Experimental study on desorption for carbon dioxide absorbent rich liquid based on coke fountain phenomenon

Yuanyuan LIU[1, a],Weiran LYU[2,b], Kang CHEN [1,c], Jianyi LU*[1, d]

[1]School of Environmental Science and Engineering, North China Electric Power University, Baoding 071003, P.R.China

[2] No. 3 High School of Baoding, Baoding 071003, P.R.China.

[a] Liuyuanyuan051988@163.com, [b]lyuweiran@163.com , [c]huadiangaojie@163.com,

[*]Corresponding author, [d]Lujianyi@tsinghua.org.cn

Keywords: Mint; Carbon dioxide; Desorption; Absorbent rich liquid

Abstract. The experimental study on desorption for carbon dioxide is based on the phenomenon that pouring mints into coke can form coke fountain. In this study, the commonly used liquid monoethanolamine (MEA) was assumed as the absorbent for carbon dioxide, then the mint and its main compositions such as glucose, menthol, Arabic gum, gellan gum and Custer sugar were added into the absorbent rich liquid respectively. In addition, for studying the influence of the physical structure of the matter, chalk powder and activated carbon were also added separately. Under specific experimental conditions and different temperature, the effect on the desorption rate of different compositions and different materials were compared, through the determination of carbon dioxide desorption quantity in absorbent liquid. The results showed that the mint could effectively accelerate the desorption of carbon dioxide from the absorbing liquid rich, the main contributor is glucose. Contrasting the desorption results of mints ,chalk powder and activated carbon, it showed that physical structure of the carbon dioxide on the surface of the material also had great effect on the desorption rate, in addition to the influence of chemical composition.

Introduction

In recent years, with the increasing industrialization, the greenhouse effect has been becoming more serious and much more further attention has been paid to it. Though carbon dioxide can cause the greenhouse effect, at the same time it is also a kind of valuable carbon resources. The effective desorption and collection of the industrial waste gas, especially for the carbon dioxide in the coal-fired flue gas, can control the greenhouse effect and produce significant economic benefits. At present, there are many methods about carbon dioxide absorption , such as several physical methods (for instance heat up and vacuum) and chemical method (for example chemical solution absorption and desorption of carbon dioxide). But the absorption and desorption rate haven't reach the expectation. Therefore, considering the efficiency and cost for carbon dioxide desorption, it is imperative to find efficient and economic desorption methods of carbon dioxide.

The study based on the phenomenon observed in daily life, coke will produce a large number of bubbles and inflation when adding mint , then it will occur fountain. Coke is a kind of carbonated drink - a matter which is rich in carbon dioxide, it will dissolve and erupt fast when combining with mint . This fountain phenomenon inspired us that we could apply this principle to the desorption of carbon dioxide in industrial processes. Resorting to relevant data, the main compositions of mint are glucose, menthol, Arabic gum, gallant gum and Custer sugar. The study compared the effects of different composition and materials on the desorption rate by detecting desorption amount after adding the material respectively, so that it could provide a certain enlightenment and help on carbon dioxide absorption and desorption in industrial processes.

Experimental

Preparation of absorbents. The main industry absorber for recovering carbon dioxide from flue gas was the MEA, the absorbent we took for the experiment is supplied by Tianjin Kemiou Chemical Reagent Co., Ltd. MEA has a amino and hydroxyl groups. The former provided the required alkalinity and prompted the absorption of acid gases, and the latter could reduce the vapor pressure and increase the solubility in water[1]. MEA solution has lots of advantages, such as strong alkaline, fast response rates with carbon dioxide and low cost ,but the reaction process was easy to generate a stable carbamate which resulted in a decreasing absorption, difficulty regeneration and strong corrosion phenomenon[2]. Adding piperazine (PZ) in MEA could improve the absorption and regeneration of absorbent[3, 4]. According to lots of references, considering the effect of MEA absorption property in different ratable additives and the efficiency of the absorbent, the solution of 16% MEA+4% PZ was assumed as the efficient absorbent for carbon dioxide in this experiment.

