Experimental data of the aqueous NH$_3$ and CO$_2$ absorption at temperatures from 15 °C to 35 °C, NH$_3$ concentrations from 5% to 15% and CO$_2$ loadings from 0.2 to 0.6 measured with the Wetted Wall Column

Lillia, Stefano; Bonalumi, Davide; Fosbøl, Philip L.; Thomsen, Kaj; Valenti, Gianluca

Published in:
Data in Brief

Link to article, DOI:
10.1016/j.dib.2018.02.047

Publication date:
2018

Document Version
Publisher's PDF, also known as Version of record

Link back to DTU Orbit

Citation (APA):
Lillia, S., Bonalumi, D., Fosbøl, P. L., Thomsen, K., & Valenti, G. (2018). Experimental data of the aqueous NH$_3$ and CO$_2$ absorption at temperatures from 15 °C to 35 °C, NH$_3$ concentrations from 5% to 15% and CO$_2$ loadings from 0.2 to 0.6 measured with the Wetted Wall Column. Data in Brief, 17, 1240-1244. https://doi.org/10.1016/j.dib.2018.02.047

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain.
- You may freely distribute the URL identifying the publication in the public portal.

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.
Data Article

Experimental data of the aqueous NH₃ and CO₂ absorption at temperatures from 15 °C to 35 °C, NH₃ concentrations from 5% to 15% and CO₂ loadings from 0.2 to 0.6 measured with the Wetted Wall Column

Stefano Lillia, Davide Bonalumi, Philip L. Fosbøl, Kaj Thomsen, Gianluca Valent

Article Info

Article history:
Received 23 January 2018
Received in revised form 30 January 2018
Accepted 15 February 2018
Available online 2 March 2018

Abstract

The absorption between aqueous NH₃ and CO₂ is studied using the Wetted Wall Column in order to show the effect of the solvent condition on the rate of reaction. A total of 27 different cases are investigated in the region defined by temperatures from 15 °C to 35 °C, NH₃ concentrations from 5% to 15% and CO₂ loadings from 0.2 to 0.6. The paper reports the data measured during the experiments, the experimental apparatus description and the experimental procedure. The data here presented are both the raw data measured with their uncertainty and the final value of the overall mass transfer coefficient. The overall mass transfer coefficient is the result of the raw data treatment explained in the research paper related to this data. The data here reported are analyzed in the paper by Lillia et al. (2018) [1].

© 2018 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).
### Specifications Table

<table>
<thead>
<tr>
<th>Subject area</th>
<th>Environmental chemical engineering</th>
</tr>
</thead>
<tbody>
<tr>
<td>More specific subject area</td>
<td>Absorption solvent characterization and rate of the absorption measurements</td>
</tr>
<tr>
<td>Type of data</td>
<td>Table of data and text</td>
</tr>
<tr>
<td>How data was acquired</td>
<td>The data are acquired by the Wetted Wall Column apparatus. The partial pressure of the CO2 inside the reactor is measured considering the total pressure in the reactor with a pressure transducer (Rosmount 2088) and the CO2 concentration with the CO2 probe (VAISALA GMT 220). The CO2 flow absorbed by the solvent in the reactor is measured considering the difference of the CO2 concentration with the CO2 probe (VAISALA GMT 220) before and after the reactor and the gas mole flow blown to the reactor.</td>
</tr>
<tr>
<td>Data format</td>
<td>Raw measurements with uncertainties and their analysis (the overall mass transfer coefficient).</td>
</tr>
<tr>
<td>Experimental factors</td>
<td>The solvent is prepared gravimetrically in terms of ammonia composition and CO2 loading (defined as the rapport of CO2 and NH3 in the solvent).</td>
</tr>
<tr>
<td>Experimental features</td>
<td>A gas mixture of N2 and CO2 with a known composition flows in the Wetted Wall Column in contact with solvent with a known composition. The partial pressure of the CO2 inside the reaction chamber and the CO2 flux absorbed by the solvent are measured during the experiment for different compositions of gas and solvent. The result is the overall mass transfer coefficient which describes the dependence of the rate of absorption and the partial pressure of the CO2.</td>
</tr>
<tr>
<td>Data source location</td>
<td>Department of Energy of Politecnico di Milano, Milan (Italy)</td>
</tr>
<tr>
<td>Data accessibility</td>
<td>Data are provided within the attached excel file and within the article Experimental study of the aqueous CO2-NH3 rate of reaction for temperatures from 15 °C to 35 °C, NH3 concentrations from 5% to 15% and CO2 loadings from 0.2 to 0.6 [1]</td>
</tr>
</tbody>
</table>

