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Experimental Study of CO_2 Absorption Capacity Enhancement of Fe_2O_3 and SiO_2 Nanofluids and their Stability Studies

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Abstract

The major focus of this research work is the use of DI water-based Fe_2O_3 and SiO_2 nanofluids for CO_2 absorption using a specially made absorption cell, and stability of nanofluids by using UV- spectroscopy and Zeta potential. Nanofluids concentrations considered are 0.03, 0.06, 0.09 and 0.12 wt%. The experiments are conducted for initial pressures of 5, 7.5 and 10 bar inside the absorption cell. The absorption cell is made of stainless steel so that it can withstand high pressures. The temperature is kept constant at 300 K throughout. The effect of types of nanoparticles, initial pressure and concentration of nanofluid on CO_2 absorption capacity has been discussed. The stability tests were conducted right after the preparation of the nanofluid and 4 weeks after preparation. From the experimental studies, it was found that there is a CO_2 absorption capacity enhancement of 21.03%, 22.95% and 20.59% at 5, 7.5 and 10 bar, respectively, at 0.06 wt% of Fe_2O_3 nanofluid as compared to the base fluid. For SiO_2 nanofluid, the CO_2 absorption capacity was enhanced by 10.34%, 18.67% and 13.61% at 5,7.5 and 10 bar, respectively, at 0.09 wt% as compared to the base fluid. 0.06 wt% and 0.09 wt% are the optimum concentrations for Fe_2O_3 and SiO_2 nanofluids, and zeta potential studies have shown that these nanofluids are highly stable at the optimum concentration. It was observed that at equilibrium, the adsorption of CO_2 gas at the nanoparticle surface resulted higher absorption capacity of nanofluids.

Major Findings: *The CO_2 absorption was higher at higher pressure. The increase in concentration of nanofluids increased the CO_2 absorption capacity of both nanofluids. The stabilities of the nanofluids were superior even after 4 weeks of preparation.*

Keywords: *CO_2 Absorption, Fe_2O_3, SiO_2, Stability, Zeta Potential*

1.0 Introduction

Due to the higher energy consumption in the last few decades, the emission of CO_2 into the environment has led to higher environmental pollution. This is due to the large volumes of carbon dioxide released into the atmosphere. As an acidic gas, CO_2 poses a threat to the ozone layer and plays a significant role in accelerating global warming[1,2]. In an effort to protect the ozone layer and the environment, many nations have committed to significantly cutting down their carbon dioxide emissions, aiming to achieve net-zero levels by the year 2035. In this regard, several governments have met every year to implement several technologies either to capture CO_2 or produce renewable energy so that CO_2 emissions will be negligible. The prominent technologies to capture CO_2 are CO_2 capture with a solvent. The solvents could be water, NaCl solution, nanofluids, nanoparticles and alkaline amine solutions[3–5]. Nanoparticles are being used in solvents due to their higher surface area, so that there will be an enhancement

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in absorption. In reducing the CO_2 emissions, the Carbon Capture and Storage (CCS) method has been instrumental in addressing carbon emissions[1]. Different technologies exist for CO_2 capture, such as absorption[6], adsorption[7], cryogenic technique and hollow fibre membrane technology[8,9]. Bubble column method, Packed bed column, direct contact method, thermostatic reactor, etc, are the different available methods used for CO_2 absorption using solvents[10].

Several experimental studies were conducted using a packed bed column to evaluate the absorption performance of several nanofluids. Experiments were conducted to analyse the performance of CO_2 absorption by water-based TiO_2 nanofluid in a packed bed column. Experiments on the counterflow condition of CO_2 gas and TiO_2 nanofluid were also conducted. The effect of the flow rate of gas and nanofluid concentration in the experimental setup of the packed bed absorption column has been studied. 30 LPH, 60 LPH and 90 LPH of the flow rates of gas were used with 0.5 to 3.0 vol%. The optimum absorption was taking place at 3.0 vol%[11]. For the first time, a study using artificial neural networks was carried out to build a model for the prediction of CO_2 absorption performance of nanofluids in a packed bed column. A 6-input ANN model was used to predict CO_2 absorption by water-based SiO_2, Al_2O_3, Fe_3O_4 and TiO_2 nanofluids. Later, other base fluids considered in the ANN study are diethanolamine (DEA) solution, sulfinol and propylene carbonate. The mean square error was 0.0000236, the mean absolute error was 0.326, and the correlation coefficient was 0.9996 for all data. The results have shown a better accuracy and performance of the ANN model for the prediction of CO_2 absorption[12]. In another study, a rotating packed bed column has been used. Al_2O_3, SiO_2 and Fe_2O_3 nanofluids were used to evaluate the absorption of CO_2 into the fluids. It was found that Fe_2O_3 nanofluids were effective compared to other nanofluids. 40 nm nanoparticles were effective compared to 20 nm nanoparticles[13]. The correlation was the microconvection effect of nanoparticles and surface tension[14]. Another technology is CO_2 absorption by using a Hollow Fibre Membrane Contactor (HFMC) experimental setup for CNT[8,15,16] and it found that the results showed that CO_2 absorption was enhanced up to 34% at 0.05 wt% CNT nanofluid. It was reviewed that characteristics of different HFMC systems were compared to study their advantages and disadvantages[17]. Thermostatic reactor is another method which is used to measure the absorption capacity of a solvent, in which a stirrer is used to keep the nanoparticles uniformly in the base fluid[18,19]. Such experiments were conducted for SiO_2, TiO_2 and Al_2O_3 nanofluids at different concentrations. The base fluid used was Methyldiethanolamine (MDEA). It was found that TiO_2 showed a better CO_2 absorption rate as compared to other nanofluids. As the base fluid is an amine solution, the results have shown that the absorption of CO_2 of the nanofluid increases as the organic amine concentration increases[20].

CO_2 absorption using the direct contact method has been used to evaluate the absorption capacity of water and amine-solutions based CNT, Al_2O_3, Fe_3O_4 and SiO_2 nanofluids[5]. SiO_2 and Al_2O_3 are hydrophilic and have been shown to increase CO_2 absorption capacity by 21% and 18%, respectively. At 0.02 wt%, Fe_3O_4 and CNT nanofluids have enhanced CO_2 absorption by 24% and 34%, respectively. Fe_2O_3 and CNT are hydrophobic. CNT nanofluid is more efficient for methyldiethanol amine solution as compared to diethanol amine solution, and is found to enhance the enhancement of absorption capacity by 23%. It is to be noted that, in equilibrium conditions, gas adsorption on the nanoparticles' surface increases the absorption capacity of nanofluids[21]. The absorption experiment was conducted in a thermostatically stirred cell in which the base fluid is propylene carbonate, and TiO_2 nanoparticles are used, and a theoretical model has been developed for the same[22]. Both results were compared. The impact of concentration and nanoparticle size on CO_2 absorption was evaluated. Size of the particle plays a crucial role in the CO_2 absorption, and the smaller the nanoparticles, the higher the surface area, and this leads to higher CO_2 absorption[23,24]. CO_2 absorption by Al_2O_3 nanoparticles was conducted[25,26] in NaCl solution in a bubble column with a concentration of 0.005 to 0.1 vol%. It was observed that 0.01 vol% is the optimum concentration. CO_2 absorption was enhanced by 11%, 12.5% and 8.7% at 30, 20 and 10 ^{0}C, respectively. It was reported that the stability of nanoparticles will not be high in NaCl solution[27]. UV Vis and Zeta potential tests were used to measure the stability of Al_2O_3 and SiO_2 nanofluids. These highly stable nanofluids were used later in the application of heat and mass transfer[28]. It was found that the Al_2O_3 nanofluids have shown better stability after

preparation and 4 weeks after preparation. It was seen from the results zeta potential[29] for Al_2O_3 at 0.06 wt% after preparation was -42.3 mV, and 4 weeks after preparation was -60.7 mV[30].

