solution in Example 2, while for Examples 3 and 4, 2.5 mole/litre 3-(methylamino)propylamine salt of 2-aminoacetic acid (GLYMAPA) and 2.5 mole/litre 3-(methylamino)propylamine salt of 3-aminopropanoic acid (B-ALAMAPA) were used, respectively. The results thus obtained are shown in Table 1.

**Comparative Example 1**

An absorption/desorption experiment was carried out in the same manner as in Example 1, except that an aqueous solution containing 2.5 mole/litre of monoethanolamine (MEA) as an absorbent was used as an absorbing solution, in place of the aqueous solution containing KSAR. The result thus obtained is shown in Tables 1 and 2.

**Table 1**

| | Absorbing Solution | cCO2 Rich end $molCO_2/L$ | cCO2 Lean end $molCO_2/L$ | ΔcCO2 Per Cycle $molCO_2/L$ | % CO2 Removed Per Cycle |
|---|---|---|---|---|---|
| Example 1 | 2.5M KSAR | 1.272 | 0.583 | 0.689 | 54.185 |
| Example 2 | 2.5M SARMAPA | 1.318 | 0.460 | 0.858 | 65.127 |
| Example 3 | 2.5M GLYMAPA | 1.296 | 0.451 | 0.846 | 65.246 |
| Example 4 | 2.5M B-ALAMAPA | 1.296 | 0.527 | 0.769 | 59.351 |
| Comparative Example 1 | 2.5M MEA | 1.332 | 0.569 | 0.763 | 57.288 |

From results shown in Table 1, it can be seen that when aqueous solutions of SARMAPA, GLYMAPA and B-ALAMAPA, which are amine salts of amino acid in

accordance with the present invention, are used as absorbing solutions for $CO_2$-gas, the amount of $CO_2$ absorbed per litre solution is somewhat equal to that absorbed by MEA, but the amount of $CO_2$ liberated after regeneration by amine salts of amino acid is higher than when an aqueous solution of MEA is used particularly for SARMAPA and GLYMAPA. Amine salts of amino acids are thus found to have better desorption potential than MEA; they remove a higher amount of $CO_2$ per cycle. Of particular interest is the lower $CO_2$ removal ability of the inorganic salt of the amino acid, in this case, potassium salt of 2-(methylamino)acetic acid (KSAR). It is found that this absorbent absorbs lowest amount of $CO_2$ at 40°C and desorbs lowest amount of same at 80°C thus exhibiting a significantly weaker temperature effect.

**Examples 5-6**

An absorption/desorption experiment was carried out in the same manner as in Example 1, except that an aqueous solution containing an excess of 15% by weight MAPA in 2.5 mole/liter potassium salt of 2-(methylamino)acetic acid (KSAR) as an absorbent was used as an absorbing solution in Example 5 while an aqueous solution containing an excess of 15% by weight MAPA in 2.5 mole/liter 3-(methylamino)propylamine salt of 2-(methylamino)acetic acid (SARMAPA) as an absorbent was used as an absorbing solution in Example 6, in place of the aqueous solution containing KSAR. The results thus obtained are shown in Table 2.

**Table 2**

| | Absorbing Solution | cCO2 Rich end $molCO_2/L$ | cCO2 Lean end $molCO_2/L$ | ΔcCO2 Per Cycle $molCO_2/L$ | % CO2 Removed Per Cycle |
|---|---|---|---|---|---|
| Example 1 | 2.5M KSAR | 1.272 | 0.583 | 0.689 | 54.185 |
| Example 2 | 2.5M SARMAPA | 1.318 | 0.460 | 0.858 | 65.127 |
| Example 5 | 2.5M KSAR + 15wt% MAPA | 2.955 | 1.874 | 1.081 | 36.593 |
| Example 6 | 2.5M SARMAPA + 15wt% MAPA | 2.881 | 1.526 | 1.354 | 47.014 |
| Comparative Example 1 | 2.5M MEA | 1.332 | 0.569 | 0.763 | 57.288 |

From the results shown in Table 2, it can be seen that addition of excess amine, in this case MAPA to alkali and amine salts of amino acid, KSAR and SARMAPA respectively, results in increasing the amount of $CO_2$ absorbed per litre solution and the amount of $CO_2$ liberated per cycle by these absorbents. Excess amine therefore further enhances $CO_2$ absorption performance of amine salts of amino acid. However it can be seen that the percentage of $CO_2$ removed per cycle decreased for each of the amine salts of amino acid when treated with excess amine. Of interest also is the lower $CO_2$ removal performance of an inorganic salt of amino acid, in this case, potassium salt of 2-(methylamino)acetic acid (KSAR) when treated with excess amine compared to an amine salt of amino acid in this case 3-(methylamino)propylamine salt of 2-(methylamino)acetic acid (SARMAPA) when treated with excess amine.

