

Article

Highly Efficient Removal of CO₂ Using Water-Lean KHCO₃/Isopropanol Solutions

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Abstract: The use of aqueous carbonate as an inorganic absorbent is not only inexpensive but also stable and environmentally friendly. However, the regeneration processes for aqueous carbonate sorbents require high regeneration heat duty; this energy intensity makes their wide utilization unaffordable. In this work, a low-temperature, energy-saving, and environmentally friendly carbon dioxide desorption method has been investigated in potassium bicarbonate-water-alcohol solutions. The addition of alcohol, particularly isopropanol, to the potassium bicarbonate-water solution can significantly increase carbon dioxide desorption capacity. The potassium bicarbonate-water-isopropanol solution used in this study (36 wt % isopropanol) resulted in 15.2 mmol of carbon dioxide desorption within 2400 s at 80 °C, which was 2000-fold higher than the potassium bicarbonate-water solution. This research demonstrates a water-lean solvent-based carbon dioxide removal route with the potential to be economical, environmentally safe, and energy-efficient. CO₂ sequestration, capture, and utilization technologies will play a key role in reducing CO₂ emissions. The excellent desorption kinetics and relatively moderate desorption temperatures (80 °C) of water-lean solvent could help in reducing the cost of CO₂ capture, particularly in terms of the heat demand at the regenerator.

Keywords: desorption; CO₂ capture; bicarbonate solution; isopropanol; water-lean



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1. Introduction

Emissions of greenhouse gases (GHG) have increased substantially since the start of the industrial revolution. The rising levels of carbon dioxide (CO₂) in the atmosphere have received significant attention due to increased global temperatures and noticeable climate change [1]. CO₂ capture and storage (CCS) or utilization technologies reduce GHG emissions in the atmosphere to minimize their warming effects and slow climate change. Post-combustion capture removes CO₂ from flue gas (composed primarily of 10% CO₂, H₂O vapor, O₂, N₂, trace gases, and fly ash) after burning fossil fuel. At present, conventional coal-fired power plants combust primary coals to directly generate power [2]. Thus, post-combustion capture is the most viable choice for existing coal-fired power plants.

The implementation of post-combustion CO₂ capture from fossil fuel-fired power plants requires using different methodologies, including solid sorbents, membranes, and solvents [3]. Membrane-capture technologies, solid inorganic sorbents (such as CaO, K₂CO₃, and Na₂CO₃), and solid organic sorbents (such as metal-organic frameworks (MOFs) and amine-modified biochar) are at various stages of development and proximity to commercialization [4–9]. The major disadvantage of membrane-capture technologies is the

increased mass transfer resistance, especially when membranes are wetted [10]. Likewise, the solid inorganic sorbents have a disadvantage because there is a decrease in reactivity during multiple absorption/regeneration cycles at low temperatures (<200 °C) [11,12]. The adsorption capacity of biochar for CO₂ in flue gas is low, but amine-modified biochar has good absorption ability and industrial application prospects [7].

Currently, the implementation of an absorption–desorption process using a chemical solvent is the most developed and adequate process for deployment in the near- to middle-term [13]. The main drawback of the solvent-based CO₂ capture process is that the consumption of heat energy for solvent regeneration, referred to as regeneration heat duty (Q_{reg} , kJ/kg CO₂), is very high. For example, the Q_{reg} of monoethanolamine (MEA)-based technology accounts for about 70% of the overall operating cost [14]. Thus, the Q_{reg} is a critical parameter in the post-combustion CO₂ capture process. The Q_{reg} consists of [15]: (i) sensible heat (Q_{sen}) for raising the temperature of the solution, (ii) absorption heat (Q_{abs}) for desorbing the CO₂ from the solution, and (iii) vaporization heat (Q_{vap}) for evaporating liquid water to vapor for CO₂ stripping.

During the past few decades, water-lean solvents have been extensively studied as a possible method of reducing the consumption of commercial absorbents with high energy consumption demands [16,17]. Compared with water-based solvents, water-lean solvents have similar chemical selectivity but far lower specific heat, due to their lack of water. In principle, significant improvements could be achieved in regeneration energy. Alcohols [18,19], polyalcohols [20], and mixtures of glycol ethers [21] are popular organic solvents that lower both the required reaction temperature and solvent regeneration energy. Lin et al. [22] reported that the Q_{reg} of PZ/DETA/H₂O was 2.99 GJ/ton CO₂, whereas the Q_{reg} of PZ/DETA/MeOH/H₂O was 1.84 GJ/ton CO₂ at 120 °C. The addition of an organic alcohol (MeOH) reduced the Q_{reg} by 38.5%. Among the many strategies to reduce Q_{reg} , the use of new and more effective water-lean solvents has promise, since they directly affect the capture performance and operating conditions. In addition, it is easy to apply these solvents to existing CO₂ capture plants [23]. Alcohols are versatile high-purity oxygenated chemical solvents that provide unique combinations of solvency and solubility, with complete or at least partial miscibility with water and the ability to dissolve a range of polar components, including other organic solvents. Short-chain alcohols (C1–C5) are categorized as green solvents since they can be obtained by fermenting renewable resources, such as sugars, starches, or lignocellulosics; they represent a low-cost solvent compared with other solvents [24,25].

