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# CARBON DIOXIDE CHEMICAL ABSORPTION WITH GLUCOSAMINE IN AIR-LIFT REACTOR

Alicia García-Abuín, Diego Gómez-Díaz, José M. Navaza, Isabel Vidal-Tato
[1] Department of Chemical Engineering. ETSE. Rúa Lope Gómez de Marzoa s/n. University of Santiago de Compostela. Santiago de Compostela. E-15782. Galicia. Spain. alicia.garcia@rai.usc.es

**Abstract**
The behaviour of glucosamine aqueous solutions has been studied to be used in carbon dioxide capture through absorption with chemical reaction using an air-lift reactor. Experimental results indicate that this reagent has a similar behavior than other common amines widely used in CO2 capture, with regard to rate of capture of this acidic gas. The value of mass transfer rate has been determined, and the effect of different operation conditions upon the value of this parameter and gas-liquid interfacial area has been analyzed (amine concentration, pH and gas flow rate).

**Keywords**: absorption, glucosamine, carbon dioxide, air-lift reactor, bubbles

## 1. Introduction
Currently, aqueous alkanolamines solutions based on monoethanolamine, diethanolamine, 2-dipropanolamine and methyldiethanolamine are most commonly used in industry. These amines have shown fast or moderately fast regimes of absorption accompanied by a chemical reaction, which has a high importance as regards the aim of capturing higher quantities of carbon dioxide, as well as the scale-up of operation units. The most recent research studies are also related to the development and testing of new reagents and/or amines to capture carbon dioxide[1], as well as the use of blends of different amines[2,3] with the aim of achieving a certain enhancement in pollutant gas capture, due to their combined action. For these reasons, it is important to determine kinetic data for these kinds of reactions with the aim of understanding the behaviour of different amines or blends when reacting with the carbon dioxide present in a gas stream, so that we can calculate the capture efficiency or the geometrical characteristics[4] to design gas-liquid contactors.

Recently our research team has performed very interesting studies using 2-amino-2-deoxy-D-glucose, called glucosamine, to carbon dioxide capture in a gas-liquid contactor. Capture of CO2 in this system is due to chemical reaction between glucosamine and $CO_2$ previously absorbed in the liquid phase. This is a first-order reaction with regard to both compunds ($CO_2$ and GA) as it has been concluded for our research group in previous studies. The mechanism suggests for this reaction is zwiteronic type, in which the global process of absorption with chemical reaction has a moderately fast regime, because Hatta number takes values between $0.3 < Ha < 3$ for the experimental conditions used in the present work.

This work introduces the absorption process of carbon dioxide using a new amine (2-amino-2-deoxy-D-glucose, called glucosamine). This substance has been explored for the removal process by absorption of carbon dioxide from the environment. Moreover, it could be a highly interesting compound for its use in carbon dioxide capture procedures by means of absorption accompanied by a chemical reaction. Glucosamine could be a highly interesting reagent due to its special characteristics in relation to the safety requirements with negligible negative effects upon equipment maintenance. Moreover, the treatment of exhaust aqueous solutions of glucosamine is also easier than other amines employed in carbon dioxide absorption.

## 2. Experimental section
Different quantities of 2-Amino-2-deoxy-D-glucose hydrochloride or glucosamine hydrochloride (GA) supplied by Fluka (CAS number 66-84-2) has been employed to produce aqueous solutions to use in a bubble column reactor. The solutions were prepared by mass using a balance with a precision of $\pm 10^{-7}$ kg. To prepare the absorbent phases (in the range 0 – 0.4 $mol \cdot L^{-1}$), bi-distilled water has been employed. Commercial grade carbon dioxide of 99.998% purity, supplied by Carburos Metálicos, was

also used in this work. Appropriate sodium chloride quantities were added to the GA aqueous Solutions to remove the acidic character.

All experiments were performed operating in batches with respect to the liquid phase. The airlift contactor used in the present work was constructed in Perspex with 0.07 m inside diameter. The height of the riser-tube was 0.37 m with an inside diameter of 0.032 m. Air was used as gas stream in the gas-liquid contactor and it was fed at the bottom of the bubble column using a five holes sparger that allows us to analyze carefully the influence of the operation conditions on the bubbles size. The volume of the liquid phase employed in the bubble contactor was 3.5 L.