A few sets of experiments are conducted for Fe_3O_4 water-based nanofluids using a packed column[31-33] and a packed column which is equipped with a magnetic field. CO_2 absorption rate has been enhanced by 12% for Fe_3O_4 when compared with pure water. Because of the magnetic properties of Fe_3O_4 nanoparticles, the magnetic field has a positive effect on the CO_2 absorption performance of the nanofluid[34].

A review has been carried out to find out the reasons behind CO_2 absorption enhancement, A few reasons are the grazing effect (shuttle effect[35,36]), hydrodynamic effect and micro convection effect[4,5,37]. The shuttle mechanism and micro-convection mechanisms were the causes of the increased CO_2 absorption. The effect of nanofluid concentration and temperature upon CO_2 absorption was explored in a constant temperature stirred quasi-static cell for SiO_2 and ZnO nanofluids. The CO_2 absorption has been enhanced by 14% and 7%, respectively[38], by SiO_2 and ZnO at 0.1 wt%. It was also observed that an increase in temperature causes the absorption to decrease[39]. It was widely discussed about the application of nanofluids in mass transfer applications[40]. The stability of nanofluids plays a crucial role in the enhancement of heat and mass transfer or absorption performance of nanofluids. Methods to evaluate the stability of nanofluids are UV-spectroscopy and Zeta Potential. Based on the stability of nanofluid theory, a higher value of zeta potential results in higher solubility of particles in the suspension[41–44]. It is cautioned that nanofluids that have a zeta potential of 5 mV or less are unstable and agglomerate. Nanofluids with more than 60 mV have exceptional stability, while those with a zeta potential of more than 30 mV have superior stability. Nanofluids with 20 mV of zeta potential have limited stability. The enhancement of absorption performance will be higher when the stability of nanofluids is high. These tests help in determining the enhancement mechanism. In this research work, the CO_2 absorption capacity of Fe_2O_3 and SiO_2 nanofluids has been quantified using the direct absorption method at 0.03, 0.06, 0.09 and 0.12 wt% concentrations and also at 5, 7.5 and 10 bar initial pressure.

2.0 Materials

The SEM studies were conducted for Fe_2O_3 and SiO_2 nanoparticles, and Figure 1 and Figure 2 show the SEM images for Fe_2O_3 and SiO_2 nanoparticles, respectively. The properties of Fe_2O_3 and SiO_2 nanoparticles are shown in Table 1. It can be observed that the smaller the nanoparticles, the higher the surface area. Nanoparticles

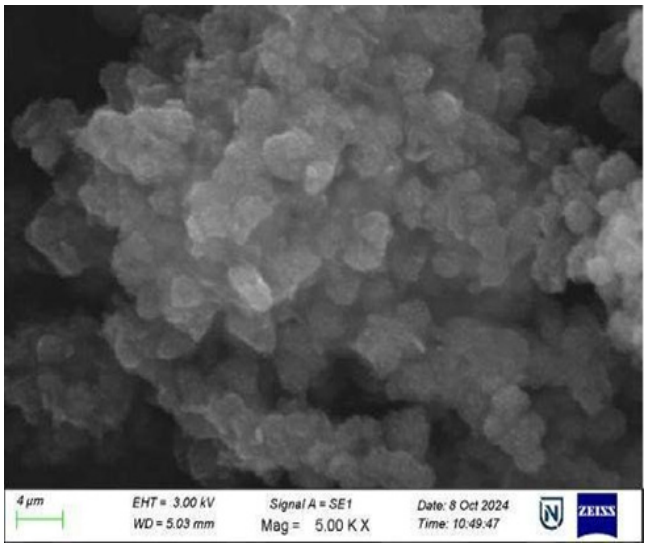


Figure 1. SEM of Fe_2O_3 nanoparticles.

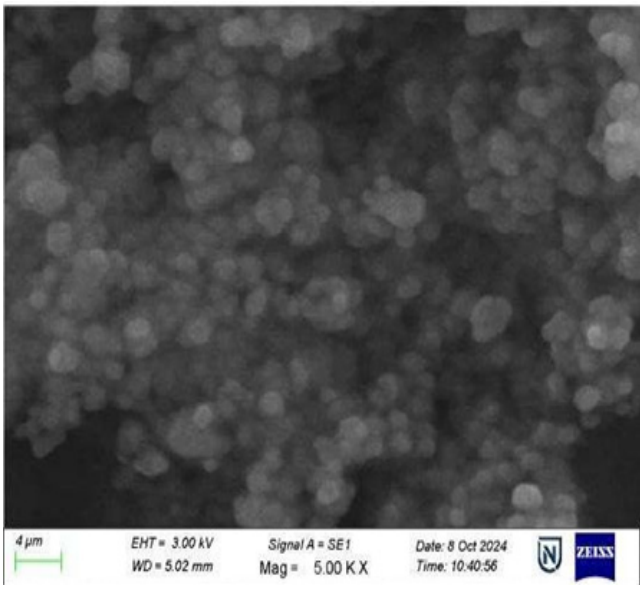


Figure 2. SEM of SiO_2 nanoparticles.

are purchased from Sigma-Aldrich, and the base fluid is DI water. Bangalore Gas Agencies, Bengaluru, supplied CO_2 gas of 99% purity and 1% humidity for the experiments on CO_2 absorption. The pressure inside the cylinder was 50 bar. From the SEM images, it can be observed that the size of nanoparticles was 30-60 nm and 20-50 nm for Fe_2O_3 and SiO_2 nanoparticles, respectively.

Table 1. Properties of SiO_2 and Fe_2O_3 nanoparticles

Properties	Fe_2O_3	SiO_2
Purity	99.9%	99%
Average Particle Size (nm)	30-60	20-50
Molecular Weight (g/mol)	159.69	231.53
Bulk Density (/cm^3)	0.69	0.27
SSA (m^2/g)	80-100	175-200
Morphology	Spherical	Spherical

2.1 Preparation of DI Water-Based Fe_2O_3 and SiO_2 Nanofluids

After weighing right amount of nanoparticles was added to 120 mL DI water as per the concentration. The solution is magnetically stirred for about 30 min at 930 rpm. It was followed by 90 min of ultrasonication (20 kHz, 400W) to distribute the nanoparticles uniformly in the base fluid. The stirring has been shown in Figure 3. The samples of Fe_2O_3 and SiO_2 nanofluids at 0.03, 0.06, 0.09 and 0.12 wt% are shown in Figure 4 and Figure 5 Respectively. The SiO_2 nanoparticles are hydrophilic, and there is no need to add surfactant to disperse the nanoparticles in DI water uniformly during preparation. Whereas Fe_2O_3 nanoparticles are hydrophobic, the particles repel water



Figure 3. Stirring.