Currently, amine-based organic sorbents are the leading CO₂ capture technology in the industry [26,27]. Compared with organic absorbents, inorganic sorbents are not only inexpensive but also stable and environmentally friendly [12,28,29]. However, like any other CO₂ solvent sorbents, their slow CO₂ desorption kinetics make their widespread utilization unaffordable, considering that the energy consumption of the CO₂ desorption step accounts for 70–80% of the total energy needed for the overall CO₂ capture process [30]. Therefore, this current research focuses on investigating the significant effect of alcohols on promoting water-lean potassium bicarbonate (KHCO₃) solution decomposition on CO₂ desorption kinetics.

2. Materials and Methods

2.1. Materials

Ethanol (EtOH) (Sigma-Aldrich, St. Louis, MO, USA, ≥98%), isopropanol (IPA) (Alliance Chemical, Taylor, TX, USA, ≥99%), methanol (MeOH) (Fisher Chemical, Waltham, MA, USA, ACS grade), 1-butanol (Fisher Chemical, Waltham, MA, USA, ACS grade), H₂O, and KHCO₃ (Chem-Impex International Inc., Wood Dale, IL, USA, ≥99.7%) were utilized without further purification. Mixed gas (10% CO₂, 10% O₂, 80% N₂ molar concentration, Praxair, Burr Ridge, IL, USA) was used to simulate flue gas, and pure N₂ (Praxair) was used as a purge gas. Mass flow controllers (RED-Y, Sierra, Monterey, CA, USA), with a ±1% accuracy, were used to control the flow of gases from the gas cylinders to the reactor. A gas

analyzer (ZPA, CAI, Orange, CA, USA) was used to monitor gas levels, and a paperless recorder (DataChart 2000, Monarch, Amherst, NH, USA) was used to collect and read the data. The accuracies of these instruments were ± 0.5 and $\pm 0.1\%$ of the full scale, respectively. The estimated error for the data reported in the results section is no more than 2%.

2.2. Methods

CO₂ desorption tests were performed using the setup shown in Figure 1. Each trial run started with 200 g of solvent solution. Blank trials were prepared with 10 wt % KHCO₃ and 90 wt % H₂O. Tests with and without the addition of different alcohols were performed to evaluate the effect of alcohols on desorption. Thus, the remaining trials were prepared with 10 wt % KHCO₃, (90–X) wt % H₂O, and X wt % alcohol (X = 18, 27, 36, and 45).

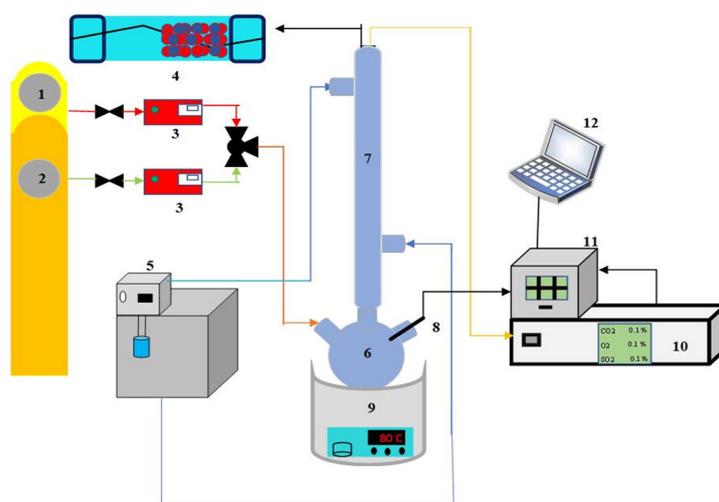


Figure 1. CO₂ capture experiment setup. (1) N₂ cylinder, (2) mixed gas cylinder, (3) mass flow controller, (4) desiccator, (5) thermostatic bath, (6) 500 mL three-necked flask, (7) condenser, (8) thermocouple, (9) heater/stirrer, (10) gas analyzer, (11) paperless recorder, (12) laptop.

Pure N₂ (1) was used during the CO₂ desorption step to flush out residual gas at the end of each desorption experiment. The mixed gas (2) was also used to calibrate the equipment twice per week to obtain accurate results. Mass flow controllers (3) were used to regulate the gas feed rates. The CO₂ absorption and desorption steps were performed in a 500 mL reactor (6), surrounded by an adjustable electric heater (9).

