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*Original Research Article*

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

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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

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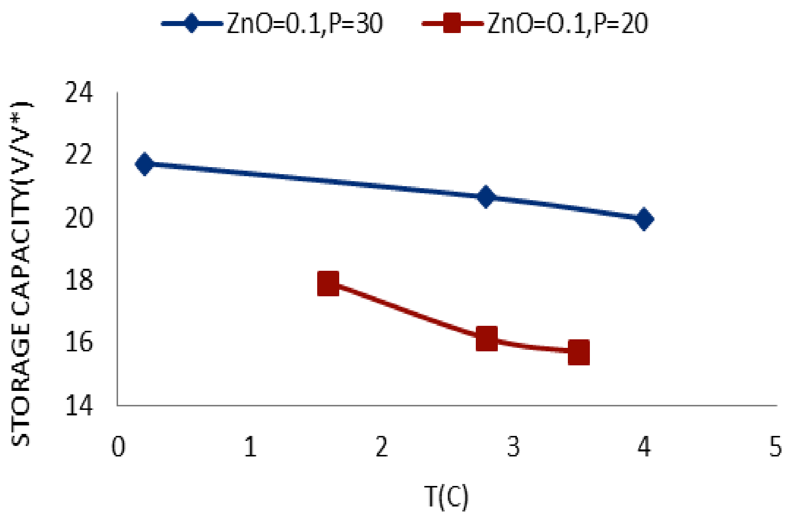
**GRAPHICAL ABSTRACT**




## 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.

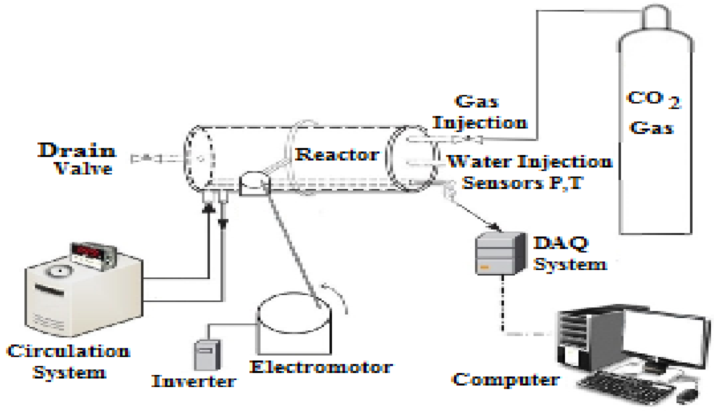



**Figure 1.** Schematic of the hydrate device [35].

## 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.

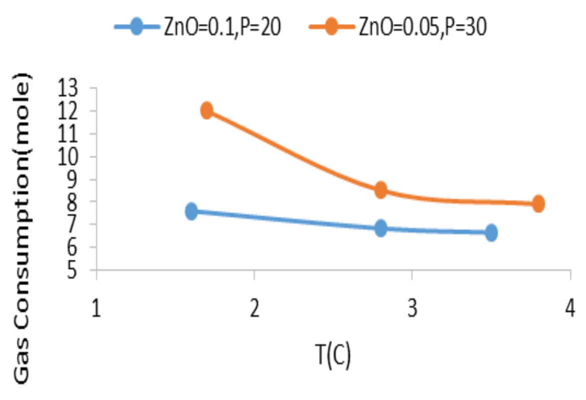



**Figure 2.** The effect of pressure and temperature on the amount of mol consumed in different concentrations of zinc oxide

### 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.

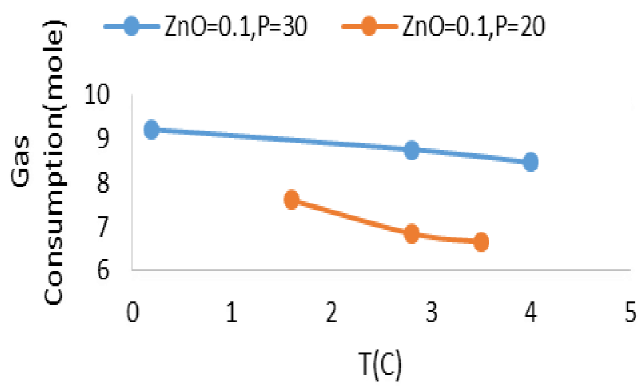



**Figure 3.** The effect of pressure and temperature on the amount of mol consumed in the same concentrations of zinc oxide