To determine the gas-liquid interfacial area, a photographic method was used. A bubble column, with geometrical characteristics of 4 cm inside side-length and height of 65 cm, was used. The same gas sparger used in the mass transfer experiments was employed. Since the diameter and height are similar to those of the riser's airlift reactor, results can be extrapolated. The bubbles diameter was measured using a photographic method based on images of the bubbles taken along the height of the column, from the bottom to the top. The column height was divided in three sections and a minimum number of 50 well-defined bubbles along the column were used to evaluate the size distribution of the bubbles in the liquid phase for the different gas flow-rates tested. A complete description of experimental procedure is included in previous papers[5].

The gas flow-rate was measured and controlled with two mass flow controllers (5850 Brooks Instruments). The mass flow controllers employed in the present study for the gas flow-rate and pressures were calibrated by the supplier. The gas flow-rates employed have been included into 18-40 $L{\cdot}h^{-1}$. The pressure drop was measured between the column's inlet and outlet, using a Testo 512 digital manometer.

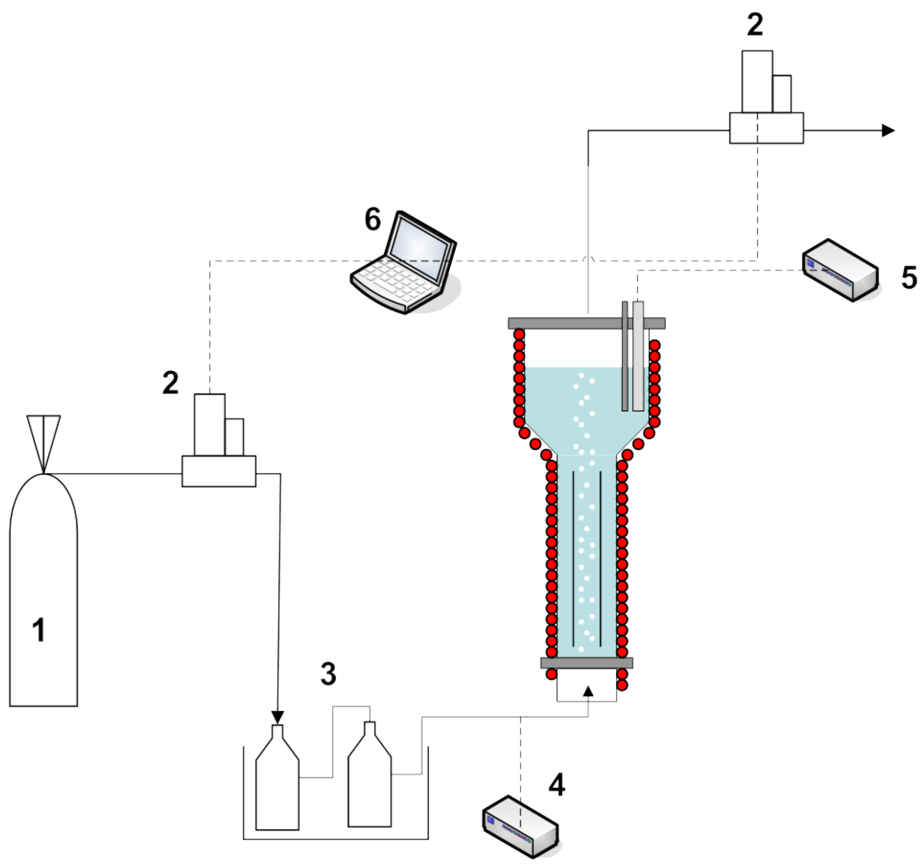
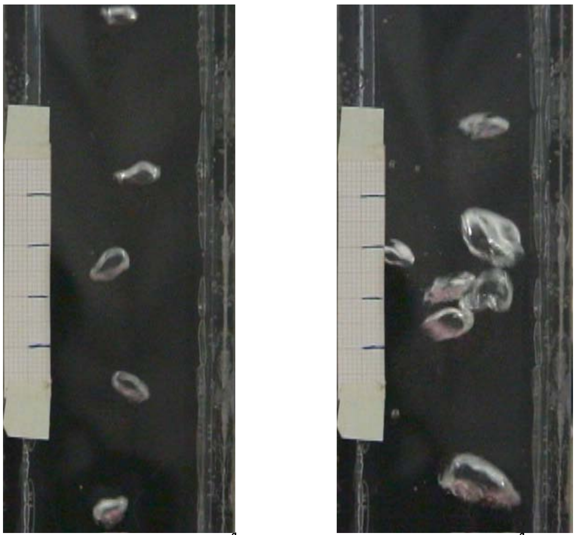



**Figure 1**. Experimental set-up employed in carbon dioxide absorption experiments. (1) Gas cylinder; (2) Mass flowmeter/controller; (3) Humidifier and thermostatic bath; (4) Pressure gauge; (5) Temperature gauge; (6) Flow data recorder.

