CO_2 absorption by diethanolamine mixed with sodium humate

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ABSTRACT

In this paper, the CO_2 absorption performance of diethanolamine (DEA) mixed with sodium humate as an absorbent was investigated. The promotion of CO_2 absorption by diethanolamine by sodium humate was investigated in particular. Experiments were conducted to test the CO_2 absorption capacity and stability of different proportions of mixed solutions by configuring different proportions of mixed solutions through the controlled variable method. The effect of concentration, temperature, and flue gas flow on the effect of sodium humate mixed with diethanolamine on CO_2 absorption was studied. The results showed that the mixed solution exhibited higher CO_2 absorption efficiency compared to the single component.

Keywords: Diethanolamine, sodium humate, CO_2 absorption

1. INTRODUCTION

In recent years, reducing carbon emissions has been a hot topic of global research. DEA and sodium humate have certain functionalities in their respective applications, but there are not many studies on CO_2 absorption when they are mixed. Among the methods for absorbing CO_2, the biggest drawback of the amine capture and recovery process for CO_2 is that high absorption rates and low regeneration energy consumption cannot coexist[1-4]. The development of efficient solvents is one of the effective ways to solve this problem[5]. With the addition of a physical solvent or a mixture of chemical additives, this method effectively integrates the advantages of different alcohol-amine solutions[6]. Humic acid (abbreviated as HA) is mainly used in the environmental field for exhaust gas treatment, wastewater treatment, and soil improvement. Sodium humate (HA-Na) is a versatile polymer compound[7]. It contains many active groups such as hydroxyl, quinone, and carboxyl groups and has the functions of ion exchange, adsorption and complexation[8]. Sodium humate (HA-Na) has a large specific surface area and is non-sticky like water under dilute solution conditions. The addition of sodium humate to DEA enhances the specific surface area and promotes absorption.

2. EXPERIMENTAL DEVICE

The experimental setup is shown in Figure 1, which mainly consists of gas sources (CO_2, N_2), valves, flow meters, a heating reactor, an infrared gas analyzer, conical cylinders, U-tubes, etc. The CO_2 and N_2 are controlled by a pressure divider valve and a mass flow meter through the pressure and flow rate of a high-pressure gas cylinder[9].

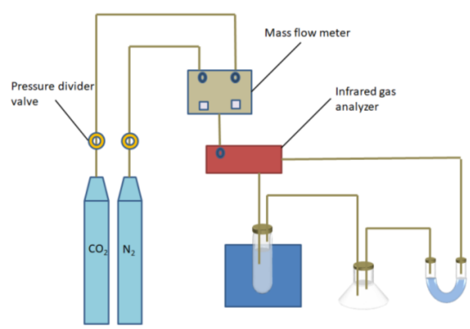

Figure 1. Schematic diagram of the reaction device.

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3. SAMPLE PREPARATION

The required amount of sodium humate was weighed using an electronic balance and the required amount of DEA was measured using a measuring cylinder and mixed according to the experimental requirements. Samples of different mixtures were obtained. The amounts of different mixtures are given in Table 1.

Table 1. Preparation of sample ratios and abbreviations.

Proportion	Abbreviation
0.1 gHA-Na+50 mLDEA	HA-1
0.2 gHA-Na+50 mlDEA	HA-2
0.3 gHA-Na+50 mlDEA	HA-3
0.4 gHA-Na+50 mlDEA	HA-4
0.5 gHA-Na+50 mlDEA	HA-5

4. RESULTS AND DISCUSSION

4.1 Effect of the amount of sodium humate on CO_2 absorption

The amount of mixed sodium humate had an effect on the effectiveness of CO_2 absorption. According to Figure 2, the initial efficiency of CO_2 absorption by HA-1 was 20.4%. The initial efficiency of CO_2 absorption by HA-2 was 23.1%. The initial efficiency of CO_2 absorption by HA-3 was 25.5%. The initial efficiencies of CO_2 absorption of HA-4 and HA-5 were 27% and 27.1%, respectively. In terms of sustained effect, the more the amount of sodium humate added the relatively better the sustained effect. At 0.4 g of added sodium humate, the absorption of CO_2 by DEA mixed with sodium humate has reached the best effect.