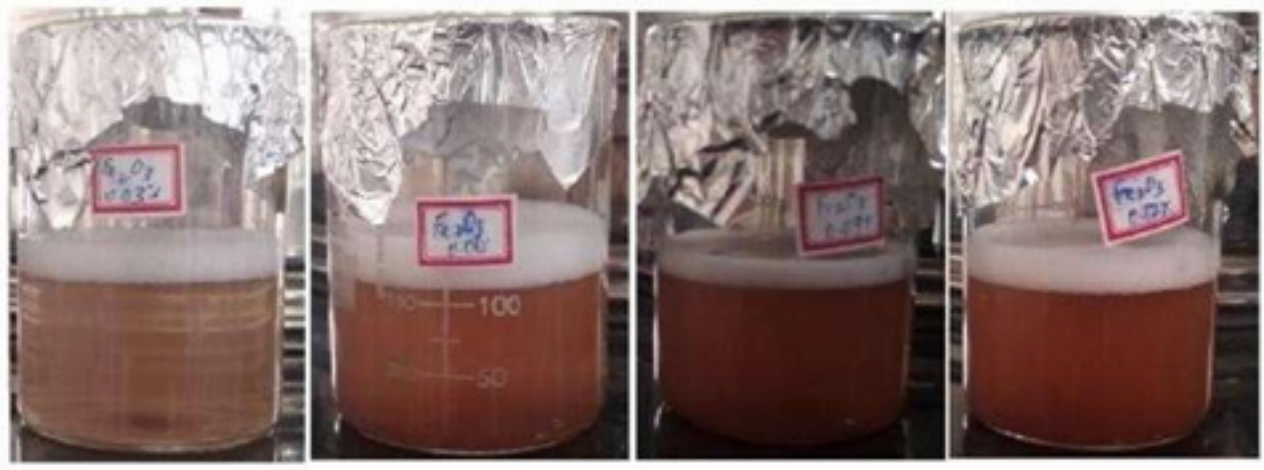


Figure 4. DI water-based Fe_2O_3 nanofluid.

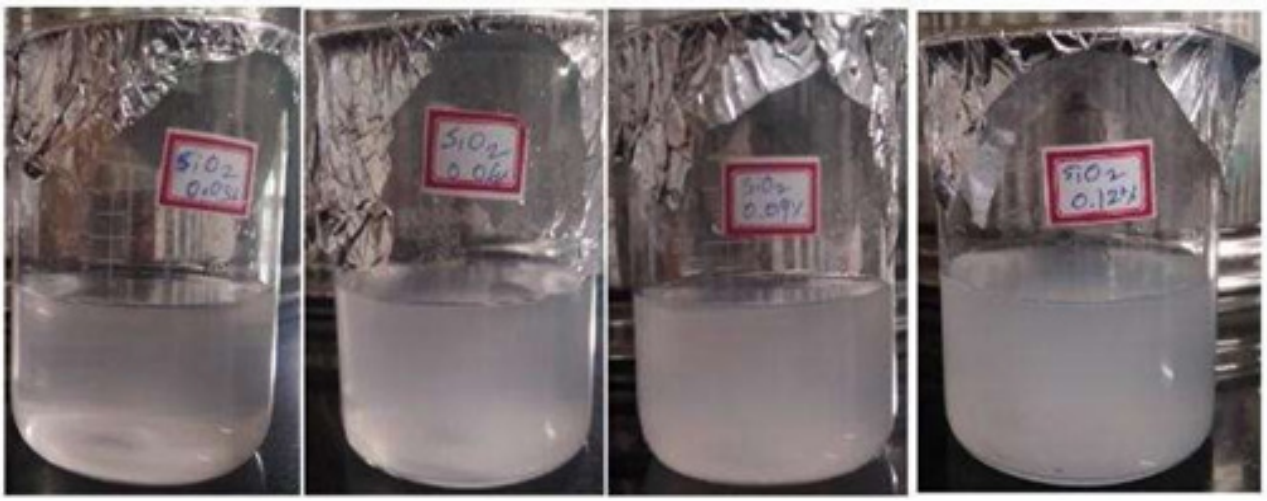


Figure 5. DI water-based SiO_2 nanofluid.

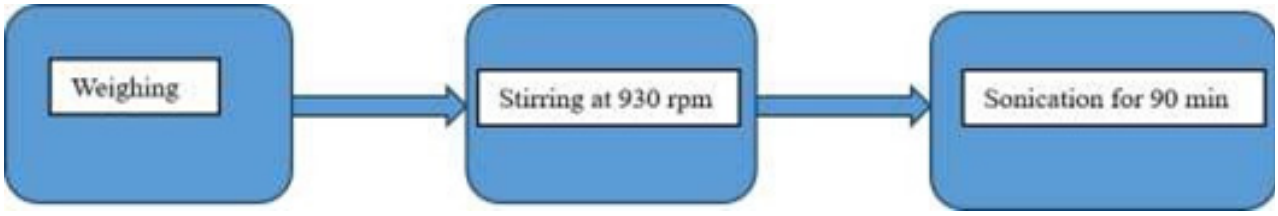


Figure 6. Preparation of Fe_2O_3 and SiO_2 nanofluids.

molecules, and it is difficult to disperse nanoparticles in DI water. There is a need to add surfactant to disperse nanoparticles during preparation.

Hence, Sodium Dodecyl Benzene Sulfonate (SDBS) has been used as the surfactant at a ratio of 1:1 with that of nanoparticles. It was also experimented with SDS and Gum Arabic as surfactants for Fe_2O_3 nanofluids, but the stability of Fe_2O_3 nanofluid was poor as compared to the stability of the nanofluid when SDBS was used as surfactant. The stability of the nanofluid plays a crucial role in the absorption capacity experiment. If no surfactant is added, all the Fe_2O_3 nanoparticles will accumulate at the bottom of the vessel. Such a nanofluid cannot be used for any application. Figure 6 Shows the step-by-step procedure for the preparation of nanofluids.

3.0 Methodology and Experimentation

The research employed a direct contact methodology. A 316 L stainless steel absorption cell, chosen for its ability to endure high pressures, was utilised. The cell has a capacity of 300 cc, with 120 cc allocated for the nanofluid and the remaining 180 cc for CO_2 gas above

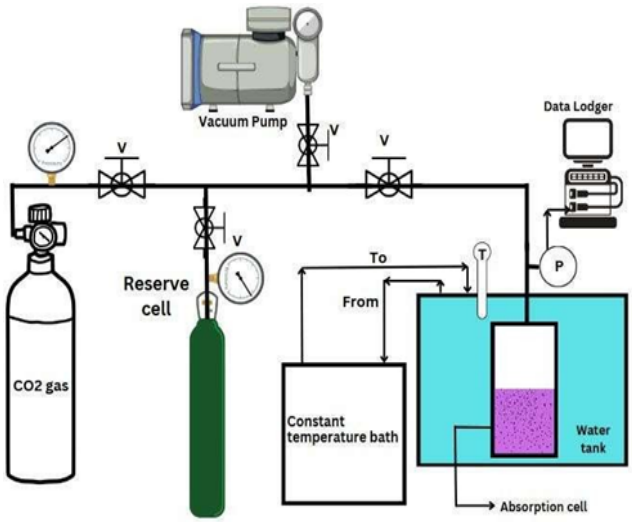


Figure 7. Experimental setup for the direct contact method.

the nanofluid. The experimental setup is schematically depicted in Figure 7. A Vacuum pump was employed to eliminate atmospheric air from the nanofluid's surface within the absorption cell. A reserve cell was used to store CO_2 gas, pressurised to 25 bar from the main cylinder, before being introduced into the absorption cell. The CO_2 gas used had a purity of 99.99%. To ensure the integrity of the setup, a leak test was conducted using a soap solution at each joint, confirming that only the absorption of CO_2 would lead to a pressure drop. The absorption cell used is capable of withstanding elevated internal pressures. A pressure transducer was connected to the cell to monitor pressure changes periodically. To maintain a consistent temperature during the absorption process, a water bath was utilised, with the temperature stabilised at 300 K.

