Introduction

Underground sequestration of carbon dioxide is an effective way to reduce atmospheric emissions of greenhouse gases (IPCC 2005). Several large-scale carbon capture, utilization and storage (CCUS) and carbon capture and storage (CCS) projects are under operation globally (Global CCS Institute 2024). For example, Petrobras Santos Basin Pre-Salt Oil Field CCUS project in Brazil has carbon capture capacity of 10.6 million tonnes per annum (Mtpa), with CO_2 used for enhanced oil recovery, Chevron Gorgon CCS project in Australia has carbon capture capacity of 4 Mtpa, with CO_2 stored in deep saline formation (Global CCS Institute 2024).

Large amounts of flue gas from burning fossil fuels such as coal contain low concentrations (approximately 15%) of CO_2 and other components such as N_2 (Hu and Hao 2020). The cost of low concentration CO_2 capture under current technology is high, which restricts the large-scale application of CO_2 underground storage (McGuire et al. 2016). It has been reported in the literature that transport of CO_2-N_2 mixture in underground porous medium can cause chromatographic partitioning (Bachu and Bennion 2009). This can help separating CO_2 and N_2, leaving CO_2 storage in the formation. High purity N_2 can then be used for energy storage in the form of compressed gas.

This paper is focused on the effect of phase behavior, transport properties, chemical reactions and adsorption on CO_2-N_2 chromatographic partitioning.

Method and/or Theory

Solubility experiments were performed with flue gas with 15 mol% CO_2 and 85 mol% N_2 in formation brine solutions with different salinity and ion compositions. Based on solubility experiments, fractional flow analysis was performed to investigate the effect of solubility and transport properties on CO_2-N_2 chromatographic partitioning (Fig. 1). Numerical simulation models were constructed to investigate the effect of mineral composition and adsorption on chromatographic partitioning.

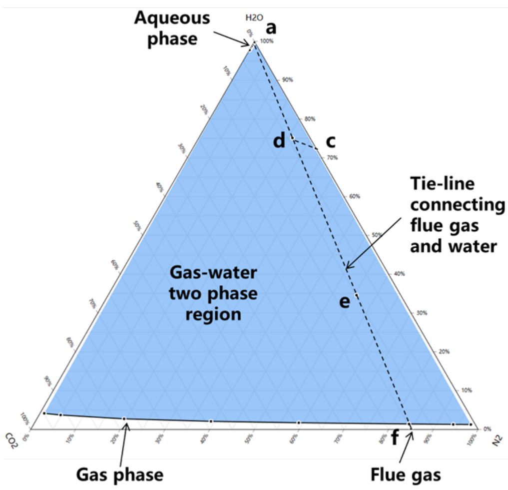

Fig. 1 CO_2-N_2-H_2O ternary diagram (95˚C and 20.7MPa)

Results

Effect of CO_2-N_2 differential solubility: Experimental results show that solubility difference between CO_2 and N_2 decreases with increasing of salinity. Fractional flow analysis shows that the partitioning distance between CO_2 front and N_2 front increases as CO_2-N_2 solubility difference and two-phase flow region increases (Fig. 2). As two-phase flow saturation increases from 0.6 to 0.85, the partitioning distance between CO_2 front and N_2 front increases 3 times at 0.5PVI.

Effect of chemical reaction and adsorption: Numerical simulation results indicate that quartz and calcite have little effect on chromatographic partitioning, however, the presence of olivine can increase partitioning distance. Adsorption difference between CO_2 and N_2 can also potentially increase partitioning distance.

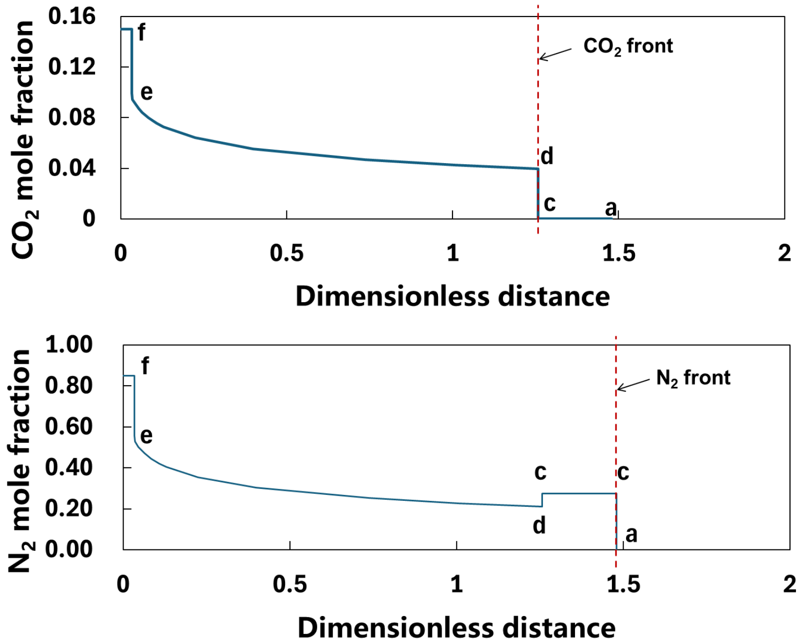

Fig. 2 Fractional flow analysis of CO_2-N_2 chromatographic partitioning

Conclusions

The chromatographic partitioning of CO_2-N_2 is mainly driven by three mechanisms including solubility difference, chemical reaction difference and adsorption difference between CO_2 and N_2, in a natural and spontaneous manner without external energy input. This research presents the feasibility of separating CO_2 and N_2 in saline aquifer, providing a potentially low-cost CO_2 capture technology.

Acknowledgements

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