Investigation of the effect of Zinc Oxide Nano-particles and Cationic Surfactants on Carbon Dioxide Storage capacity

Alireza Bozorgian

Department of Chemical Engineering, Mahshahr Branch, Islamic Azad university, Mahshahr, Iran

ARTICLE INFO

Article history
Submitted: 2020-09-26
Revised: 2020-10-16
Accepted: 2020-10-24
Available online: 2020-11-07
Manuscript ID: AJCB-2009-1064
DOI: 10.22034/ajcb.2021.118942

KEYWORDS
Gas Hydrate
Surfactant
Storage capacity
Nano-particles
Gas concentrations

ABSTRACT

One of the methods of removing, storing, recovering or transferring carbon dioxide (as one of the greenhouse gases) is the use of hydrate formation. In this study, the effect of the presence of zinc oxide nanoparticles and steel trimethyl ammonium bromide (CTAB) surfactant on the amount of mol consumed and carbon dioxide storage capacity between carbon dioxide hydrate and water at different temperatures, pressures and concentrations of the solution was investigated. For this purpose, a laboratory system was developed to perform hydrate formation experiments. Experiments were performed in the pressure range of 20 to 30 bar, temperature range from 275 to 279 degrees Kelvin. Experimental results (for mole consumption and storage capacity) showed that with increasing pressure at constant temperature for pure water, the amount of mole consumed increased and storage capacity increased by 15%. With decreasing temperature at constant pressure (20 bar), the amount of mol consumed increased by 17% and the storage capacity by 19%. Addition of zinc oxide by 0.05 wt% at constant temperature and pressure increased the amount of mol consumed by 14% and storage capacity by 13%. And 0.1% by weight of zinc oxide increases the amount of mol consumed and storage capacity by 26% and 22%, respectively.
**Introduction**

Carbon dioxide is the major responsible for global warming and its production as a result of fossil fuels combustion is increasing [1]. Different methods are recommended to separate this gas from flue gases [2]. One of the technologies that has been proposed for this purpose is based on hydrate formation. In this technology it is suggested that carbon dioxide be extracted and stored in deep sea waters as hydrate. Gas hydrates or clathrate hydrates are non-stoichiometric compounds formed when small gas molecules (guest) are trapped in the cavities of the lattice made by water molecules (host) through hydrogen bonding at low temperatures and high pressures [3]. When a minimum number of cages in the lattice are filled, hydrate crystals will be stabilized [4]. Carbon dioxide (CO$_2$) is the main greenhouse gas that has led to dramatic changes in global warming and climate change [5-8]. The concentration of this gas has increased significantly in recent years and now reaches about 400 ppm [9-14]. Since CO$_2$ is the most important cause of greenhouse effects and global warming, it is very important to control the concentration of CO$_2$ in the Earth's atmosphere [15, 16]. Currently, the focus of global research is to develop new, high-efficiency, low-energy methods for CO$_2$ capture [17-23]. Emission and storage of greenhouse gases is one of the most fundamental environmental issues today [24-29]. One of the methods of separation and storage of carbon dioxide is the use of hydration phenomenon, which has attracted the attention of many researchers [30-34].

**Description of the experiment**

The tuber was first rinsed with water by a continuous rotating system for ten minutes and then rinsed with distilled water. To ensure the exit of air into the tube and water droplets remaining in it, the vacuum pump was used for 5 minutes. 100 cm$^3$ of the solution with concentrations of 0.1 and 0.05 wt% of ready-made zinc oxide nanoparticles. And injected into the tubercle. By setting the refrigerant temperature to the desired temperature and after stabilizing the temperature, CO$_2$ gas was injected with an initial pressure of 20 bar and the
swing stirrer was turned on at a constant speed. With the start of the hydrate formation process and the consumption of carbon dioxide, the system pressure is reduced and temperature and pressure data are stored on the computer at specified intervals. Then, for comparison, the cationic surfactant (CTAB) is added to the system and the results are stored in the data entry system.

**Figure 1.** Schematic of the hydrate device [35].

**Results and Discussion**

**Effect of pressure and temperature on the amount of mol consumed in different concentrations of zinc oxide**

Zinc oxide increases the number of cavities that are ready to receive guest gas molecules, and this helps to consume more gas. In contrast, increasing the temperature reduces the amount of moles of carbon dioxide consumed.

**Figure 2.** The effect of pressure and temperature on the amount of mol consumed in different concentrations of zinc oxide

**Effect of pressure and temperature on the amount of mol consumed at the same concentrations of zinc oxide**

In Figure 3, it can be seen that increasing the temperature still has the opposite effect on the amount of moles of carbon dioxide consumed. As the temperature increases, the amount of mol consumed by carbon dioxide gas decreases and increasing the pressure with the same concentrations of zinc oxide nanoparticles increases the amount of mol consumed.

**Figure 3.** The effect of pressure and temperature on the amount of mol consumed in the same concentrations of zinc oxide
**Effect of pressure and temperature on storage capacity at different concentrations of zinc oxide**

As can be seen in Figure (4), with increasing temperature, the storage capacity decreases due to the calorific value of the hydrate process, but increasing the pressure has a greater effect on increasing the storage capacity than increasing the driving force relative to the oxide concentration.

![Figure 4. Effect of pressure and temperature on storage capacity at different concentrations of zinc oxide](image)

**Effect of pressure and temperature on storage capacity at the same concentrations of zinc oxide**

Figure 5 shows that when working with a constant concentration of additive (zinc oxide nanoparticles), the increase in pressure also increases the storage capacity and the temperature increases the opposite effect.

![Figure 5. Effect of pressure and temperature on storage capacity at the same concentrations of zinc oxide](image)

**Investigation of the effect of surfactant (CTAB) on the amount of mole consumed and storage capacity**

Addition of surfactant to the building for the following reasons and according to the diagrams has a great effect on the amount of moles used and storage capacity: These materials (CTAB) have a hydrophilic end and a hydrophobic end.

![Figure 6. Effect of CTAB and pressure and zinc oxide with different concentrations on storage capacity](image)
Figure 6. Effect of CTAB and pressure and zinc oxide with different concentrations on storage capacity

Effect of CTAB and pressure and zinc oxide with different concentrations on the amount of mol consumed

Figure 7, as in Figure (6), still shows the effect of surfactant on increasing the amount of moles consumed, so that both higher concentrations of zinc oxide nanoparticles and increasing pressure in the presence of surfactant increases the amount of carbon dioxide consumption.

Figure 7. Effect of CTAB and pressure and zinc oxide with different concentrations on the amount of mol consumed

Conclusion

According to the obtained experimental results and Figures (2) to (7), it can be concluded that the experimental results (for mole consumption and storage capacity) showed that with increasing pressure at constant temperature for pure water, the amount of mole consumed is 8% and Storage capacity increased by 15%. With decreasing temperature at constant pressure (20 bar), the amount of mol consumed increased by 17% and the storage capacity by 19%. Addition of zinc oxide by 0.05 wt% at constant temperature and pressure increased the amount of mol consumed by 14% and storage capacity by 13%. And 0.1% by weight of zinc oxide increases the amount of mol consumed and storage capacity by 26% and 22%, respectively.

Conflict of Interest

No conflict of interest was declared by the author.

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HOW TO CITE THIS ARTICLE
DOI: 10.22034/ajcb.2021.118942
URL: http://www.ajchem-b.com/article_118942.html