3.1 Calculations

Several moles of CO_2 gas absorbed by a nanofluid in a specifically made absorption cell may be used to determine its CO_2 absorption capability. The pressure within the absorption cell drops as CO_2 is absorbed into the nanofluid. The number of moles of CO_2 being absorbed is computed using pressure fluctuation. The amount of CO2 being absorbed into the nanofluid per unit mass of nanofluid is provided by Equation (1). It is nothing more than the nanofluid's absorption capability during the allotted period.

$$\alpha = \frac{V_g}{R * V_{liq} * \rho_{liq} * 300}\left[\frac{P_0}{Z_0} - \frac{P_t}{Z_t}\right] \quad \text{mol/kg} \tag{1}$$

Z is the CO_2 gas compressibility factor, and the Redlich–Kwong equation of state is used to calculate it. The relationship between volume, temperature, and pressure is provided when the temperature is higher than the critical temperature. CapΔn = Moles of CO_2 absorbed, α = Absorption capacity of nanofluid, Vg = Volume of gas in absorption cell, $Vliq$ = Volume of nanofluid in absorption cell, $P0$ = Initial pressure of CO_2 in absorption cell, Pt = Pressure at different intervals of time $Z0$ and Zt = Compressibility factor initially and at different intervals of time, R = Universal gas constant, ρliq = Density of nanofluid, RAI = Relative absorption Index, nf = Nanofluid, w = DI water. Equation (2) provides the Relative Absorption Index (RAI), which shows how much better the absorption performance of the nanofluid is than that of DI water. Repeatability was ensured by conducting experiments repeatedly.

$$RAI = \frac{\alpha_{nf} - \alpha_w}{\alpha_w} \tag{2}$$

3.2 Uncertainty Analysis

To determine the repeatability, each experiment trial was carried out at least three times. In temperature, volume, and pressure measurements, the uncertainties (u) are u(T)=0.5 K, u(V)=0.0000005 m^3, and u(P)=5000 Pa, in that order. Equation (3) is used to compute the absorption uncertainty. Since the process is completely experimental, an uncertainty analysis is required to validate the results and consider the uncertainty involved in each component of thesetup.

$$U(\alpha_n^{nf})^2 = \left(\alpha_n^{nf}\frac{u(V_{gas})}{V_{gas}}\right)^2 + \left(\alpha_n^{nf}\frac{u(V_{liq})}{V_{liq}}\right)^2 + \left(\alpha_n^{nf}\frac{u(T)}{T}\right)^2 + \left(\frac{u(P_0)}{RTZ_0}\right)^2 + \left(\frac{u(P_n)}{RTZ_n}\right)^2 \tag{3}$$

$U(\alpha nf) = \pm 0.002906$ Mol/kg is the uncertainty for the absorption.

4.0 Results and Discussion

In the current study, DI water-based nanofluids containing SiO_2 and Fe_2O_3 are prepared at varying concentrations. The absorption performance is assessed by monitoring the initial pressure and the pressure at specific time intervals within the absorption cell. The experiment for each nanofluid sample is conducted over 150 minutes. The absorption performance of the nanofluids is then compared to that of the base fluid, DI water, under identical conditions. To quantify this comparison, the Relative Absorption Index (RAI) is employed.

4.1 Effect of nanoparticle concentration on absorption capacity

Absorption performance of nanofluids is affected by the concentration of nanoparticles. In this research work, the absorption capacity was tested for nanofluids with

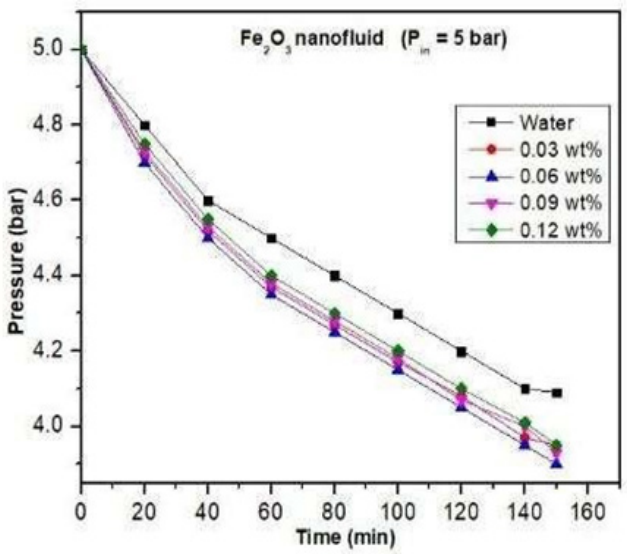


Figure 8. Pressure vs time for Fe_2O_3 nanofluid at 5 bar.

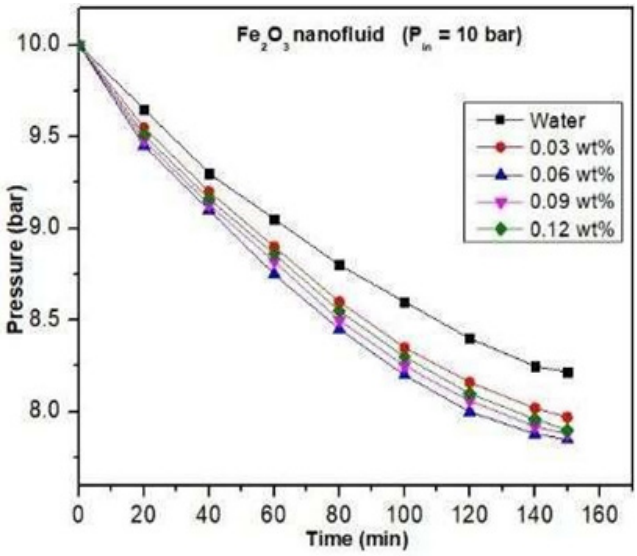


Figure 10. Pressure vs time for Fe_2O_3 nanofluid at 10 bar.

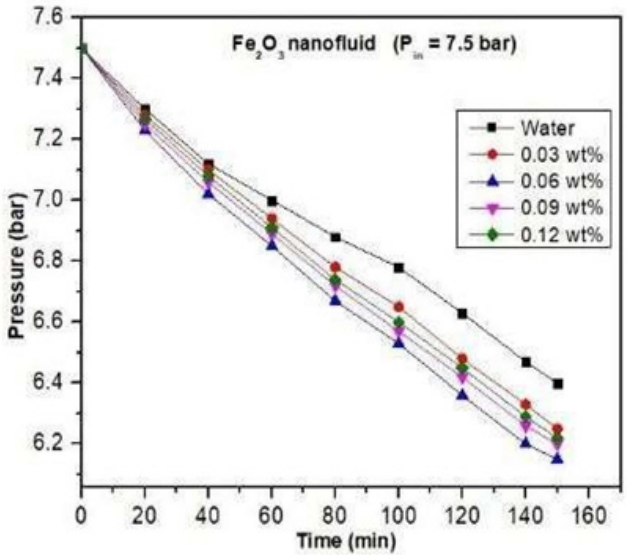


Figure 9. Pressure vs time for Fe_2O_3 nanofluid at 7.5 bar.

