Chemical Engineering Journal 218 (2013) 126–132

Contents lists available at SciVerse ScienceDirect

Chemical Engineering Journal

journal homepage: www.elsevier.com/locate/cej

Pre-combustion capture of CO_2 by gas hydrate formation in silica gel pore structure

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HIGHLIGHTS

- ▶ Carbon dioxide (CO_2) hydrate formation in a fixed-bed type reactor.
- ▶ Enhanced CO_2 separation for pre-combustion capture.
- ▶ Efficient hydrate-based CO_2 separation process.

ARTICLE INFO

Article history:
Received 2 October 2012
Received in revised form 29 November 2012
Accepted 30 November 2012
Available online 8 December 2012

Keywords:
Gas hydrate
CO_2
Separation
Silica gel
Pre-combustion
Capture

ABSTRACT

This study presents an efficient hydrate-based CO_2 separation process from a binary mixture consisting of 40.3 mol% CO_2 and balanced H_2, which is a simulated fuel gas from the integrated gasification combined cycle (IGCC), in the presence of porous silica gel particles containing water. According to our previous work (Y. Seo, S.P. Kang, Enhancing CO_2 separation for pre-combustion capture with hydrate formation in silica gel pore structure, Chem. Eng. J. 161 (2010) 308–312), the cage occupancy of CO_2 in mixed gas hydrates with H_2 is enhanced by the use of a silica gel pore structure containing water. Based on that result, a simulated fuel gas is applied to form gas hydrates, and a richer CO_2 containing gas stream is thereby retrieved through dissociation of the hydrates from a single-stage reactor. Equilibrium dissociation pressures of CO_2 + H_2 gas mixtures were measured with silica gel particles with pore sizes of 25, 100, and 250 nm. The effect of CO_2 concentration on equilibrium dissociation pressures was also investigated at a silica gel pore diameter of 100 nm. The results indicate that when a simulated fuel gas has formed in 100 nm silica gel pores, a gas stream containing more than 96 mol% of CO_2 is achieved by one-stage gas hydrate formation in a silica gel pore structure, which is comparable to the result (88–92) from hydrate formation in bulk water. In addition to demonstrating enhanced distribution of CO_2 in coexisting phases, gas hydrate formation in a fixed-bed type reactor charged with silica gel particles containing water in pores is investigated. The formation of gas hydrates in silica gel pores occurred to a high extent and at a high rate, and the proposed method is thus expected to be a promising CO_2 capture tool for pre-combustion.

1. Introduction

CO_2 emissions from the burning of fossil fuels have been identified as the main contributor to greenhouse gas emissions, which have led to global warming and subsequent climate change. In 2008, 43% of CO_2 emissions from fuel combustion were produced from coal, 37% from oil, and 20% from gas [1]. Coal is fulfilling much of the growing energy demand of developing countries, where energy-intensive industrial production is growing rapidly and is responsible for 80% of power generation. For these reasons, several techniques have been developed to reduce CO_2 emissions from fossil fuel power plants: oxyfuel combustion, post-combustion CO_2 capture from exhaust flue gas, and pre-combustion CO_2 capture. Oxyfuel combustion is related to improved combustion efficiency, subsequently reducing CO_2 emissions. Post-combustion capture can be achieved in the flue gas stream of power station and is accomplished using amine-based solvents at present. Pre-combustion CO_2 capture involves the removal of CO_2 prior to combustion and is concerned to produce hydrogen (H_2). H_2 combustion produces no CO_2 emission except water vapor and it is used in a gas turbine or a fuel cell. H_2 is considered an attractive future clean energy source. Even though H_2 production should ultimately be achieved from renewable energy sources, for example solar or wind power, production of H_2 from conventional fossil fuels is

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http://dx.doi.org/10.1016/j.cej.2012.11.131