American Journal of Analytical Chemistry, 2023, 14, 175-183
https://www.scirp.org/journal/ajac
ISSN Online: 2156-8278
ISSN Print: 2156-8251

# Empirical Investigation of Treatment of Sour Gas by Novel Technology: Energy Optimization

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**How to cite this paper:** Monfared, E. and Farahbod, F. (2023) Empirical Investigation of Treatment of Sour Gas by Novel Technology: Energy Optimization. *American Journal of Analytical Chemistry*, **14**, 175-183.
https://doi.org/10.4236/ajac.2023.144010

**Received:** April 3, 2023
**Accepted:** April 25, 2023
**Published:** April 28, 2023



## Abstract

The sour gas sweetening is one of the main processes in gas industries. Gas sweetening is done through chemical processes. Therefore, it requires high cost and energy. The results show that increasing the operating temperature increases the mass transfer coefficient and increases the mass transfer rate. Theoretical and experimental data show that sulfur removal in 4.5 W magnetic field is desirable. The increase in sulfur removal percentage in the magnetic field of 4.5 W and 6.75 W is about 16.4% and 15.2%, respectively. According to the obtained results, the effect of temperature increase from 18.8˚C to 23.4˚C is more evident than the effect of temperature change from 23.4˚C to 32.2˚C. Because more thermal energy is needed to provide higher temperatures. Therefore, the temperature of 23.4˚C is reported as the optimal temperature. The results of this research show that the percentage of sulfur removal is also high at this temperature.

## Keywords

Oil and Gas Industries, Optimized Energy, Treatment Process, Empirical Investigation

## 1. Introduction

Many different processes are used to refine natural gas and bring it to pipeline gas quality for transmission. Sulfur is usually present as an impurity in fossil fuels [1] [2] [3]. With the combustion of fuels, sulfur is released in the form of sulfur dioxide, an air pollutant, which itself is the cause of respiratory problems and acid rain [4] [5] [6]. Environmental regulations have placed increasing restrictions on sulfur dioxide emissions. This has caused much attention to be paid to removing sulfur from fuel and exhaust gases in fuel processing processes [7] [8] [9] [10]. The cost of removing sulfur from natural gas and oil in the United

States was approximately $1.25 billion in 2008 [11] [12] [13]. In natural gas, sulfur occurs mainly in the form of hydrogen sulfide. While in crude oil it is in the form of organic compounds [14] [15] [16] [17]. The cost of removing sulfur from natural gas and oil in the United States was about $1 billion in 2013 [18] [19] [20] [21]. In crude oil, sulfur is in the form of organic compounds that are converted into hydrocarbons and hydrogen sulfides during hydrogen desulfurization. In both cases, hydrogen sulfide gas is highly toxic and corrosive [22] [23] [24] [25]. Sulfur is converted in recycling processes and safely shipped for sale [26] [27] [28] [29]. During sulfur processing, fluids containing hydrogen sulfide are produced [30] [31] [32] [33]. Hydrogen sulfide is a weak acid that is hydrolyzed during the following 2 steps by dissolving it in water. Both steps (1 and 2) are reversible and dependent on acidity [34]-[44].

$$H^2S \leftrightarrow H^+ + HS^- \quad (1)$$

$$HS^- + OH^- \leftrightarrow S = +H_2O \quad (2)$$

In this research, a magnetic field with different intensities and different volume percentages of zinc oxide nanoparticles in water has been used for gas sweetening. Since the mass transfer flux to remove sulfur compounds from sour gas depends on various parameters, various operational and non-operational factors have been discussed in this research.

## 2. Materials and Methods

In this research, sour gas is used as reactor feed. Two pressure tanks with a volume of 10 liters and containing sour gas are connected to the laboratory pilot. It is not possible to use both feeding tanks at the same time. The studied reactor is a stainless steel tank with an inner diameter of 8 cm and a height of 60 cm. From the top and bottom of the reactor, 10 cm of free space is considered for the flow distributor and holder. The effective height of the reactor is 40 cm and glass balls with a diameter of 2.5 cm are used as filler. Two nets inside the reactor tank have divided it into three parts. The feed gas enters the bed with a velocity higher than the minimum velocity and passes through the flow distributor. The nanofluid containing different volume percentages of zinc oxide nanoparticles with a diameter of 50 nm enters from the top of the tank and passes through the distributor with a different flow rate. An electric current is generated in a circular spiral around the tank to create a magnetic field and influence the movement of the nanofluid and sour gas molecules. A spiral of 1.1 mm thick copper wire and several loops 30 cm long is placed around the steel tank in such a way that it is 0.5 cm away from it, considering the glass wool around the reactor tank. The inlet pressure under the flow distributor is measured by a digital manometer.