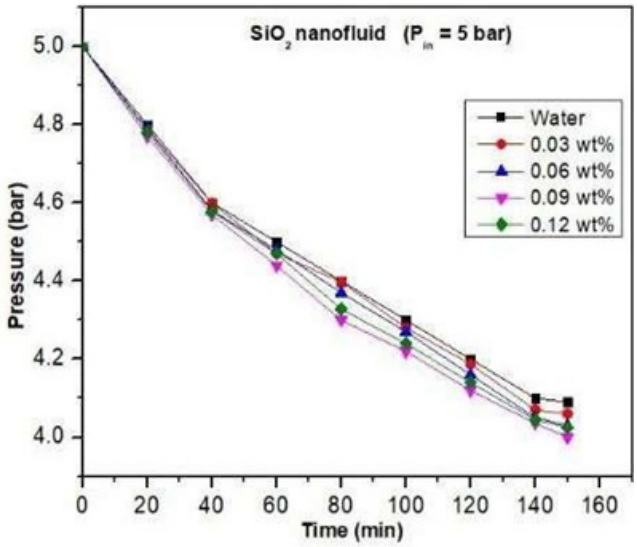


Figure 11. Pressure vs time for SiO_2 nanofluid at 5 bar.

concentrations of 0.03, 0.06, 0.09 and 0.12 wt% for Fe_2O_3 and SiO_2 nanofluids. Figure 8, Figure 9 and Figure 10 Represent pressure variation at different intervals of time during the absorption process at 5, 7.5 and 10 bar initial pressures, respectively, for Fe_2O_3 nanofluid. From this, it can be observed that the rate of pressure drop at the beginning is more than the pressure drop at the end of the absorption process. The more the absorption of CO_2 into the nanofluid, more will be the pressure drop. Figure 11, Figure 12 and Figure 13 Show the variation of pressure with time for SiO_2 nanofluid at 5, 7.5 and 10 bar initial pressure, respectively. A similar trend concerning pressure change for SiO_2 nanofluid can be seen as that of Fe_2O_3 nanofluid.

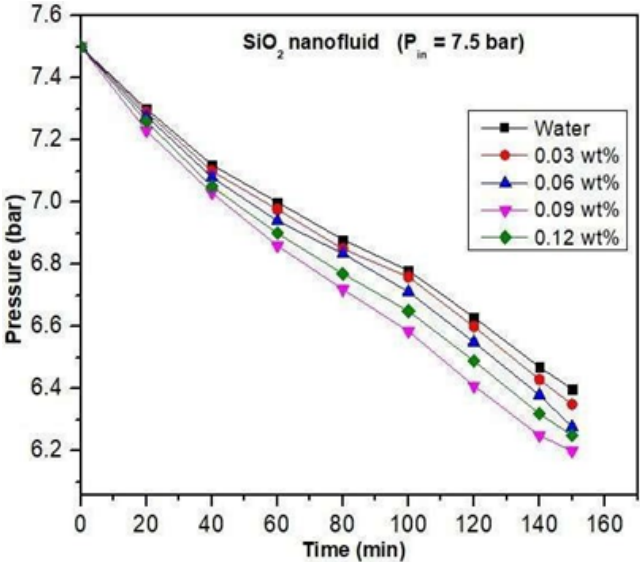


Figure 12. Pressure vs time for SiO_2 nanofluid at 7.5 bar.

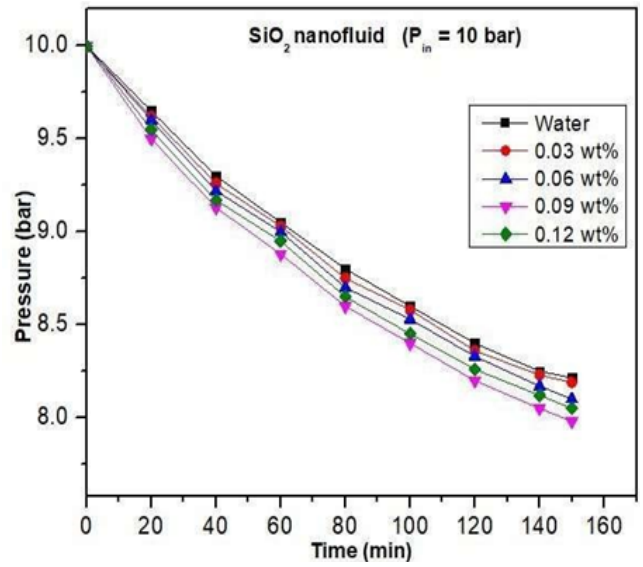


Figure 13. Pressure vs time for SiO_2 nanofluid at 10 bar.

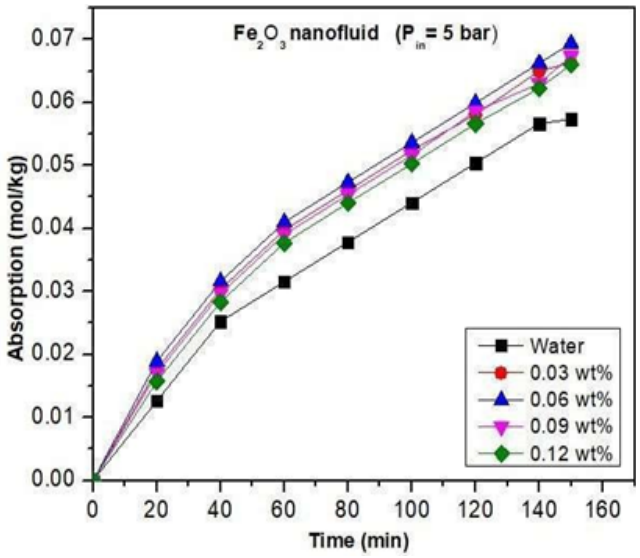


Figure 14. Absorption for Fe_2O_3 nanofluid at 5 bar.

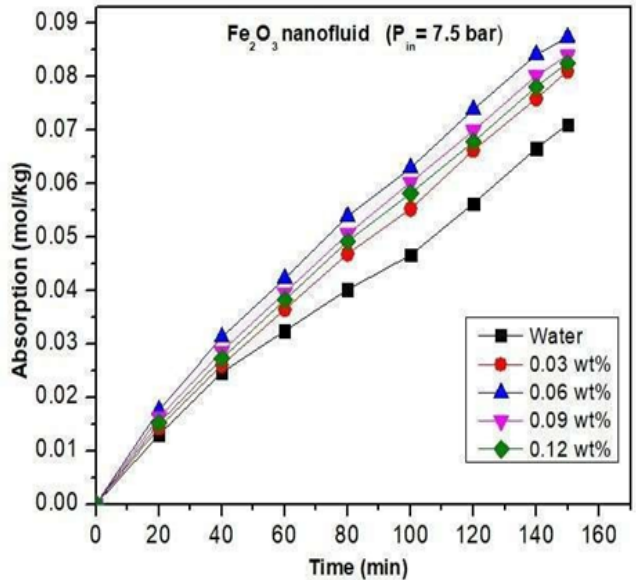


Figure 15. Absorption for Fe_2O_3 nanofluid at 7.5 bar.