**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.

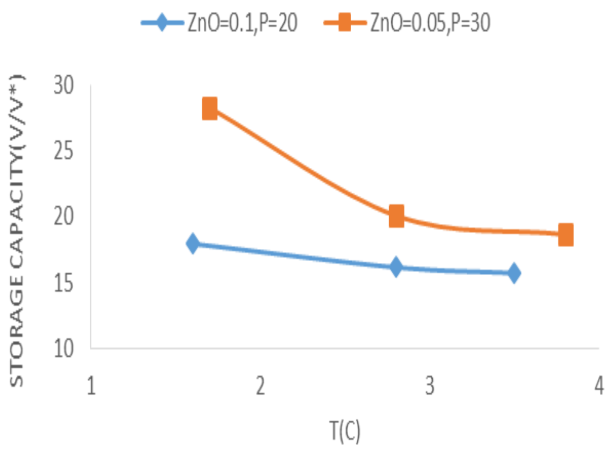



**Figure 4.** Effect of pressure and temperature on storage capacity at different concentrations of zinc oxide

***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.

**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.

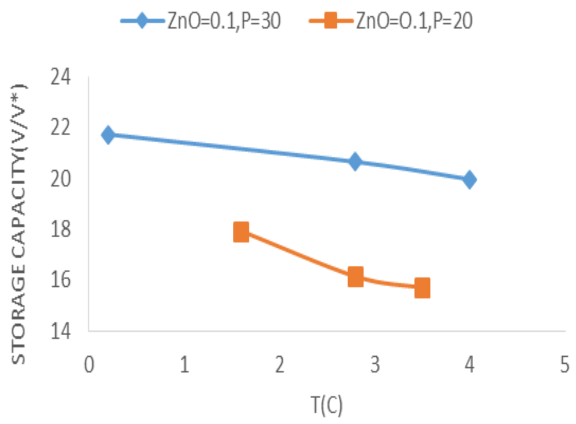



**Figure 5.** Effect of pressure and temperature on storage capacity at the same concentrations of zinc oxide

The best place for these materials to form hydrates is the liquid-gas interface. Because the hydrophilic head tends towards water and the hydrophobic head tends towards gas. Due to the bond between the hydrophilic head and the hydrophobicity of these materials with water and gas, the interfacial tension between water and gas is reduced and the penetration of gas into the water is faster and the rate of hydrate formation is increased.

Carbon monoxide has a high solubility in water. The presence of surfactants and foam created by them can sometimes increase the resistance of gas penetration into the liquid and reduce the solubility of $CO_2$. This assumption is strengthened when the rate of hydrate formation decreases further with increasing concentration of the solution.

Effect of CTAB and pressure and zinc oxide with different concentrations on storage capacity Figure 6 shows that the addition of a surfactant has a significant effect on the amount of storage and increasing the concentration of zinc oxide nanoparticles increases this effect and increases the storage capacity as the pressure increases.

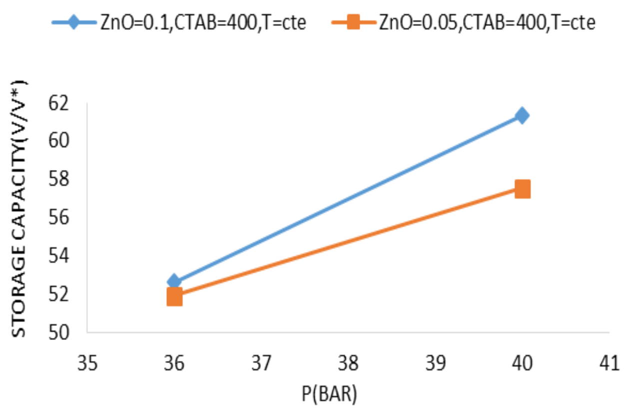



**Figure 6.** Effect of CTAB and pressure and zinc oxide with different concentrations on storage capacity

***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.

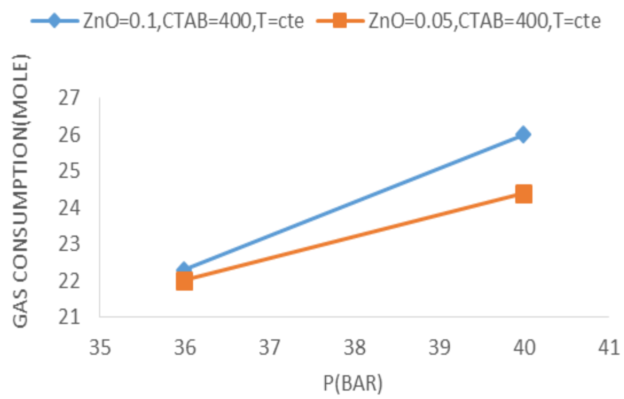



**Figure 7.** Effect of CTAB and pressure and zinc oxide with different concentrations on the amount of mol consumed

## 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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