DOW AL-DAHHAN CELL FOR MEASURING INTRINSIC KINETICS OF A REACTION IN TWO-FULID-PHASE SYSTEM

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Abstract
We have constructed a Lewis cell offshoot based on a design proposed by Al-Dahhan and Wicks, named the Dow Al-Dahhan cell, for measuring the intrinsic kinetics of a mass transfer-limited reaction in a two-fluid-phase system. In this work, we demonstrated that the Dow Al-Dahhan cell is capable of measuring the intrinsic kinetics of CO2 absorption in aqueous methyldiethanolamine (MDEA). The estimated first order rate constant at 23.5 °C is consistent with the values reported in the literature.

Keywords
Two-phase system, mass transfer, interface area, Lewis cell, surface contactor, intrinsic kinetics.

Introduction

Knowledge of the intrinsic reaction kinetics is critical for scaling up a chemical process. In cases where the mass transfer rate between the two fluid phases is comparable to the observed rate, the apparent rate is a combination of the intrinsic reaction kinetics and mass transfer; hence, the observed rates cannot be used to derive intrinsic kinetics.

One means of measuring the mass transfer rate is to use a surface contactor where the two partially immiscible phases are contacted with known interfacial area. A common contactor is the Lewis Cell, which consists of two stirred cells separated by an interface plate at the liquid-liquid or liquid-gas interface with openings of known area through which mass transfer occurs.

The main shortcoming of most surface contactors is the unstable interface1. Al-Dahhan and Wicks developed a surface contactor that minimizes interface fluctuations1. We further modified the Al-Dahhan Cell by adding jacket for temperature control. To affect good heat transfer, the cell was modified to increase wall to fluid contact area. We named this modified cell the “Dow Al-Dahhan cell”.

In this work, we test the device for measuring the intrinsic rate constant using CO2 absorption in MDEA. The obtained rate constant is within the values reported in the literature.

Experimental Section

For CO2 absorption in MDEA, at the beginning of an experiment, lab nitrogen (>760 ml/min) was fed into the Dow Al-Dahhan cell to purge the reactor. Then, 6.1 wt% MDEA aqueous solution was loaded into the cell until the liquid surface was located in the openings of the interface plate. We gradually increased the agitation speed in the bottom cell to 250 rpm and waited for ~30 min. The temperature was controlled to 23.5±1 °C by adjusting the jacket temperature. After 30 min, we changed the agitation speeds of the top and bottom impellers to the desired rotation per minute (rpm) and then switched from nitrogen flow to CO2 flow (>760 ml/min) to fill the top cell with CO2. After 2 min, we decreased the CO2 flow rate to 60 ml/min. The consumption of MDEA was monitored using

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in-situ Raman spectroscopy with a Kaiser RXN1 785 nm system and an immersion optic.

**Result and Discussions**

The chemistry of CO\(_2\) absorption in aqueous MDEA is shown in Figure 1. MDEA reacts with CO\(_2\) and water to form methyldiethanolammonium and bicarbonate. In the Dow Al-Dahhan cell, the observed rate of CO\(_2\) absorption did not change with agitation speeds in the range 100-300 rpm as shown in Figure 2.

![Figure 1. CO\(_2\) absorption in aqueous MDEA](image)

**Figure 1. CO\(_2\) absorption in aqueous MDEA**

The estimated intrinsic rate constant at 23.5 °C is 2.38x10\(^{-3}\)±0.07 m\(^3\) mol\(^{-1}\) s\(^{-1}\). This rate constant can give a reasonable description of the reaction rates as shown in Figure 4. The estimated intrinsic rate constant in this work is close to the low end of the values reported in the literature (which is 2.02x10\(^{-3}\) m\(^3\) mol\(^{-1}\) s\(^{-1}\)).

![Figure 4. Measured values of [MDEA]/[MEDA]\(_0\) vs. predicted values.](image)

**Figure 4. Measured values of [MDEA]/[MEDA]\(_0\) vs. predicted values.**

**Conclusions**

The Dow Al-Dahhan cell was constructed and was used to measure the intrinsic kinetics of CO\(_2\) absorption in MDEA. We found a regime that the observed rates were independent of agitation speed, and hence we could utilize specific equations to extract the intrinsic rate constant at 23.5 °C. The estimated intrinsic rate constant in this work is within the values reported in the literature.

**Reference**