Figures 14, 15 and Figure 16 represent absorption variation at different intervals of time during the absorption process at 5, 7.5 and 10 bar initial pressures, respectively, for Fe_2O_3 nanofluid. Similarly, Figure 17, Figure 18 and Figure 19 show the absorption with time at 5, 7.5 and 10 bar initial pressure, respectively, for SiO_2 nanofluid. It was seen that the absorption capacity increases with an increase in the concentration of the nanofluid. But if there is a further increase in concentration, there will be a decrease in the absorption of CO_2 by the nanofluid. That concentration is called the optimum concentration. The optimum concentration for Fe_2O_3 nanofluid is 0.06 wt%, and for SiO_2 nanofluid is 0.09 wt%. It can be seen that higher absorption performance is achieved by Fe_2O_3 nanofluid as compared to SiO_2 nanofluid.

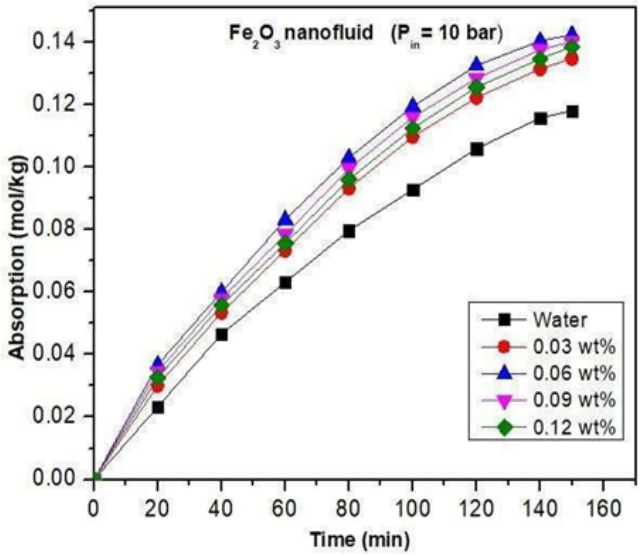


Figure 16. Absorption for Fe_2O_3 nanofluid at 10 bar.

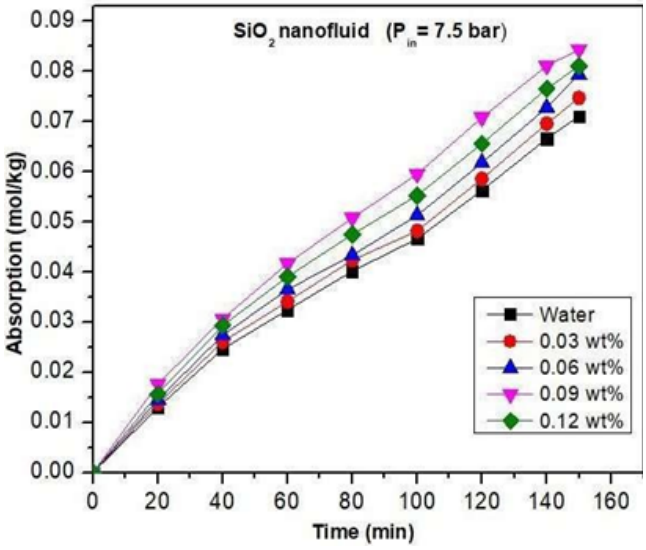


Figure 18. Absorption for SiO_2 nanofluid at 7.5 bar.

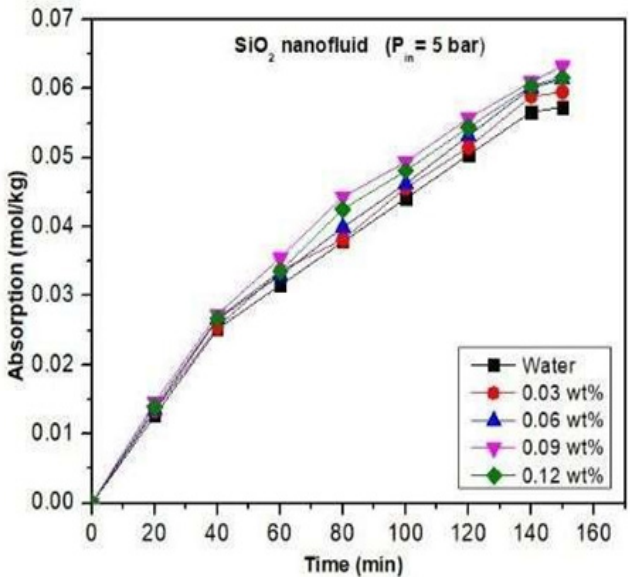


Figure 17. Absorption for SiO_2 nanofluid at 5 bar.

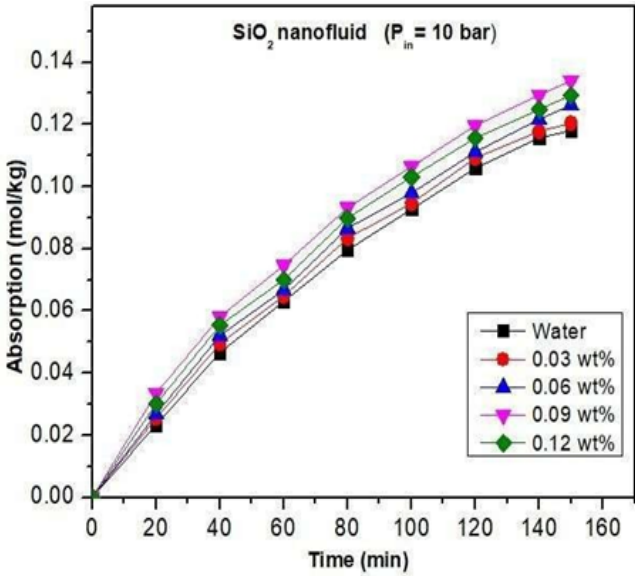


Figure 19. Absorption for SiO_2 nanofluid at 10 bar.

Relative Absorption Index (RAI) is an index used to compare the absorption capacity of a nanofluid with that of the base fluid. Figure 20, Figure 21 and Figure 22 show RAI for Fe_2O_3 and SiO_2 nanofluids at 5, 7.5 and 10 bar pressures, respectively. It can be seen that for Fe_2O_3 nanofluid, the absorption capacity increased by about 21.03%, 22.95% and 20.59% as compared to DI water at 5, 7.5 and 10 bar initial pressure, respectively. For SiO_2 nanofluid, the absorption capacityincreased by about 10.31%, 18.67% and 13.61% as compared to DI water at 5, 7.5 and 10 bar initial pressure, respectively. The stability of the nanofluid plays a big role in the absorption rate of the nanofluid. The increase in CO_2 absorption into the nanofluids is due to the shuttle effect, grazing effect, micro convection effect and Brownian motion of nanoparticles in the base fluids.