**Example 7**

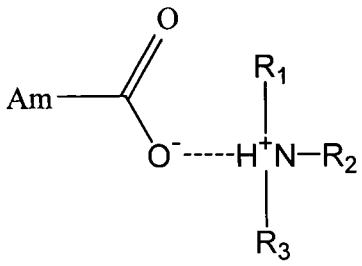
Figure 1 shows equilibrium measurement results for KSAR and SARMAPA at 40 and 80°C. It shows that partial pressure of $CO_2$ over KSAR does not increase significantly with increase in temperature as compared to the SARMAPA system. This is consistent with the weak temperature effect earlier observed in the KSAR system. This property is seen as a disadvantage in terms of energy use in the KSAR system.

**Example 8**

Figure 2 shows the pilot plant experimental study results in terms of energy input in KJ/kg $CO_2$ removed for the SARMAPA and KSAR systems. It clearly shows that SARMAPA has significantly less energy consumption than KSAR. Higher energy demand found in KSAR is attributed to the weak temperature effect that it exhibits.

CLAIMS

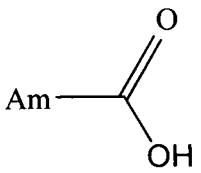
1. A liquid absorbent for removing carbon dioxide from a gas stream, characterized in comprising an aqueous solution of an amine salt of an amino acid of the general formula [1]



1

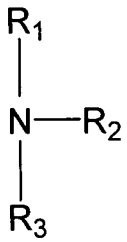
wherein Am is an amino acid backbone containing 1 to 4 carbon atoms and at least one amine group; and $R_1$, $R_2$ and $R_3$ are selected from hydrogen, $C_{1-4}$ alkyl, $C_{1-4}$ alkanol, or a straight chain, cyclic or aromatic amine group, wherein at least one of $R_1$, $R_2$ and $R_3$ is an $C_{1-4}$ alkyl, $C_{1-4}$ alkanol or a straight chain, cyclic or aromatic amine group.

2. The liquid absorbent according to claim 1, wherein the amine salt 1 is prepared by mixing essentially stoichiometric proportions of an organic acid of the general formula [2]:



2

and an organic base of the general formula [3]:



3

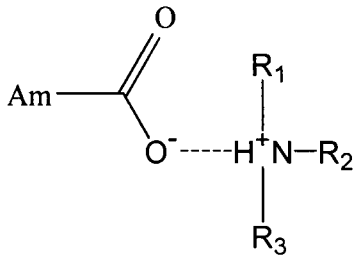
wherein Am, $R_1$, $R_2$ and $R_3$ are as defined in claim 1.

3. The liquid absorbent of claim 2, wherein [2] is an amino acid selected from the group consisting of 2-aminoacetic acid, 2-(methylamino)acetic acid and 3-aminopropanoic acid.

4. The liquid absorbent of claim 2, wherein [3] is an amine selected from the group consisting of 3-(methylamino)propylamine, piperazine and diethylenetriamine.

5. A process for removing carbon dioxide from a gas stream,
characterized in

- absorbing carbon dioxide gas from a gas stream by contacting and scrubbing said gas with an absorbent liquid comprising essentially of an amine salt of amino acid with the general formula [1]



1

wherein Am is an amino acid backbone containing 1 to 4 carbon atoms and at least one amine group; and
$R_1$, $R_2$ and $R_3$ is selected from hydrogen, $C_{1-4}$ alkyl, $C_{1-4}$ alkanol or a straight chain, cyclic or aromatic amine group, wherein $R_1$, $R_2$ and $R_3$ is an $C_{1-4}$ alkyl, $C_{1-4}$ alkanol or a straight chain, cyclic or aromatic amine group; and

- regenerating the rich absorbent liquid.

6. The process according to claim 5, wherein the amine salt [1] is present in the absorbent liquid in an amount from 1 mole/litre to 7 mole/litre.

7. The process according to claim 5 or 6, wherein excess amine is added to the liquid absorbent and the excess amine is selected from the group consisting of monoethanol-amine (MEA), diethylenetriamine (DETA), N-aminoethylethanolamine(AEEA), tetra-ethylenepentamine(TEPA), piperazine(PZ), 3-methylaminopropylamine (MAPA), monomethylethanolamine(MMEA), 2-methylpiperazine and 2,5-dimethylpiperazine.