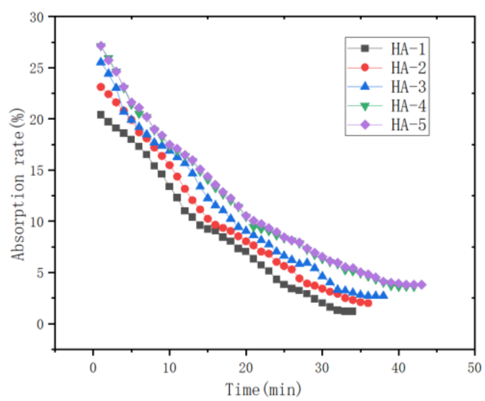

Figure 2. Absorption efficiency corresponding to different amounts of sodium humate.

4.2 Effect of DEA concentration on CO_2 absorption

Figure 3 shows that the initial efficiency of CO_2 absorption is 26.2% when DEA is added at a concentration of 0.6 mol/L. When DEA was added at a concentration of 1 mol/L, the initial efficiency of CO_2 absorption was 28.9%. The initial efficiency of CO_2 absorption was 32.2% with the addition of DEA at a concentration of 1.5 mol/L. Increasing the concentration of DEA to 2 mol/L resulted in an initial efficiency of 35.1% for CO_2 absorption. The initial efficiency of CO_2 absorption was 33.1% when DEA was added at a concentration of 3 mol/L. The higher the concentration of DEA, the more efficient the initial absorption of CO_2 by DEA mixed with sodium humate. But the general trend in absorption efficiency is similar. When specifically analyzing the state of adding 2 mol/L and 3 mol/L of DEA, it was found that the concentration of DEA was increased by 1 mol but the effect of CO_2 absorption was increased by less than 1%. When analyzing 0.6-1 mol/L, 1-1.5 mol/L, and 1.5-2 mol/L, it was found that the effect of CO_2 absorption was enhanced by about 4% in all cases. In order for the DEA mixed with sodium humate to work better in the absorption of CO_2 the concentration of DEA is most suitable between 1.5 mol/L and 2 mol/L.

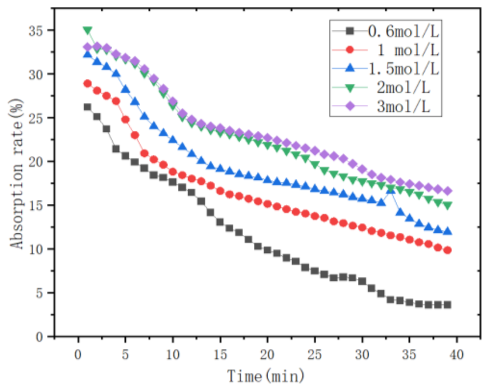

Figure 3. Absorption efficiency corresponding to different concentrations of DEA.

4.3 Effect of CO_2 concentration on absorption

The concentration of CO_2 has a great influence on the absorption of the samples. Figure 4 shows that the initial absorption efficiency of CO_2 absorption by DEA mixed with sodium humate was essentially the same for CO_2 flux concentrations of 5%, 10%, 12%, and 15%. The sustained absorption effect deteriorates as the concentration of CO_2 increases. The higher the concentration of CO_2 introduced, the less effective the sustained absorption of CO_2 by DEA mixed with sodium humate.

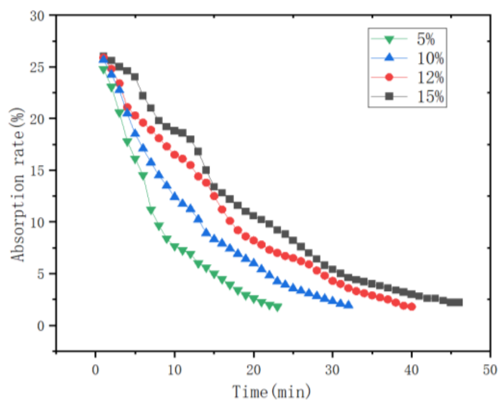

Figure 4. Absorption efficiencies corresponding to different concentrations of CO_2.