- (i) Absorption: The CO₂ absorption experiments were conducted at a constant laboratory room temperature of 20 °C. A cooling liquid at 5 °C from the thermostatic bath (5) was circulated through the condenser (7) to return vapors to the reactor. A desiccator (4) was used to trap any fugitive water vapor. The simulated flue gas (10 vol % CO₂, 10 vol % O₂, and 80 vol % N₂) with a flow of 500 mL/min was employed for the CO₂ absorption. The mixed gas reactor feed percolated into the solution through a muffler, and the outlet gas CO₂ concentration was measured to determine the absorption capacity. The absorption step was conducted for 60 min.
- (ii) Desorption: The CO₂ desorption experiments were performed by heating the solution to 80 °C. A cooling liquid at 5 °C from the thermostatic bath (5) was circulated through the condenser (7) to return the vapors to the reactor. A desiccator (4) was used to trap any fugitive water vapor. A flow of 500 mL/min of N₂ was used to carry CO₂ gas from the solution, and the pulled gas was analyzed. The desorption step was conducted for 40 min.

- (iii) Loading estimation: “ $Absorbed_{CO_2}$ ” (mmol CO_2) is the amount of CO_2 absorbed during the entire absorption experiment. It was calculated via the following material balance [31]:

$$Absorbed_{CO_2} = \frac{Q \times \rho_{CO_2}}{M_{CO_2}} \times \int_0^t \left(\frac{C_{in} - C_{out}}{1 - C_{out}} \right) C_{out} \times dt \times \frac{T}{T_0}.$$

“ $Desorbed_{CO_2}$ ” (mmol CO_2) is the amount of CO_2 desorbed during the entire desorption experiment. It was calculated via the following material balance [31]:

$$Desorbed_{CO_2} = \frac{Q \times \rho_{CO_2}}{M_{CO_2}} \times \int_0^t C_{out} \times dt \times \frac{T}{T_0}.$$

Here, Q is the total flow rate (mL/min); ρ_{CO_2} is the CO_2 density at 20 °C and 101.325 kPa (kg/m^3); M_{CO_2} is the molecular weight of CO_2 (kg/mol); C_{in} and C_{out} are the inlet and outlet CO_2 concentrations (vol %), respectively. T denotes the reaction temperature (K), and T_0 is 273 K.

“ CO_2 -rich/lean loading” is the amount calculated by dividing the number of moles of CO_2 by the number of moles of $KHCO_3$. “Maximum capacity” is the amount calculated by dividing the number of moles of CO_2 by the mass of solvent (alcohol + water).

The desorbed solvents from the CO_2 desorption experiments were analyzed using Raman spectroscopy. Sample spectra were collected at 5-minute intervals using a Horiba MacroRAM Raman spectrometer (Irvine, CA, USA) with a 785 nm excitation.

3. Results

3.1. Effects of Different Alcohols on CO_2 Absorption and Desorption

CO_2 capture experiments with 200 g sorbents containing 10 wt % $KHCO_3$, 45 wt % H_2O and 45 wt % alcohols were performed using the setup shown in Figure 2. The CO_2 absorption and desorption with and without the use of MeOH, EtOH, IPA, and butanol were conducted to evaluate the effect of alcohols on the CO_2 capture performance of $KHCO_3-H_2O-45$ wt % alcohol sorbents. As shown in Figure 2a, all the curves nearly overlap each other; the amount of CO_2 absorbed by the $KHCO_3-H_2O-45$ wt % alcohol sorbents after the absorption step is ~0.42 mmol and the rates of CO_2 absorption are near 0 mmol/s after 200 s (Figure 2b). The loading for CO_2 in $KHCO_3-H_2O$ -alcohol solvent is about 0.5; alcohol does not add additional CO_2 loading. This work focuses on improving the desorption behavior of inorganic sorbent with a combination of alcohols and DI water. Using $KHCO_3-H_2O$ -alcohol solvent can avoid the desorption changes being affected by inconsistent absorption, and the effect of alcohol on desorption is independent [29,32,33]. In the following section, we will investigate the effect of alcohols on promoting aqueous $KHCO_3$ decomposition and CO_2 desorption kinetics.

Table 1 summarizes the effects of alcohols on the CO_2 desorption conditions at 80 °C under 2400 s. It was expected that alcohols would promote increased CO_2 desorption capacity, as reported in a previous study [19]. As shown in Table 1, $KHCO_3-H_2O$ -alcohol sorbents show increased amounts of CO_2 desorption within the 2400 s period. Similarly, our results demonstrate that adding alcohols, especially MeOH, EtOH, and IPA, to the $KHCO_3-H_2O$ solution increases the CO_2 desorption capacity. According to Table 1, $KHCO_3-H_2O$ -IPA has the highest CO_2 desorption capacity, compared to the other combinations.