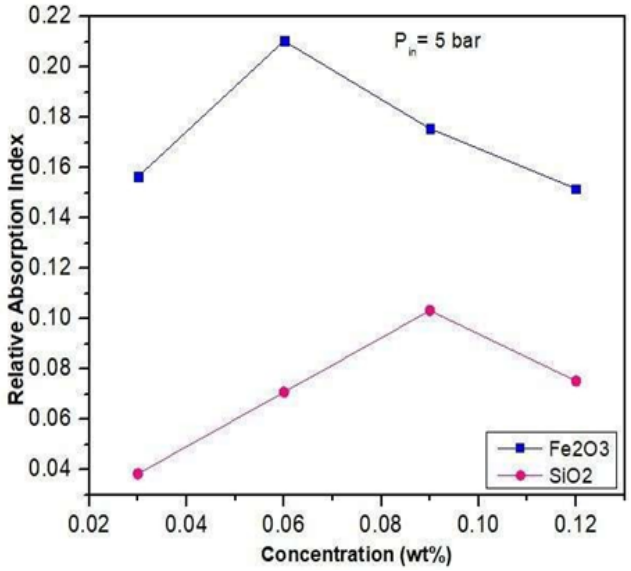


Figure 20. RAI at 5 bar.

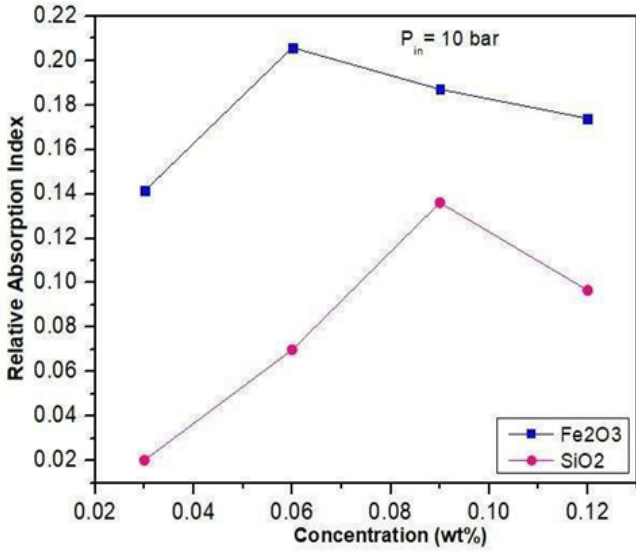


Figure 22. RAI at 10 bar.

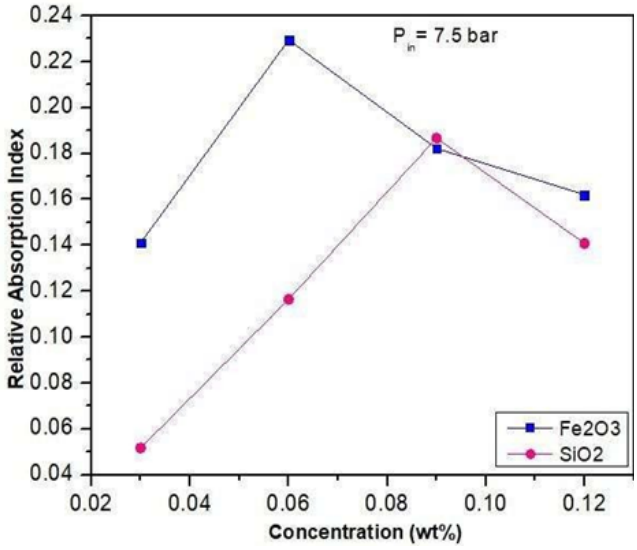


Figure 21. RAI at 7.5 bar.

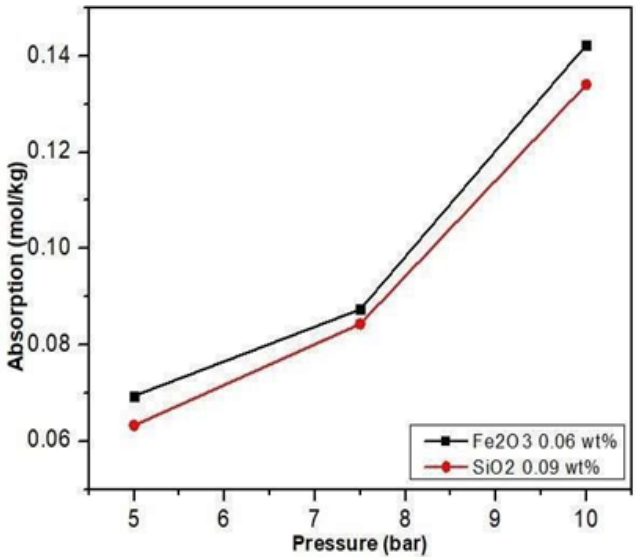


Figure 23. CO_2 absorption at different pressures.

4.2 Effect of Initial Pressure on Absorption Capacity

The initial pressure inside the absorption cell also affects the nanofluid's absorption capacity. Figure 23 Shows the absorption capacity of Fe_2O_3 and SiO_2 nanofluid at 5, 7.5 and 10 bar initial pressure at their optimum concentration of 0.06 wt% and 0.09 wt%, respectively. It can be understood that the higher the pressure, the higher the absorption capacity. It is because the nanofluid's Brownian motion will be higher at higher pressure, which leads higher absorption capacity of CO_2 into the nanofluid.

4.3 Stabilities of Nanofluids

The stabilities of nanofluids play an important role in heat and mass transfer applications. To get better results



Figure 24. Carrying out the stability test in the Malvern Zetasizer.

Table 2. Zeta potential

Nanofluid	Concentration	After preparation (mV)	After the 4th week of preparation (mV)
Fe_2O_3	0.03 wt%	-38.6	-36.3
	0.06 wt%	-39	-37.5
	0.09 wt%	-40.4	-38.1
	0.12 wt%	-43.5	-39.4
SiO_2	0.03 wt%	-44.5	-41.1
	0.06 wt%	-51.2	-48.7
	0.09 wt%	-50.4	-48.5
	0.12 wt%	-51.2	-47.9

of improved mass transfer, the stability of nanofluids should be high. Hydrophilic nanoparticles show better stability as compared to hydrophobic nanoparticles without surfactant. However, to get better stability for hydrophobic nanoparticles, a good surfactant should be added 1:1 as the of nanoparticles. As the nanoparticles are suspended in the base fluid, the lower stability indicates that the nanoparticles are accumulated at the bottom of the vessel within a shorter time. Whereas the higher stability indicates that the nanoparticles are evenly distributed in the base fluid for a longer duration. The lower stability limits the Brownian motion of nanoparticles. In this research, the stability of nanofluids has been studied using by Zeta potential method. Malvern Model equipment with specification of accuracy 0.2, range: 0.3 nm-10 microns, measurement angles: 13°+173°, Zeta potential range: > ±500mV. Instruments measure zeta potential using Electrophoretic Light Scattering (ELS), specifically through a technique known as Laser Doppler Electrophoresis. Figure 24 Shows the image of equipment used for measuring the stability of nanofluids.