## 3. Results and discussion

The first part of the research work included in present manuscript has been centred on the analysis of certain hydrodynamic conditions corresponding to the air-lift reactor employed in this work. More specifically the studies involve the gas-liquid interfacial area determination and the gas hold-up in the experimental conditions. In relation with the first parameter (interfacial area) a photographic method has been employed, previously commented. An example of the photographs analysed to determine the interfacial area taken under different experimental conditions is shown in figure 2. In this figure is possible influence the effect of gas flow-rate upon the bubble size, observing that the bubble diameter increases when the gas flow-rate increases too. Photographs shown in figure 2 correspond to experiments using the more different gas flow rates, obtaining medium values for bubbles diameter. The obtained behaviour for the gas flow-rate range is shown in figure 3 and on the basis of the experimental data is possible conclude that a continuous and linear increase in the value of bubble diameter is observed when gas flow-rate fed to the contactor increases.



Flow-ra$Q_g$ = 18 L·h$^{-1}$ $Q_g$ = 42 L·h$^{-1}$

**Figure 2**. Examples of the bubbles produced into the bubble contactor at different gas flow-rate.

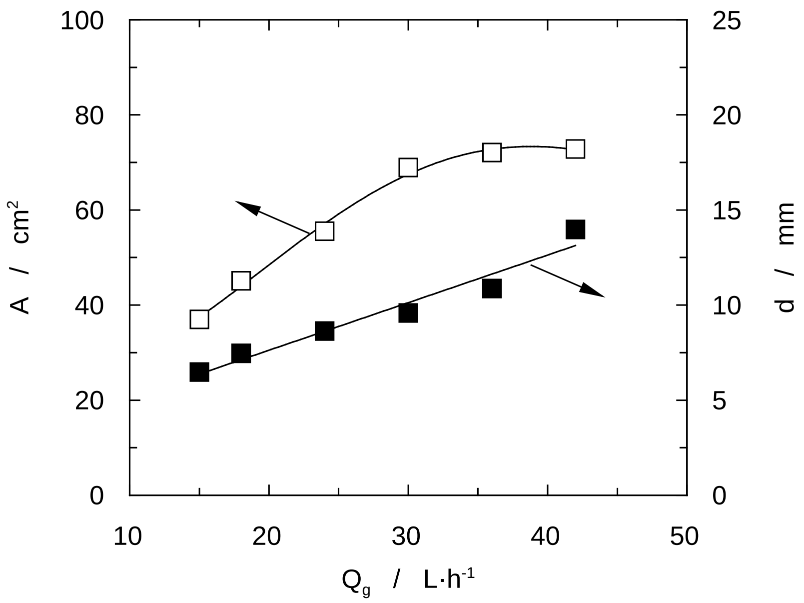



**Figure 3**. Influence of gas flow-rate upon the bubbles diameter and gas-liquid interfacial area.

From the value of bubbles diameter previously determined at different sections of bubble contactor and under the different operation conditions, the gas-liquid interfacial area was determined and the obtained behaviour is shown in figure 3. An increase in gas flow-rate produces an increase in the value of gas-liquid interfacial area until a certain value. Over this value of gas flow-rate, the value of interfacial area remains constant and the importance of this operation variable loose importance. On the basis of the experimental results (shown in figure 3) corresponding to the bubble diameter is possible extract the conclusion that the gas-liquid interfacial area must decrease when gas flow-rate increases, due to bubble diameter increases. But the behaviour observed is the opposite (see figure 3) for the interfacial area. This behaviour is due to the gas hold-up, that increases with increasing gas flow-rate with a linear trend that implies an homogeneous regime in the bubble contactor. Then when gas flow-rate increases, an increase in the quantity of gas hold in the contactor that produce an increase in the number of bubbles in contact with liquid phase and this behaviour produces an increase in interfacial area.

Regards the influence of glucosamine concentration in the liquid phase upon the value of gas-liquid interfacial area and then, upon the gas hold-up and bubbles diameter, the experimental studies developed show that not exist difference upon the values for this parameters when glucosamine concentration is changed. This behaviour is related with the low influence of glucosamine composition upon different physical properties such as viscosity and/or surface tension, with influence upon these hydrodynamic parameters.