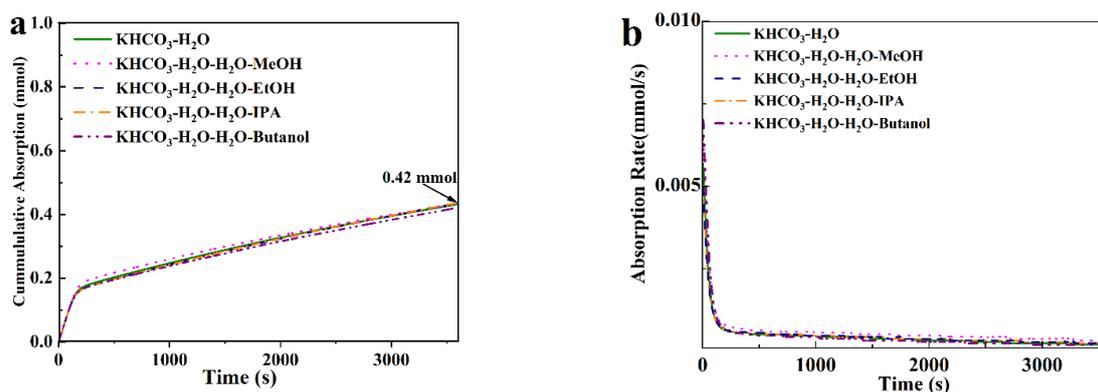


Figure 2. The effects of different alcohols on CO₂ absorption in KHCO₃–H₂O and KHCO₃–H₂O–45 wt % alcohol solutions: (a) effects of alcohols on the quantities of absorbed CO₂. (b) The rates of CO₂ absorption.

Table 1. Summary of the effects of alcohol on CO₂ desorption with KHCO₃–H₂O–alcohol solutions (10 wt % KHCO₃, 45 wt % H₂O, 45 wt % alcohol) at 80 °C under 2400 s.

KHCO ₃ –H ₂ O–Alcohol Solutions	Solvent Composition (KHCO ₃ , H ₂ O, Alcohol)	Desorbed CO ₂ (mmol)	Rich Loading (mol CO ₂ /mol KHCO ₃)	Lean Loading (mol CO ₂ /mol KHCO ₃)	Maximum Capacity (mol CO ₂ /kg Solvent)
KHCO ₃ –H ₂ O	10 wt %, 90 wt %, 0 wt %	7.0×10^{-3}	0.5	0.5	3.9×10^{-5}
KHCO ₃ –H ₂ O–MeOH	10 wt %, 45 wt %, 45 wt %	2.9	0.5	4.8	1.6×10^{-2}
KHCO ₃ –H ₂ O–EtOH	10 wt %, 45 wt %, 45 wt %	7.0	0.5	4.6	3.9×10^{-2}
KHCO ₃ –H ₂ O–IPA	10 wt %, 45 wt %, 45 wt %	14.9	0.5	4.2	8.3×10^{-2}
KHCO ₃ –H ₂ O–Butanol	10 wt %, 45 wt %, 45 wt %	3.6×10^{-2}	0.5	0.5	2.0×10^{-4}

The CO₂ desorption trials were conducted in five distinct experiments, as previously described. One experiment involved running a blank trial with a KHCO₃–H₂O solution (10 wt % KHCO₃) to establish a baseline. The four other experiments used KHCO₃–H₂O–alcohol solution (10 wt % KHCO₃, 45 wt % H₂O, and 45 wt % alcohol). From these experiments, the trend of the effects on the desorption rate of the alcohols was established. At least two trials of each method were performed, and the average desorption values were used for data analysis. Figure 3 shows the cumulative CO₂ desorbed during the desorption experiments. As shown, the addition of alcohols increased the amount of CO₂ that was desorbed. KHCO₃–H₂O–EtOH, KHCO₃–H₂O–MeOH, and KHCO₃–H₂O–butanol solutions desorbed approximately 7.0, 2.9, and 3.6×10^{-2} mmol of CO₂, respectively. However, the KHCO₃–H₂O–IPA solution resulted in 14.9 mmol of CO₂ desorption within 2400 s. According to the previous literature, the addition of alcohols offers several advantages in the CO₂ desorption process. First, alcohols can change the reaction pathway by forming R-OCO₂[−] instead of HCO₃[−] (which is difficult to decompose) [19]. Second, alcohols can reduce the dielectric constant of the solvent and, thus, are able to reduce the dissociation constant (and basic strength) of the sorbent, which allows for the release of acidic CO₂ from the absorbent at a lower temperature. The reduced basic strength may also lower the activation energy of CO₂ desorption [34]. The regeneration heat duty includes three terms: the sensible heat, the heat of water evaporation, and the heat of CO₂ desorption. Low-carbon alcohols (C₁–C₃ alcohols) have a lower enthalpy of vaporization than water. Besides the change in CO₂ solubility and kinetics, another advantage of replacing some of the water with a more volatile substance is that the boiling temperature of the system is lowered [35]. Finally, the regeneration heat duty of KHCO₃ solutions can be reduced because adding alcohols to an aqueous KHCO₃ solution shifts the equilibrium isotherms at high temperatures to lower loadings, thus facilitating the desorption of CO₂ [35]. The boiling points of MeOH, EtOH, IPA, and butanol are 64.7, 78, 82.5, and 117.7 °C, respectively. The cumulative CO₂ desorption amounts of KHCO₃–H₂O solution after adding alcohol are not related to boiling-point order. The effect of alcohol may be a combination of the above three functions. The boiling point of butanol is much

higher than the desorption temperature and, since it shows almost negligible desorption, it illustrates the important role of the regeneration heat duty.