The Zeta potential tests were conducted for both nanofluids right after preparation and 4th weeks after preparation. In the CO_2 absorption application, the nanofluid needs to have higher stability for enhanced mass transfer. It was conducted for 0.03, 0.06, 0.09 and 0.12 wt% of Fe_2O_3 and SiO_2 nanofluids. Table 2 Shows the zeta potential results of above mentioned nanofluids. It

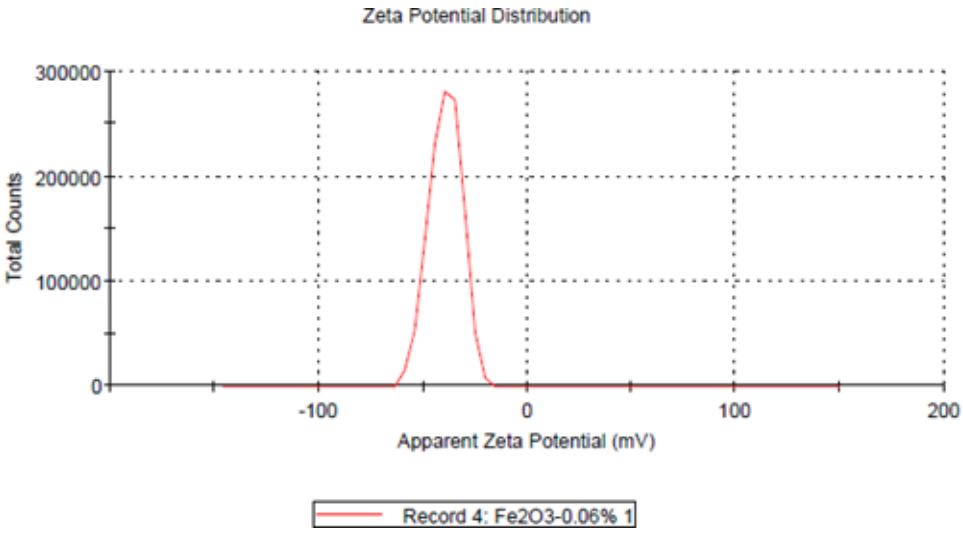


Figure 25. Zeta potential for Fe_2O_3 at 0.06 wt%.

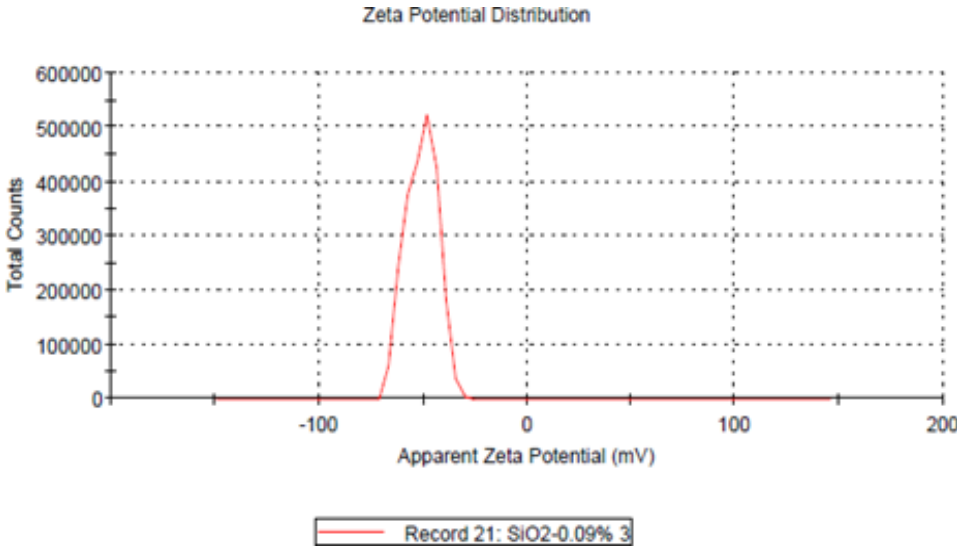


Figure 26. Zeta potential for SiO_2 at 0.09 wt%.

can be seen from the results that SiO_2 is hydrophilic; it shows higher stability as compared to Fe_2O_3 nanofluid, which is hydrophobic. At higher concentrations, the stability decreases. This is the reason for the higher CO_2 absorption capacity by SiO_2 nanofluid at 0.09 wt% compared to other concentrations. The 0.09 wt% shows about 13.25% higher stability as compared to the 0.03 wt% nanofluid.

The Fe_2O_3 nanofluid was showing better stability at 0.06 wt%. That's why the Fe_2O_3 nanofluid at 0.06 wt% was showing better CO_2 absorption as compared to other concentrations of Fe_2O_3. The 0.06 wt% Fe_2O_3 nanofluid was 2.5% more stable than the 0.03 wt%. Figure 25 and Figure 26 show the zeta potential results obtained from experiments for Fe_2O_3 nanofluid at 0.06 wt% and SiO_2 nanofluid at 0.09 wt%, respectively. From the zeta potential studies, it was found that the SiO_2 and Fe_2O_3 nanofluids are found to be more stable at optimum concentration. Similar zeta potential tests were conducted for the same samples after the 4th week of preparation. From the results, there is a small decrease in the stability due to the particles getting accumulated, but due to the

impact of the surfactant added, the stability of nanofluids is better, even after 4 weeks of preparation. The stability after 4 weeks for Fe_2O_3 at 0.06 wt% and SiO_2 at 0.09 wt% decreased by 3.85% and 3.67%, respectively.

5.0 Conclusion

This research work investigates the CO_2 absorption performance of Fe_2O_3 and SiO_2 at 0.03, 0.06, 0.09 and 0.12 wt% nanofluid at initial pressures of 5, 7.5 and 10 bar in the direct contact method. The experimental results show that an increase in the concentration of nanofluid increases the CO_2 absorption. However, there has existed an optimum concentration beyond which any further increase in concentration decreases the CO_2 absorption. The CO_2 absorption by Fe_2O_3 nanofluid was enhanced by 21.03%, 22.95% and 20.59%, respectively, at 5, 7.5 and 10 bar initial pressure at 0.06 wt% concentration. The SiO_2 nanofluid demonstrated an enhancement of 10.34%, 18.67% and 13.61% at 5, 7.5 and 10 bar initial pressure, respectively, at 0.09 wt% concentration. Fe_2O_3 nanofluid showcased a better performance than SiO_2 nanofluid consistently. Furthermore, the effect of initial pressure in the absorption cell also plays a vital role in the enhancement of CO_2 absorption. It was observed that absorption of Fe_2O_3 nanofluid at 10 bar initial pressure showed by 105% and 62.8% higher than 5 bar and 7.5 bar initial pressure, respectively. While that of SiO_2 nanofluid at 10 bar initial pressure outperformed by 111.9% and 58.9% than 5 bar and 7.5 bar initial pressure, respectively. From the stability tests conducted by using Zeta Potential, optimum concentrations of nanofluids exhibited higher stability. The stability values are -39 mV for Fe_2O_3 at 0.06 wt% and -50.4 mV for SiO_2 at 0.09 wt%. The surfactant added to the nanofluid ensures higher stability even after 4 weeks of preparation.

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Nomenclature

Δn: number of moles of CO_2 absorbed Vg: Volume of CO_2 gas

R: Universal Gas Constant T: Temperature

P0: Initial Pressure

Pt: Pressure after time t Z: Compressibility factor PC: Critical Pressure TC: Critical Temperature

α: Absorption Capacity Vliq: Volume of nanofluid

ρliq: Density of nanofluid nf: Nanofluid

w: water

RAI: Relative Absorption Index

$U(\alpha nf)$: Uncertainty for the Absorption Capacity