Also studies about mass transfer rate of carbon dioxide upon liquid phase have been developed in the air-lift reactor previously characterized regards gas-liquid interfacial area. To study the way that the carbon dioxide capture process in this equipment is produced, the influence of gas flow-rate and glucosamine concentration in the liquid phase have been analysed. Figure 4 shows typical experimental results obtained for determine the quantity of carbon dioxide absorbed along the experiments. The absorption rate decreases until the saturation of liquid phase is obtained. The reagent concentration decreases due to the reaction between carbon dioxide and glucosamine.

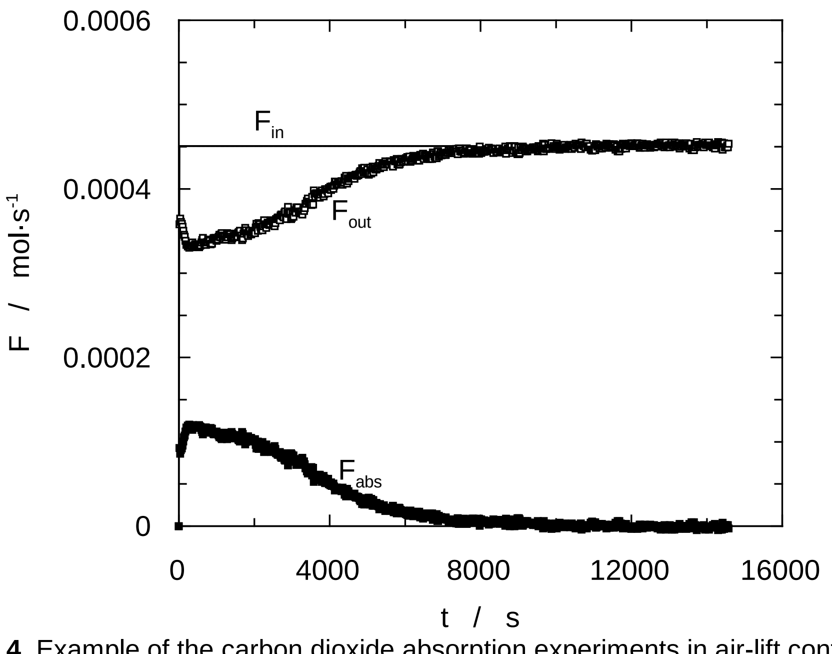



**Figure 4**. Example of the carbon dioxide absorption experiments in air-lift contactor.
$C_B$ = 0.1 mol·L$^{-1}$. $Q_g$ = 40 L·h$^{-1}$.

In relation with the effect caused by gas flow-rate a common behaviour corresponding to a bubble contactor[6] has been found: an increase in the value of the carbon dioxide gas flow-rate, produce an increase in the value of interfacial area (previously commented) and upon the turbulence in the liquid phase. These characteristics produce an increase in mass transfer rate and then, the saturation of liquid phase in carbon dioxide is produced in a minor time.

On the other hand, the influence of glucosamine concentration upon the global absorption process is shown in figures 5 and 6. In the previous study based on the influence of this variable upon the gas-liquid interfacial area, no-effect was detected. Then, the influence of this variable upon mass transfer rate only could be due to the mass transfer coefficient. Figures 5 and 6 allow obtain different conclusions about the effect of glucosamine concentration upon the absorption rate and carbon dioxide loading. Figure 5 indicates that an increase in glucosamine concentration in the liquid phase increases the quantity of carbon dioxide captured by this liquid phase. This behaviour is common because an increase in the amine concentration in the liquid phase produce an increase in the number of amine molecules that could react with the carbon dioxide absorbed. But taken into account the data shown in figure 5 and analysing this data such as carbon dioxide loading (mol of carbon dioxide/mol of amine) the conclusion reached in present study is that an increase in the glucosamine concentration produces a clear decrease in carbon dioxide loading. This behaviour is in agreement with previous studies using different amines as reagent to capture acid gases[7]. This behaviour has been assigned to different causes in previous works: (i) an increase in the liquid phase viscosity due to an increase in the amine concentration that produces a decrease in diffusion coefficients, and (ii) aggregation processes between amine molecules when the concentration increases, producing a difficult in the access of carbon dioxide molecules to the amino group to produce the reaction. The first cause commented doesn't produce the decrease in carbon dioxide loading because a reduction in gas diffusion must influence upon mass transfer rate but the carbon dioxide loading remains constant. Also, the influence of glucosamine concentration upon the viscosity value is low. Taken into account this comment, the second cause seems the behaviour that produces the reduction in carbon dioxide loading when amine concentration increases in the liquid phase.