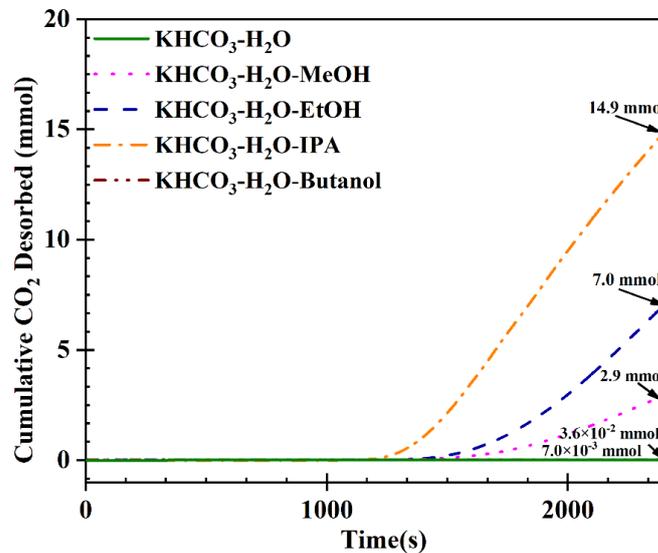


Figure 3. Effect of different alcohols on CO₂ desorption in KHCO₃–H₂O and KHCO₃–H₂O–alcohol solutions.

Although the quantity of CO₂ desorbed is important, the desorption rate reflecting the CO₂ kinetics is more critical when applying the sorption-based CO₂ capture technology because it affects the capital and operating costs [19]. Figure 4 shows the desorption rates, based on the type of alcohol used in the KHCO₃–H₂O–alcohol solution. As shown, the addition of alcohols resulted in varying CO₂ desorption rates. Specifically, KHCO₃–H₂O–EtOH, KHCO₃–H₂O–MeOH, and KHCO₃–H₂O–butanol have desorption rates of 1.1×10^{-2} , 4.9×10^{-3} , and 5.0×10^{-5} mmol/s, respectively. However, the KHCO₃–H₂O–IPA solution reached a peak desorption rate of 1.5×10^{-2} mmol/s at 1690 s. Therefore, it is concluded that the KHCO₃–H₂O–IPA solution achieves the highest desorption when compared to the other alcohols used in the experiment. As a result, the KHCO₃–H₂O–IPA solution was selected for further study.

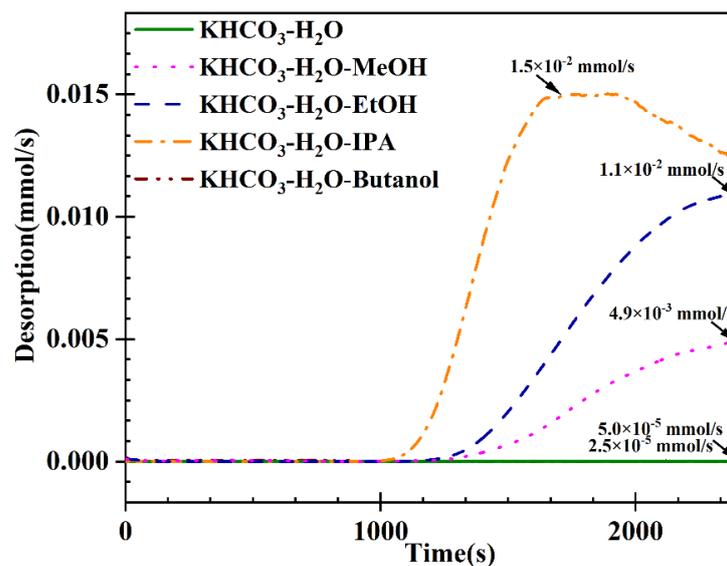


Figure 4. CO₂ desorption rates in KHCO₃–H₂O and KHCO₃–H₂O–alcohol solutions.