Fresh absorbing liquid should be made before absorption experiment. Then 100mL absorbent solution was made for each experiment. The volumetric flask was placed on the electronic balance to weigh the required MEA and the additives which should be added into the volumetric flask. The chemicals were diluted by deionized water to the graduation line after weighing, and the volumetric flask was shaken up repeatedly preparing for the subsequent absorption experiments.

Absorption experiments. Experiment set-up was showed as Fig. 1.The pure gas of carbon dioxide was employed in this experiment and the gas was provided by the bottled high pressure gas. The flow rate of carbon dioxide was 100mL/min. According to the experimental study in advance, it was 30 minutes for the absorbing liquid to be saturated under the same absorption condition, and temperature could affect the carbon dioxide absorption rate of alcohol amine solution. The flask-3-neck was placed in water bath and the absorption solution was added into the flask. The experiment was conducted when the thermometer became stable. According to the references, the absorption rate was the quickest at 40℃, so the temperature of the water bath was adjusted to 40℃ and it was the very time to conduct absorption when the thermometer became stable. The gas passed tip-mouth glass tube into flask-3-neck, and it began to count time while the gas passed tip-mouth glass tube into flask-3-neck. At the same time, gas bubbled in solution and had a certain mixing effect. The outlet concentration of CO_2 was measured per minute and was recorded after every runs.

Regeneration. After the adsorption experiment, 100mL absorption solution was taken from the flask with a pipette, and added it into a 250mL conical flask, then put it in the temperature water bath pot, the desorption temperature was set between 30℃ to 80℃, and the temperature interval was set 10℃. Regeneration set-up was showed as Fig. 2. The desorption of carbon dioxide was indicated by appearing calcium hydroxide solution precipitation in the left, and sodium hydroxide solution absorbed tail gas. It was time to set down the thermometer temperature when saturated calcium hydroxide solution became turbid and it was assumed the regeneration temperature.

Mint analysis. Pouring 100 ml absorbing liquid into the dry boiling flask-3-neck in the water bath and adding 5.4 g mint into the flask. The mass fraction of sodium hydroxide solution was 5% and putting 40ml into a beaker. The original quality was recorded “m_1”, and then recorded “m_2” as the quality of sodium hydroxide after the reaction lasting for 30 min. Then the desorption quantity was “m_1-m_2”.The controlled trial was “16%MEA+4%PZ” absorbing liquid with rich carbon dioxide.

From Fig.3, we can see that the quantity of desorption of carbon dioxide increased nearly 9 times after joining mint than that of controlled trial absorption solution, on the basis of per gram of desorption agent (unit: g/g, similarly hereinafter in this paper). So adding mint can effectively increase the desorption rate of carbon dioxide from absorbent rich liquid.