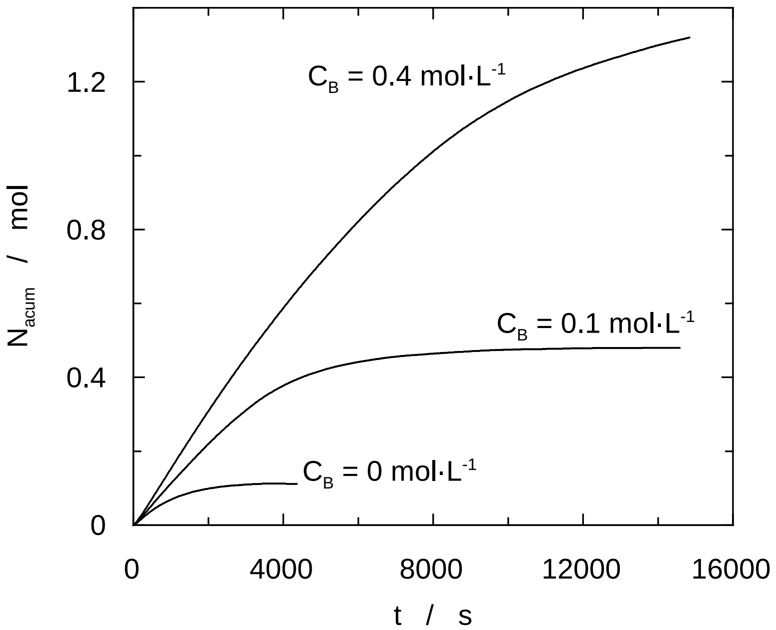



**Figure 5**. Influence of amine concentration upon accumulated carbon dioxide. $Q_g$ = 40 L·h$^{-1}$.

On the other hand, figure 6 allows obtain information about the mass transfer rate, and in the basis of the experimental data is possible observes that when glucosamine concentration increases in the liquid phase, a maximum value in the absorbed gas flow-rate increases. This behaviour is due to a higher glucosamine concentration increases the number of amine molecules in the liquid phase and the, the concentration of this reagent in the zones near to the gas-liquid interface. This fact produces an increase in the probability of reaction between both reagents.

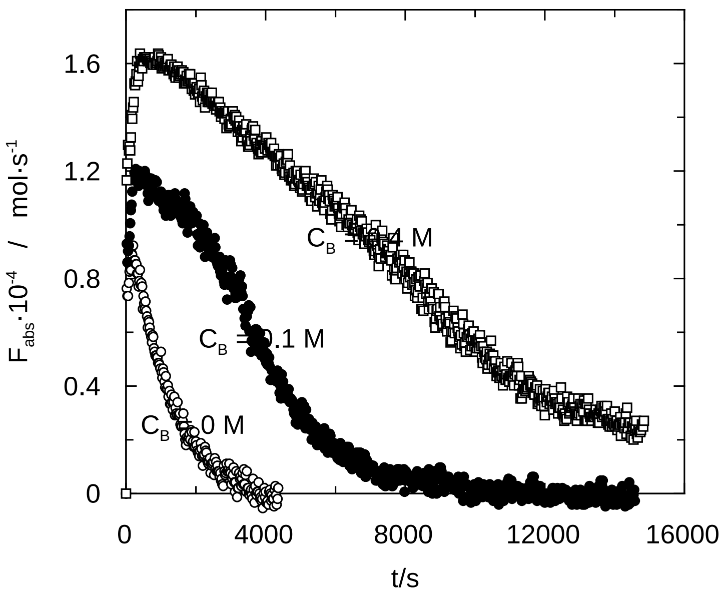



**Figure 6**. Influence of amine concentration upon absorption rate. $Q_g$ = 40 $L\cdot h^{-1}$.

## 4. Conclusions

Present work has analyzed the use of glucosamine aqueous solutions for carbon dioxide capture by means of absorption with chemical reaction between this gas and the glucosamine using a air-lift contactor. The analysis of the influence of different operation variables and conditions upon the gas-liquid interfacial area generated in a bubble column reactor has been analyzed. The results indicate that no influence of liquid phase composition (in the studied range) upon interfacial area has been observed. But the gas flow-rate fed to bubble reactor has an important influence causing an increase in this parameter due to and increase also the gas hold-up. Mass transfer studies have shown that an increase in glucosamine concentration produces an increase in mass transfer rate, but the carbon dioxide loading decreases.

## Acknowledgements

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