3.2. Effects of Different Isopropanol Concentrations on CO₂ Removal

KHCO₃–H₂O–IPA solutions with IPA concentrations ranging from 0 to 45 wt % were used to investigate the effect of IPA concentration on CO₂ removal. As shown in Figure 5, there was a significant difference in the amount of CO₂ desorbed by the 18- and 45-wt % IPA solutions. The cumulative CO₂ desorption amounts of 18 wt %, 27 wt %, 35 wt %, and 45 wt % IPA solution were 2.6, 4.8, 15.2, and 14.9 mmol, respectively. Figure 5 indicates the increase in desorption capacity as the concentration of the IPA increases, while Figure 6 illustrates the improvement of KHCO₃–H₂O–IPA desorption kinetics when 0 to 45 wt % IPA solutions are used. As can be seen, the 18- and 27-wt % IPA solutions yielded desorption rates of 3.9×10^{-3} and 5.9×10^{-3} mmol/s, respectively, while the 36- and 45-wt % IPA solutions yielded desorption rates of 1.4×10^{-2} and 1.5×10^{-2} mmol/s, respectively. The cumulative CO₂ desorption amounts of the 36-wt % IPA solution were slightly higher than the 45-wt % IPA solution. Compared with the 45-wt % IPA solution, the 36-wt % IPA solution had a slightly lower desorption rate. From the cost and effect ratio, it can be concluded that 36 wt % is the optimal concentration; thus, it was selected for further study.

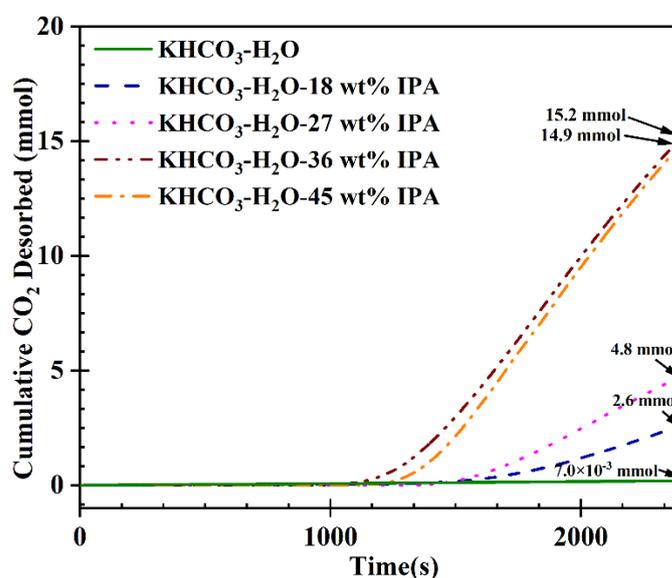


Figure 5. Effect on IPA concentration on CO₂ desorption in KHCO₃–H₂O and KHCO₃–H₂O–IPA solutions.

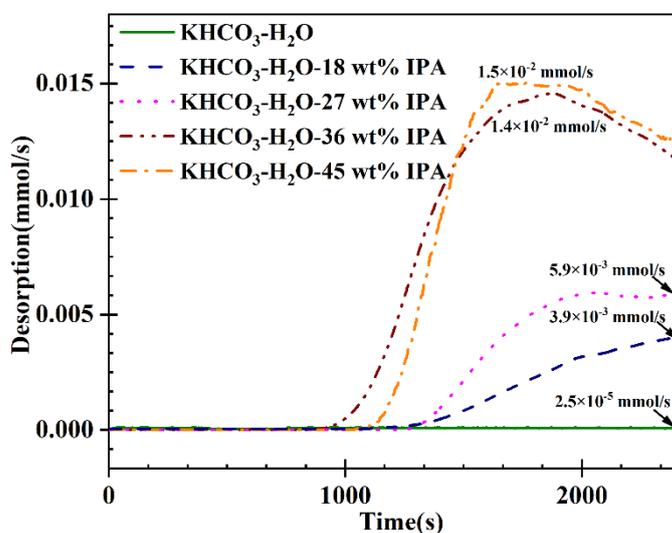


Figure 6. CO₂ desorption rates in KHCO₃–H₂O and KHCO₃–H₂O–IPA solutions.

CO₂ desorption data from the KHCO₃–H₂O–IPA solution with varying amounts of IPA are shown in Table 2. The rates of desorption observed for 36 wt % and 45 wt % were significantly higher than the rates for 18 and 27 wt %. These experiments were performed to see the effects of different concentrations of IPA on CO₂ desorption. According to the results, CO₂ desorption varied depending on the concentrations of IPA, thus proving that different concentrations of IPA affect CO₂ desorption. According to Figure 6, 36 wt % IPA is likely the best option for CO₂ removal from KHCO₃–H₂O–IPA solutions. According to the data, even though 45 wt % resulted in a slightly higher amount of CO₂ desorbed, 36 wt % had a higher desorption rate. As a result, KHCO₃–H₂O–IPA (36 wt % IPA) solution was considered the optimum concentration for the experiment. Therefore, further experiments were performed on 36 wt % IPA solution.

Table 2. Summary of the effects of IPA on CO₂ desorption with KHCO₃–H₂O–IPA solutions at 80 °C under 2400 s.