## 3. Results and Discussion

In this research, the effect of different amounts of gas flow rate, magnetic field, fluid flow rate, process temperature and volume percentage of nanoparticles distributed in pure water on sulfur removal from sour gas has been reported. Then the results of the experiments have been analyzed by drawing graphs. Also, the optimal conditions for the highest sulfur removal efficiency are provided. The transfer amount of sulfur from gas phase to the liquid phase is considered according to the force of chemical potential difference.

### 3.1. Effect of Gas Flow Rate and Zinc Oxide Concentration

Figure 1 shows the effect of increasing the volume percentage of zinc oxide nanoparticles in a nanofluid when the gas flow rate is 240 ml/min.

Increasing the amount of zinc oxide nanoparticles increases the percentage of sulfur removal in laboratory and theoretical conditions. Increasing the amount of zinc oxide nanoparticles from 0 to 0.013% by volume increases the percentage of sulfur removal by about 6%. Also, increasing the amount of zinc oxide nanoparticles from 0.013% to 0.1% by volume increases the percentage of sulfur removal per unit of time by about 10.85%. The experimental results show that with the increase in gas flow, the amount of sulfur removal increases by 21.76%.

### 3.2. Effect of Temperature, Zinc Oxide and Magnetic Field

Operating temperature is another important parameter that affects sulfur removal in the absorption process. Based on the nature of the process, the operating temperature of the absorption process in the tower must be kept low. The temperature in the experiments was 18.8, 23.4 and 32.2 degrees Celsius. The obtained results show the changes in the percentage of sulfur removal with different amounts of zinc oxide nanoparticles in a nanofluid with a magnetic field of determined power and temperature. The experimental results show an increase

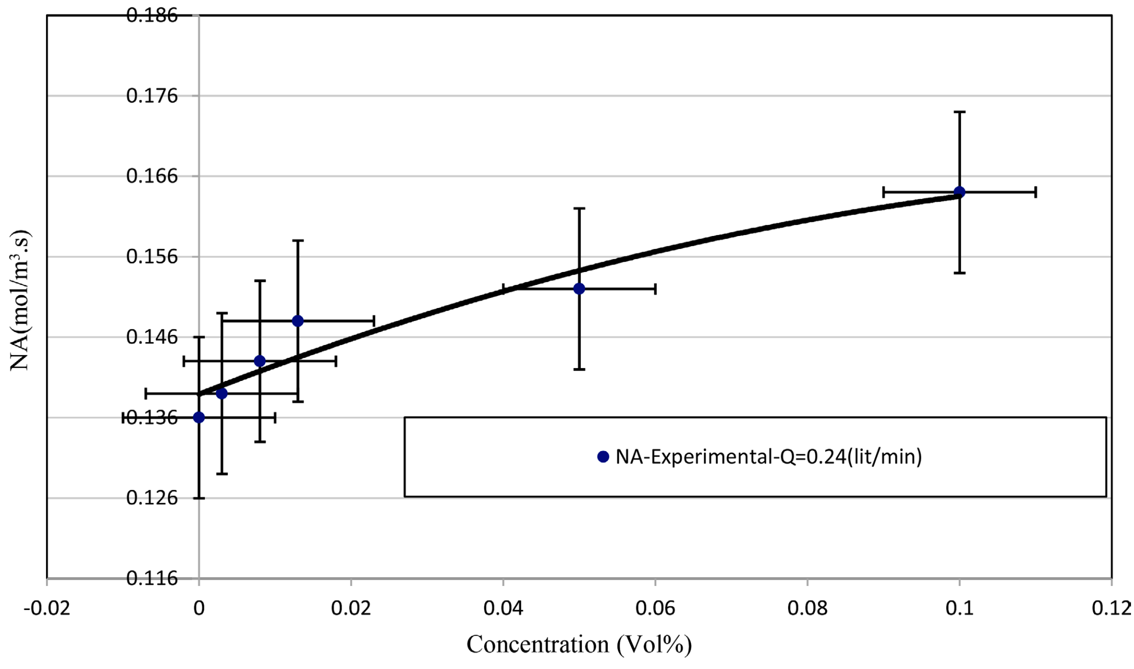


Figure 1. Mass transfer in terms of nano concentration in the column.