### Nomenclature

#### Acronyms

- VR: Value Read
- FS: Full-Scale
- WWC: Wetted Wall Column
- Liq.: Liquid phase
- Gas: Gas phase

#### Table of data

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_i^j$</td>
<td>Partial pressure of component $i$ at position $j$ [mol/s]</td>
</tr>
<tr>
<td>$\varphi_{CO_2}$</td>
<td>CO2 flux absorbed by the solvent [mol/(m² s)]</td>
</tr>
</tbody>
</table>

#### Greek symbols

- $K_{ov}$: Overall mass transfer coefficient for the CO2 transport [mol/(Pa m² s)]
Value of the data

- Enhance the number of analyzed cases for the CO₂ capture with ammonia solvents
- Raw data with their uncertainties provide information about the accuracy of the measures and the procedure used.
- Raw data are treated to compute the overall mass transfer coefficient under the hypothesis explained by Lillia et al. [1]. Other researcher can model the phenomenon under other hypothesis and treat the raw data with different procedures and compare the $K_{ov}$ results found.
- $K_{ov}$ value can be compared with other data in literature and new data measured in future works with the same method.

1. Data

The data provided by the paper are the Wetted Wall Column measurements for every case analyzed with the absolute uncertainty. The aim of the measurements is the calculation of the CO₂ flux absorbed by the solvent and the partial pressure of the CO₂ inside the Wetted Wall Column reactor. The data presented are the raw data measured by the Wetted Wall Column apparatus and their analysis following the procedure explained in the relative research article by [1]. The raw data treatment returns the overall mass transfer coefficient $K_{ov}$ [mol/(m² s Pa)] that correlates the difference of CO₂ partial pressure in the reaction chamber and the CO₂ flux absorbed by the solvent as defined in Eq. (1)

$$\varphi_{\text{CO}_2} = K_{ov} \left( P_{\text{gas CO}_2} - P_{\text{liq CO}_2} \right)$$

where $\varphi_{\text{CO}_2}$ [mol/(s m²)] is the total CO₂ molar flux absorbed, $P_{\text{gas CO}_2}$ [Pa] is the partial pressure of carbon dioxide in the bulk gas and $P_{\text{liq CO}_2}$ [Pa] the partial pressure of carbon dioxide in the bulk liquid. This constant identifies both the effect of the rate of reaction and the mass transfer of the CO₂ and it is usually reported in this kind of experimental work. Hence, also the value of the $K_{ov}$ is reported with its uncertainty.

Fig. 1. Wetted Wall Column set up pictures: (i) on the left the picture depicts the overall Wetted wall Column set up, (ii) on the right the picture shows a focus on the reaction chamber where the absorption reaction takes place.
2. Experimental design, materials, and methods

2.1. Wetted Wall Column (WWC) experimental apparatus

Fig. 1 shows the experimental apparatus used in this work and Table 1 presents the instrument list. The Wetted Wall Column allows for counter-current contact between the liquid solvent and a defined gas mixture. CO2 and N2 are supplied by gas bottles with a molar purity of 99.995% and 99.996% respectively. The streams from the bottles are controlled by two Bronkhorst mass flow controllers which determine the composition of the inlet mixture in the chamber. The gas mixture passes through a pre-saturator at ambient temperature and a saturator immersed in a thermostatic bath at the temperature of the experiment. After the saturators, the gas mixture is saturated with water at the same temperature of the thermostatic bath. Between the reaction chamber and the CO2 concentration probe (VAISALA CARBOCAP GMT 221) is positioned a condenser. The saturators and the condenser are necessary in order to have a known amount of water in the gas and consequently determine accurately the amount of CO2 in the gas flow. Before the reaction chamber, in the gas line, there is a bypass valve. The valve allows to measure the carbon dioxide concentration before and after the absorption reactions switching the flow straight to the CO2 probe or to the reaction chamber.