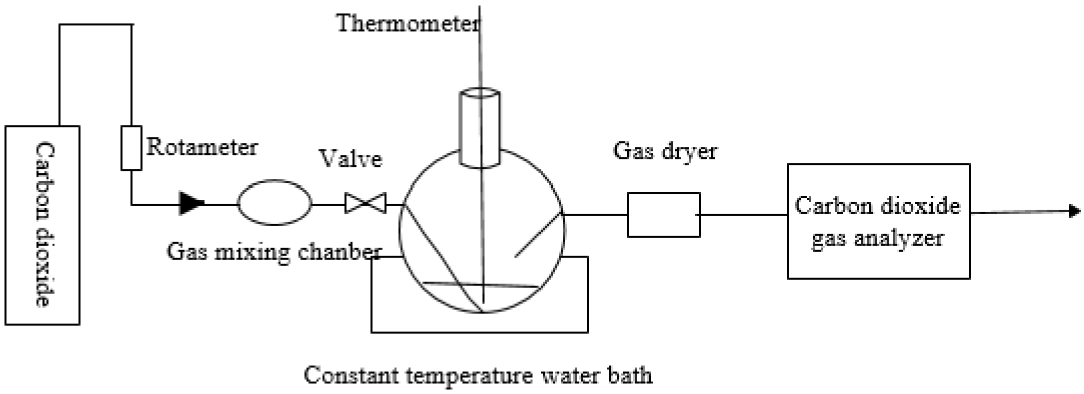

Fig. 1 The experimental set-up for absorption

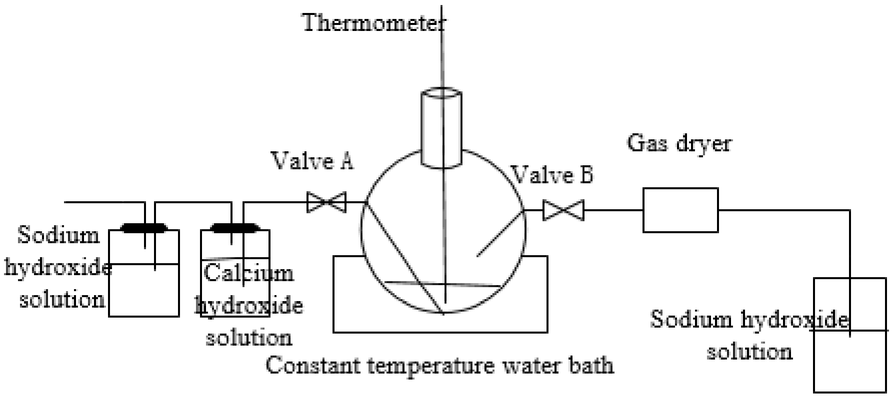

Fig. 2 The experimental set-up for regeneration

Influence of mint components. Researches showed that the main components of the mint were glucose, menthol, Arabic gum, gallant gum, Custer sugar, etc. In order to investigate the main ingredients for carbon dioxide desorption in mint, each component was taken 5.4 g to add in absorbent rich liquid for desorption experiments respectively.

From Fig.4, we can see that the main components in mint that can promote carbon dioxide desorption were glucose, Arabic gum and gallant gum, especially glucose whose desorption rate is nearly 8 times greater than that of controlled trial absorption solution, while menthol and Custer sugar were almost no desorption rates.

Desorption temperature. The desorption experiments were conducted at different temperatures separately, which was set between 30˚C to 80˚C and the temperature increment was 10˚C. Then repeated the above desorption experimental process.

As shown in Fig.5 drawn from the absorption quality- time graph in the experiments, the optimal desorption temperature was 50˚C. The promotion rate was 10 times than that in high temperature of 60˚C, 70˚C and 80˚C. While under the temperature of 50□, there was almost no acceleration in desorption.

Surface structure. Besides considering the chemical components on promotion effect of desorption, the physical structure was also taken into account. The similar surface structure of activated carbon and chalk powder were employed to conduct the desorption experiments, to compare the desorption characteristics resulted from the physical factors. So 5.4g activated carbon and chalk powder were added in coke respectively. Then repeated the desorption experiments procedures.

The result showed in Fig.5, it demonstrated that both activated carbon and chalk powder had obvious acceleration effect on desorption of carbon dioxide, but the effect was not so severer as mint. That is to say, physical structure of mint also contributes to the desorption of carbon dioxide from absorbent rich liquid besides the chemical components.

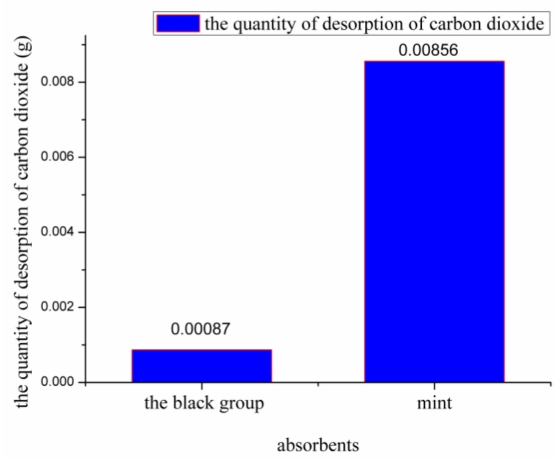

Fig. 3 Desorption quality and absorbents relational graph ,mints vs. the black group