in the removal rate of sulfur with an increase in the concentration of nanoparticles. The amount of sulfur removal was from 0.167 to 0.182 mol/m³ per second, from 0.172 to 0.194 mol/m³ per second, and finally from 0.173 to 0.2 mol/m³ per second. In this research, the effect of the magnetic field on the absorption process has also been considered. The diagram of changes in magnetic field intensity is presented in this section.

According to Figure 2 and the obtained experimental results, the effect of temperature increase from 18.8˚C to 23.4˚C is more obvious than the effect of temperature change from 23.4˚C to 32.2˚C. More thermal energy is required to provide higher temperatures. Therefore, the optimal temperature is 23.4 degrees Celsius and the sulfur removal percentage is high enough at this temperature.

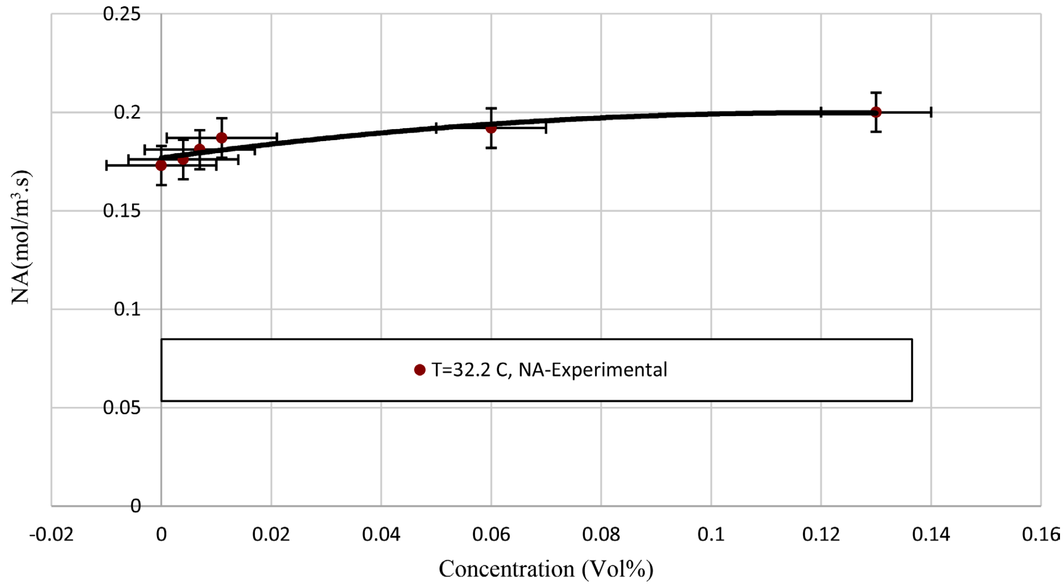


Figure 2. Mass transfer in terms of the nano-scale at 2.25 W and 32.2˚C.