KHCO ₃ –H ₂ O–Alcohol Solutions	Solvent Composition (KHCO ₃ , H ₂ O, Alcohol)	Desorbed CO ₂ (mmol)	Rich Loading (mol CO ₂ /mol KHCO ₃)	Lean Loading (mol CO ₂ /mol KHCO ₃)	Maximum Capacity (mol CO ₂ /kg solvent)
KHCO ₃ –H ₂ O	10 wt %, 90 wt %, 0 wt %	7.0×10^{-3}	0.5	0.5	3.9×10^{-5}
KHCO ₃ –H ₂ O–18 wt % IPA	10 wt %, 72 wt %, 18 wt %	2.6	0.5	4.9	1.4×10^{-2}
KHCO ₃ –H ₂ O–27 wt % IPA	10 wt %, 63 wt %, 27 wt %	4.8	0.5	4.8	2.6×10^{-2}
KHCO ₃ –H ₂ O–36 wt % IPA	10 wt %, 54 wt %, 36 wt %	15.2	0.5	4.2	8.4×10^{-2}
KHCO ₃ –H ₂ O–45 wt % IPA	10 wt %, 45 wt %, 45 wt %	14.9	0.5	4.2	8.3×10^{-2}

4. Material Analysis

4.1. Raman Spectroscopy

KHCO₃–water–IPA solutions were tested through Raman spectroscopy (Figure 7). The peaks at approximately 1005 cm^{−1} and 1060 cm^{−1} represent the presence of HCO₃[−] and CO₃^{2−}, respectively [36]. By comparing the peaks with and without IPA, it can be determined whether the presence of IPA in solution influences the rate of desorption. The intensity of the HCO₃[−] peak at 1005 cm^{−1} when IPA is present decreases at a noticeably higher rate (Figure 7a) than when the IPA is not present (Figure 7b). Additionally, the increase in peak intensity at 1060 cm^{−1} indicates that the rate of K₂CO₃ formation is significantly higher with the IPA as opposed to the rate without. The Raman analysis, therefore, confirms that CO₂ demonstrates increased desorption kinetics when the alcohol co-solvent is present.

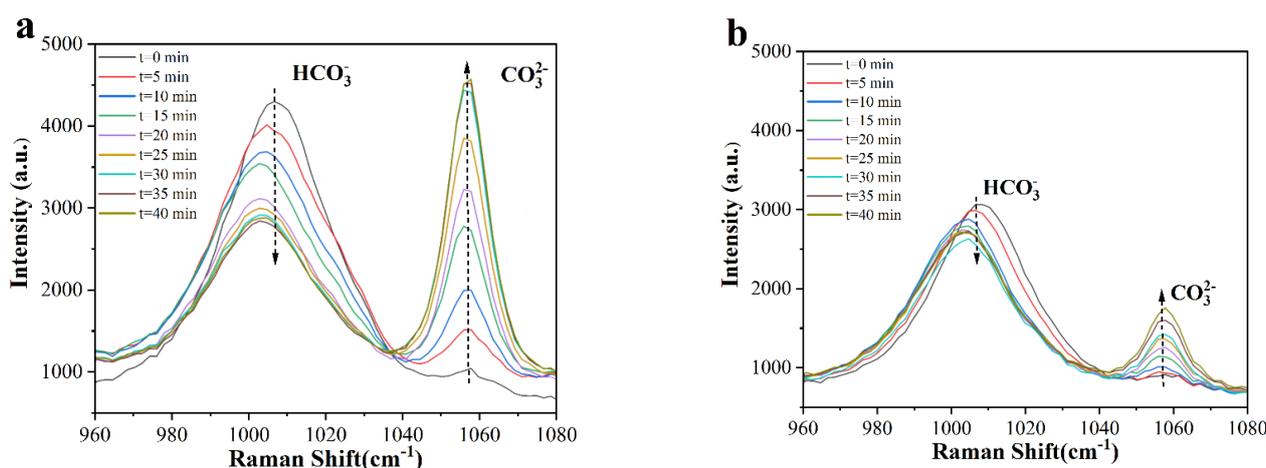


Figure 7. Raman spectra of CO₂ desorption. Measurements were taken at five-minute intervals from time 0 min to 40 min. (a) KHCO₃–water–IPA solution (36 wt % IPA). (b) KHCO₃–water solution.

Based on the Raman results, a possible evolution mechanism is proposed in Figure 8. First, potassium bicarbonate dissociates into cations and anions once it is fully dissolved in water (R1). When the KHCO₃ solution is heated, it decomposes into K⁺, CO₃^{2−}, CO₂, and

H₂O (R2). IPA can change the reaction pathway by forming C₃H₇OCO₂⁻ and H₂O (R3), thus lowering the activation energy required for CO₂ desorption.