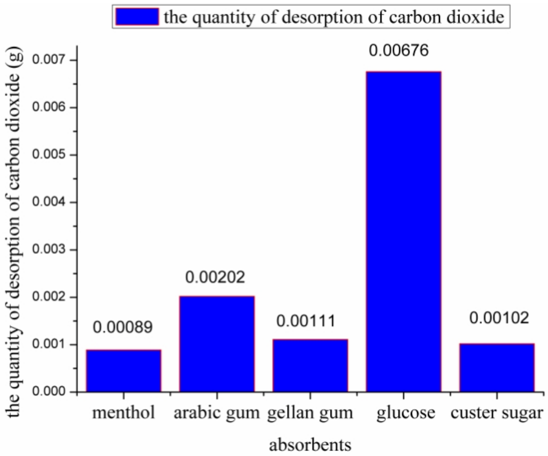

Fig 4 Desorption quality vs. different absorbents relational graph

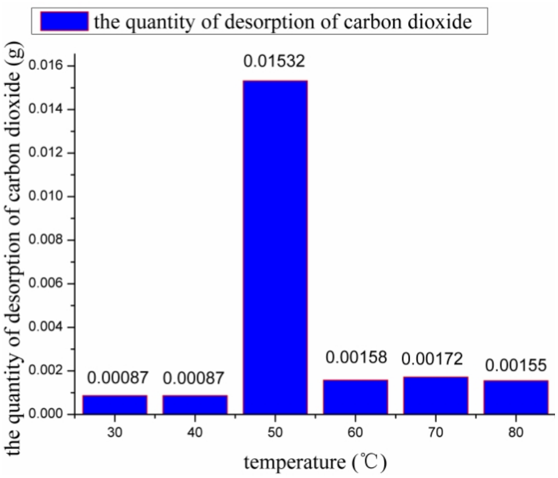

Fig 5 Desorption vs. different temperature relational graph

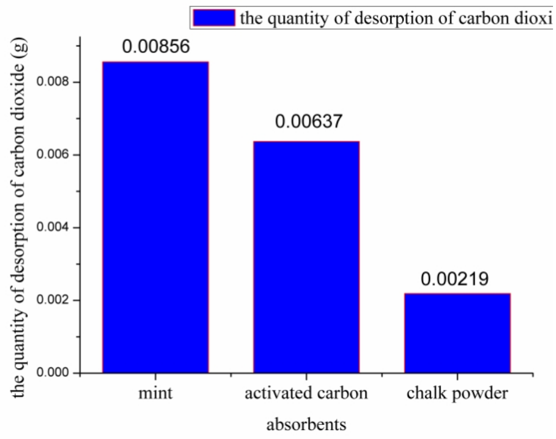

Fig 6 The desorption quantity vs. the same surface structure relational graph

Conclusions

a) Mint can obviously accelerate the desorption of carbon dioxide from absorbent rich liquid.

b) The greatest contributor for desorption acceleration of carbon dioxide in mint components is glucose.

c) Physical structure of mint also contributes to the desorption of carbon dioxide from absorbent rich liquid besides the chemical components.

d) The optimal temperature was 50˚C for the desorption of carbon dioxide from absorbent rich liquid.

e) Based on the phenomenon of Coke Fountain, this method could be used in desorbing the carbon dioxide from industrial gas by adding some materials, such as mint and materials similar to mint to accelerate the desorption of carbon dioxide from absorbent rich liquid.

Acknowledgement

This work was financially supported by the National Natural Science Foundation of China (Grant No. 51376063)

References

[1] Q.Y. Liu. CO_2 from flue gas recycling technology review. Journal of petroleum chemical engineering design, 2001, 19 (2): 44-45.

[2] X. W. Feng, G. P. Guo. Carbon steel in CO_2 saturated solution of alkanol amine corrosion electrochemical behavior. Materials protection, 2002, 35 (4): 17-19.

[3] W. J. Choi, J. B. Seo, S. Y. Jang, et al. Removal characteristics of CO_2 using aqueous MEA/AMP solutions in the absorption and regeneration process. Journal of Environmental Sciences. 2008,21(7): 907-913.

[4] G. L. Gu, H. K. Zou. Experimental research of the CO_2 absorber ,Ethanol amine as the main body. Journal of Beijing chemical university (natural science edition), 2010, 5 (3): 20-25.