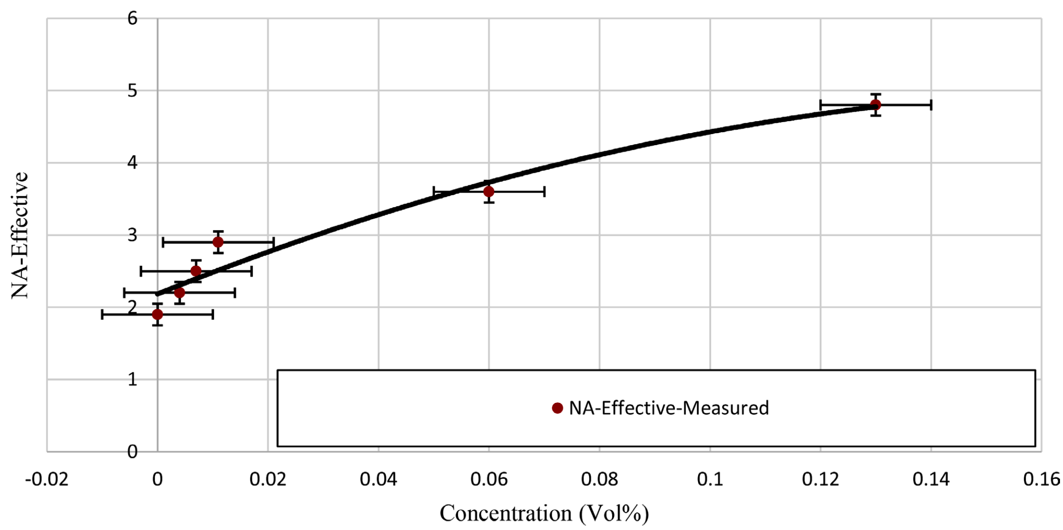


Figure 3. The percentage of removal of sulfur per unit volume of effective time based on the concentration of zinc oxide at 4.5 watts.

The effective mass transfer flux in this section is evaluated as a dimensionless group. This factor is defined as the difference between the presence of a magnetic field and the absence of a magnetic field. This definition can be a better representation of the effect of magnetic field and zinc oxide concentration on absorption. As shown in Figure 3 and Figure 4, the changes in the percentage of sulfur removal in the magnetic field are 4.5 W and 6.75 W with increasing the amount of zinc oxide from 0 to 0.13% by volume.

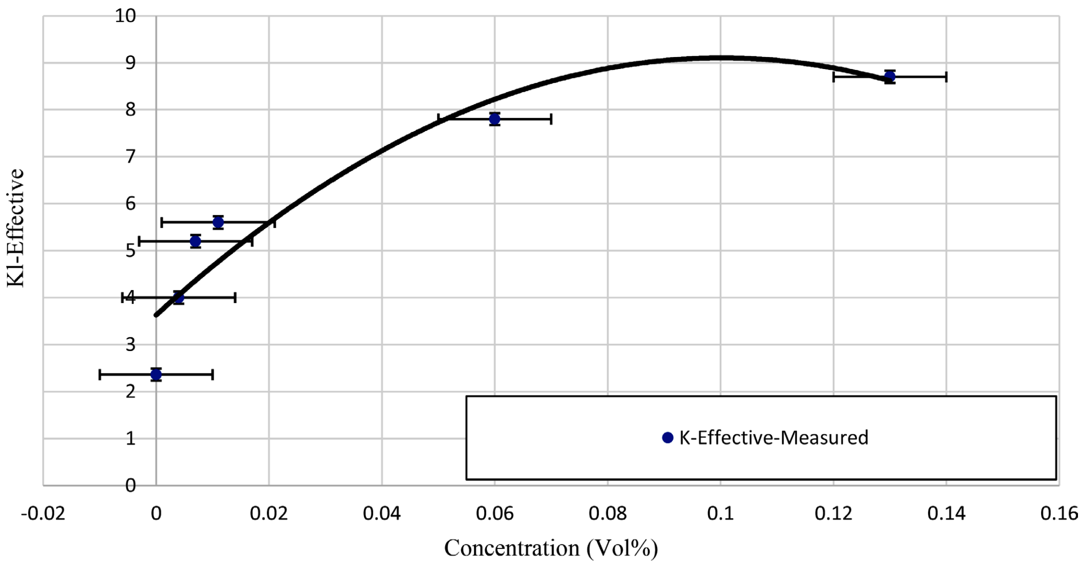


Figure 4. The effective NA level is based on the concentration of zinc oxide at 6.75 watts.

## 4. Conclusion

The investigated results show that increasing the operating temperature has increased the mass transfer coefficient and increased the mass transfer rate. The suitable operating temperature according to the minimum energy required maintaining this temperature and the acceptable rate of mass transfer at this temperature is 23.4 degrees Celsius. According to the obtained experimental results, the effect of increasing the temperature from 18.8˚C to 23.4˚C is more evident than the effect of changing the temperature from 23.4˚C to 32.2˚C. More thermal energy is required to provide higher temperatures. Therefore, the optimal temperature is 23.4 degrees Celsius and the sulfur removal percentage is high enough at this temperature.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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