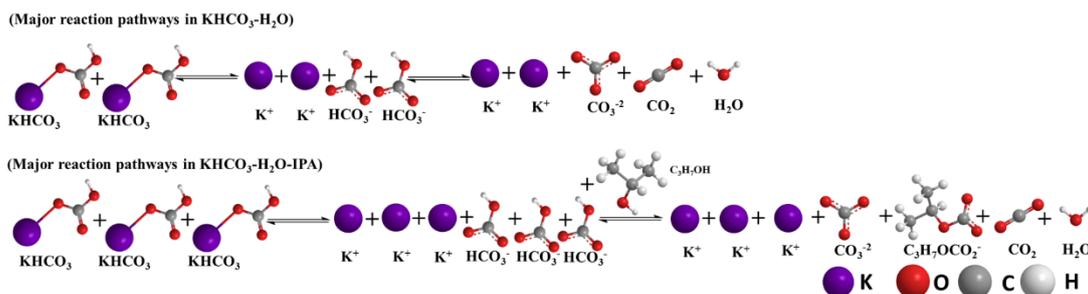
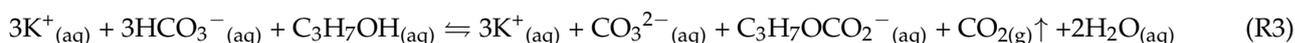
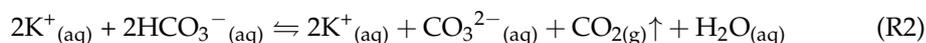
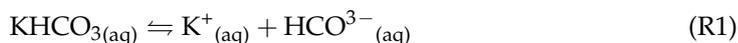


Figure 8. Major reaction pathways of CO₂ capture with KHCO₃-H₂O and KHCO₃-H₂O-IPA solutions.

4.2. Cyclic Stability

The findings in this study generated two practical questions: firstly, can the KHCO₃-H₂O-IPA solution (36 wt % IPA) be sustained during multiple regeneration cycles? Secondly, how stable is the KHCO₃-H₂O-IPA solution? In order to answer these questions, 12 cyclic regeneration experiments were performed (Figure 9). The experimental conditions for cyclic stability involved 40 min of desorption, followed by absorption for 60 min for each cycle. After 12 cycles, the CO₂ desorption capacity retention (capacity^{12th}/capacity^{1st}) was 96.7%. These results suggest that the KHCO₃-H₂O-IPA solution is reasonably stable and can be used in practical situations.

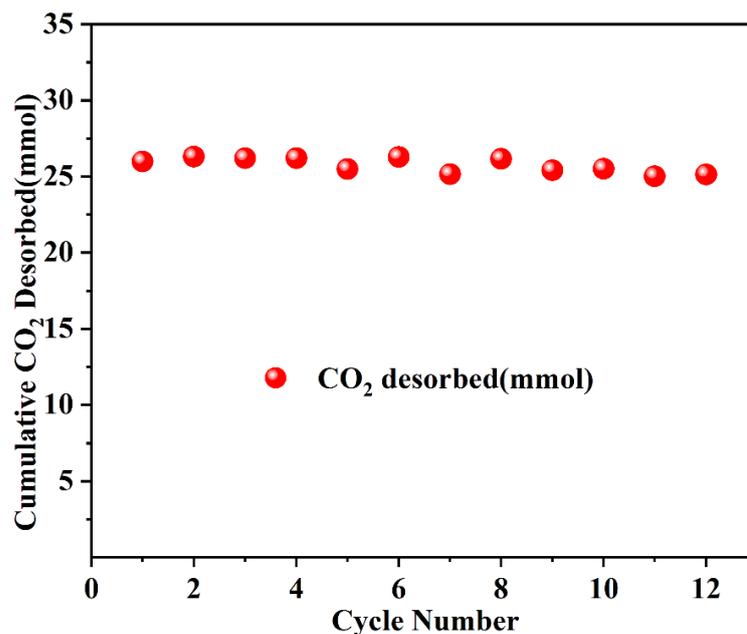


Figure 9. Stability of KHCO₃-H₂O-IPA solution (36 wt % IPA).

5. Conclusions

Different alcohol solutions were prepared using KHCO_3 , H_2O , and alcohols to study their CO_2 desorption performance. A KHCO_3 – H_2O –IPA solution (10 wt % KHCO_3 , 54 wt % water, and 36 wt % IPA) proved to be the best mixture for CO_2 capture because it increased the amount of CO_2 desorbed at room temperature from 7.0×10^{-3} mmol (blank solution) to 15.2 mmol. During 12 cycles of CO_2 desorption/sorption (CO_2 10% partial pressure) reaction, the desorption capacity showed no significant change, proving that the KHCO_3 – H_2O –IPA solution remained stable after multiple cycles. These results demonstrate that the addition of IPA can significantly improve the CO_2 desorption of KHCO_3 solutions and that a water-lean solvent CO_2 removal route can be both economical and energy-efficient.

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