8. The process according to claim 7, wherein the excess amine is added in an amount from 1.5 to 50% by weight based on the weight of the total liquid absorbent.

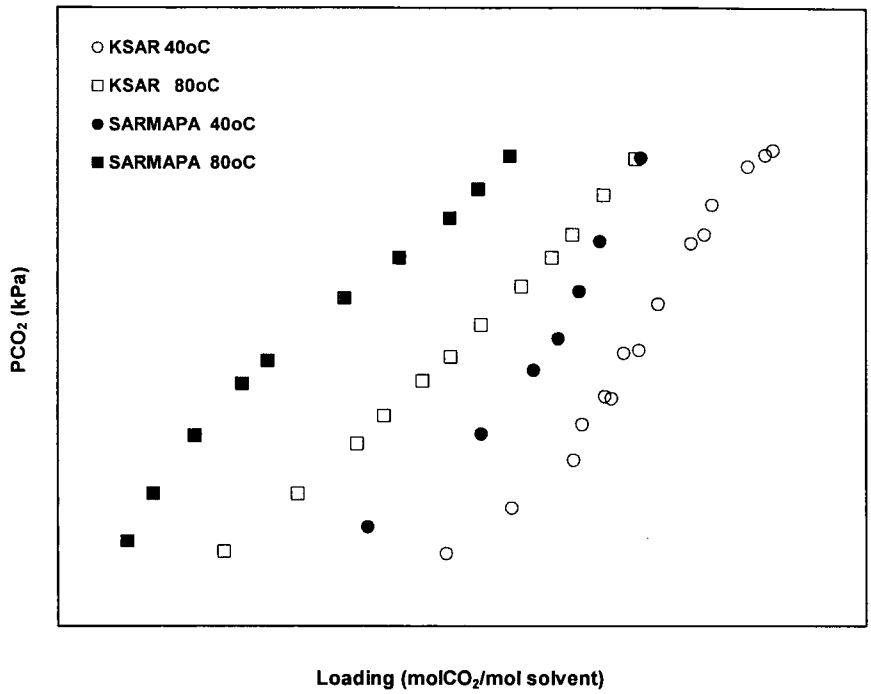



Figure 1

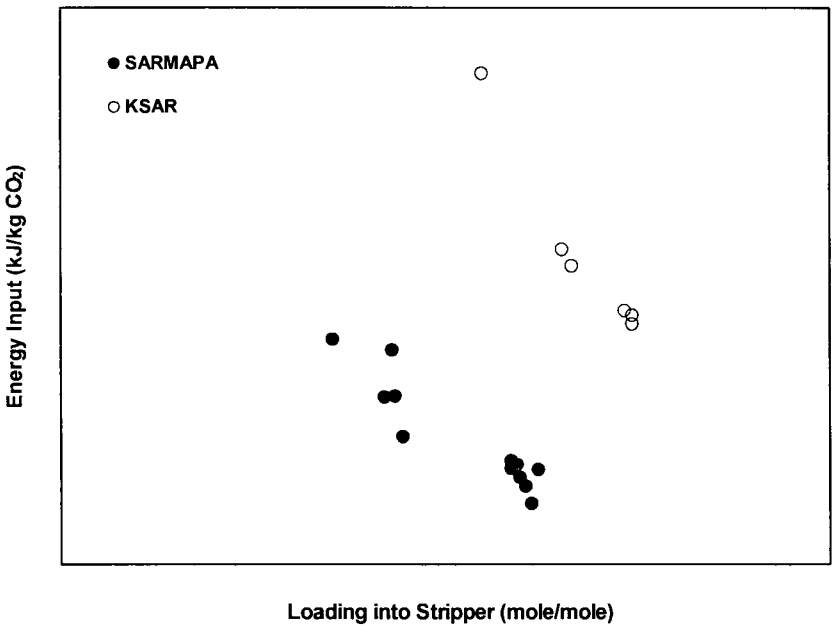



Figure 2

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO2009/000383

A. CLASSIFICATION OF SUBJECT MATTER
IPC 8 B01D53/14 (2006.01), B01D53/40 (2006.01), B01D53/62 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC B01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPODOC, WPI, CAPLUS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
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| x | US3042483 A (HOECHST AG) 3 July 1962 se whole document | 1-6 |

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 25 November 2009 | 21 December 2009 |
| Name and mailing address of the ISA/ Nordic Patent Institute, Helgesnøj Allé 81, 2630 Taastrup, Denmark<br>Facsimile No. +45 43 50 80 08 | Authorized officer Elena Eilrich<br>Telephone No. +47 22387549 |

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**INTERNATIONAL SEARCH REPORT**
Information on patent family members

International application No.
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