4.4 Effect of temperature on CO_2 absorption

Figure 5 shows that when the temperature is 10℃, the initial efficiency of CO_2 absorption is 25.2%. When the temperature is raised to 30℃, the initial efficiency of CO_2 absorption is 28%. The initial efficiency of CO_2 absorption was 34.1% at a temperature of 60℃. Setting the temperature to 80℃, the initial efficiency of CO_2 absorption becomes 36.5%. The initial efficiency of CO_2 absorption was 39.2% when the temperature was set at 100℃. This shows that the higher the temperature, the higher the initial efficiency of CO_2 absorption. After about 12 minutes of reaction, the reaction data of 30℃, 60℃, 80℃ and 100℃ start to overlap, which shows that the absorption effect at these four temperatures is very close to each other, So temperature has little effect on the overall effect of CO_2 absorption (in the case of greater than 30℃). However, the temperature should not be too low, and at 10℃ the absorption effect is much lower than at the other four temperatures.

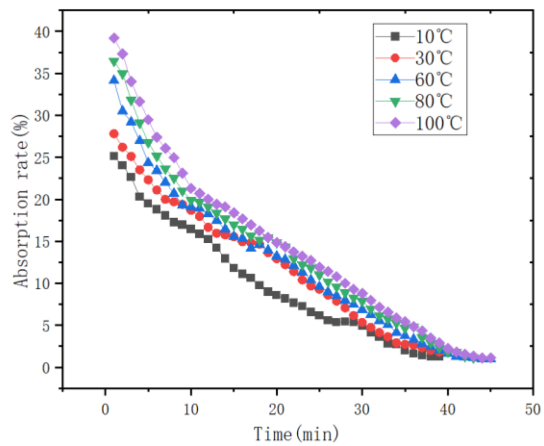

Figure 5. Absorption efficiency at different temperatures.

4.5 Effect of flue gas flow on CO_2 absorption

Figure 6 shows that the initial efficiency of CO_2 absorption is 25.8% when the simulated flue gas flow rate is 1 L/min. The initial efficiency of CO_2 absorption was 28.4% when the simulated flue gas flow rate was set to 2 L/min. When the simulated flue gas flow rate is 3 L/min, the initial efficiency of absorbing CO_2 is 31%. The initial efficiency of CO_2 absorption was 34.8% and 37.4% when the simulated flue gas flow rate was set to 4 L/min and 5 L/min, respectively. The higher the simulated flue gas flow rate, the higher the initial efficiency of absorbing CO_2. The absorption efficiencies in the five cases converge at the 10th-13th minutes. Throughout the process, the higher the simulated flue gas flow rate, the faster the absorption efficiency decreases and the less effective the continuity of CO_2 absorption is.

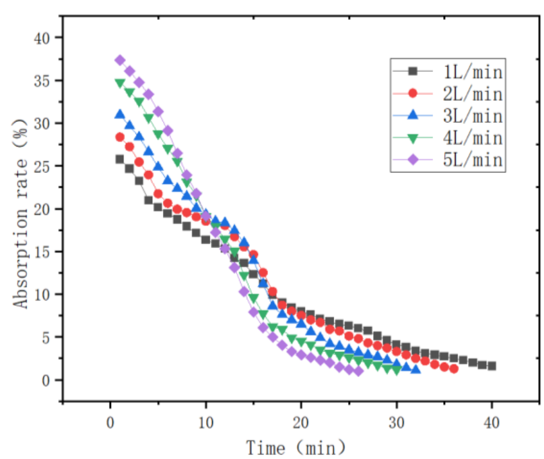

Figure 6. Absorption efficiency for different flue gas flow rates.

5. CONCLUSION

The higher the concentration of DEA the more efficient the absorption of CO_2. However, the rate of increase in absorption efficiency becomes slower and slower as the concentration of DEA increases. The concentration of DEA should not be too high, and it is relatively appropriate to control it at 1.5-2 mol/L. The more the amount of sodium humate, the higher the efficiency of CO_2 absorption, the amount of sodium humate is controlled at about 0.4 g is most appropriate. The influence of temperature is a small factor, but for good absorption efficiency, the minimum temperature should preferably not be lower than 30°C. CO_2 concentration had no effect on the initial efficiency of CO_2 absorption, but the higher the CO_2 concentration the worse the sustained effect of absorption. The higher the flue gas flow the worse the sustained effect of CO_2 absorption.

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