The thermostatic bath controls the temperature of the reaction chamber and the temperature of the inlet solvent in the reaction chamber. The solvent, prepared with a known NH3 concentration and CO2 loading is charged in a liquid reservoir of 0.7 dm3. A micro pump pushes the liquid with a controlled mass flow into the thermostatic bath and then into the reaction chamber. The reaction chamber consists of a glass tube in which a stainless steel tube is located (dimensions are reported in Fig. 1). The liquid, pushed inside the stainless steel tube, falls down in a thin film around the stainless steel tube. In this way the contact area between the gas and the liquid phase is well defined.

Based on the known contact area between the gas and the liquid, and the amount of CO2 absorbed in the chamber, it is possible to determine the dependence between the CO2 surface flux absorbed by the liquid and the CO2 partial pressure in the gas mixture at a fixed temperature. A clear scheme of the plant layout is available in the Fig. 1 in the second paragraph of the article which describes the experimental data analysis [1].

2.2. Solvent preparation procedure

The solvent is identified by two numbers: (i) the ammonia concentration, defined as the initial weight of ammonia on the weight of water (wt. NH3/wt. H2O) and (ii) the CO2 loading defined as the ratio between the CO2 and the ammonia in the solution. The chemicals used to prepare the solutions are: deionized water, ammonia solution 28 wt% and ammonium bicarbonate NH4HCO3. The solvent is prepared gravimetrically with a balance with an accuracy of 0.01 g and a full scale of 1000 g. The ammonia concentration and the CO2 loading is calculated considering the apparent concentration of H2O, NH3 and CO2. Deionized water is considered pure H2O, ammonia solution is 28 wt% NH3 and 72 wt% H2O, and one molecule of NH4HCO3 is one molecule NH3 plus one molecule H2O plus one molecule CO2.

<table>
<thead>
<tr>
<th>Instrumentation list.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Quantity measured</strong></td>
</tr>
<tr>
<td>N2 Flow [Nm^3/min]</td>
</tr>
<tr>
<td>CO2 Flow [Nm^3/min]</td>
</tr>
<tr>
<td>Pressure [mbar]</td>
</tr>
<tr>
<td>CO2 concentration [dimensionless]</td>
</tr>
<tr>
<td>Temperature [°C]</td>
</tr>
<tr>
<td>Density [g/cm^3]</td>
</tr>
<tr>
<td>Viscosity [mPas]</td>
</tr>
</tbody>
</table>
2.3. Experimental procedure

The experimental procedure for measuring the overall mass transfer coefficient is described by the following points:

1. prepare the solvent with the desired ammonia concentration and loading;
2. measure the density and the viscosity of the solvent;
3. flush the system with nitrogen for at least 15 min, corresponding to more than 300 reaction chamber volumes;
4. introduce the solvent in the experimental setup and pump the solvent in the liquid circuit until it forms a stable and uniform liquid film on the cylinder in the reaction chamber;
5. set the temperature of the thermostatic bath and wait that the temperature of the reaction chamber is stable at the desired value;
6. when the CO₂ probe reports a null concentration of CO₂ the set-up is ready for the experiment;
7. send a flow of N₂ and CO₂ with the desired concentration into the bypass gas line and measure the CO₂ concentration at steady state condition;
8. direct the gas to the reaction chamber and measure the CO₂ concentration at steady state condition;
9. repeat the last two points for four other different gas mixtures;
10. measure five points at different concentration of CO₂ following the procedure here described in the points 7–9;
11. flow nitrogen in the set-up for 20–30 min and at least 10 l of water in order to clean up the set-up;

This procedure has been repeated at temperatures of 15 °C, 25 °C and 35 °C, ammonia concentrations of 5%, 10% and 15% and CO₂ loadings of 0.2, 0.4 and 0.6 (0.5 for 15% of ammonia to avoid salt precipitations) for a total of 27 cases (3 × 3 × 3).

Transparency document. Supplementary material

Transparency document associated with this article can be found in the online version at doi:10.1016/j.dib.2018.02.047.

Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.dib.2018.02.047.

Reference