Use of acid gases in the production of sodium sulphide

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Abstract. This study was conducted to check the possibility of hydrogen sulfide as a material to produce sodium sulphide. It is a harmful substance that is released during production in many industrial production processes. In laboratory and semi-industrial conditions, the possibility of producing hydrogen sulfide using associated acid gases from hydrocarbon production as raw materials has been established. The resulting purified hydrogen sulfide, absorbed by a solution of sodium hydroxide, is a promising raw material in the production of sodium sulfide. The experiments on the production of sodium sulfide from natural gas processing waste, which contains hydrogen sulfide, showed the promise of using the proposed method. A new method and technology for the production of sodium sulfide has been developed, while the cost of the resulting product has been reduced due to the available local cheap raw materials, widely used in the chemical and mining industries and the simplification of the technological scheme and equipment used. Due to the developed method for the production of Na\textsubscript{2}S, it is possible to utilize a large number of waste gases from hydrocarbon production, as a result of which both environmental problems of the regions are solved, and it is also possible to obtain a product with great economic profitability.

1 Introduction

The growing detrimental effects of the oil and gas sector on the natural state of the environment have made environmental protection issues more pressing in recent years. [1-3]. Off-gases, or gas streams with a high concentration of H\textsubscript{2}S, can be utilized to reactively absorb H\textsubscript{2}S to create sodium sulfide (Na\textsubscript{2}S). [4-5].

Hydrogen sulfide is a typical byproduct of anaerobic metabolic activities in nature. It is also generated in considerable amounts as a byproduct of crude petroleum hydrosulfurization. As a nasty, poisonous gas, even at low concentrations, there is ongoing research into effective ways to convert it to more benign compounds [6]. Hydrogen sulfide is a potential source of two consumer products - hydrogen and sulfur, as

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well as sodium sulfide, which is the raw material for producing sulfur dyes, which are used in the textile industry for decorating cotton fabrics with these dyes, in the leather industry for removing hair from skins, in the production of paints [7-9].

The presence in exhaust gases of such components as hydrogen sulfide, carbon dioxide, and carbon disulfide in hydrocarbon gases reduces the heat of combustion of gases and impairs their operational properties, led to the development and application in industry of new methods for purifying hydrocarbon gases from acidic components to protect pipes and equipment from corrosion, protecting the population from their toxic effects, preventing poisoning of most industrial catalysts, as well as eliminating sulfur compounds by environmental requirements [10]. It is a naturally occurring gaseous signalling molecule with potential medicinal uses. Recent research suggests that it may be useful as a treatment for several cardiovascular conditions as well as severe sickness. H₂S can be delivered to the tissues by increasing endogenous sulfide concentrations by intravenous sodium sulfide injection [11].

Anhydrous, high-purity Na₂S is essential for several processes, such as chemical synthesis, energy storage, and H₂S generation in biological systems. Na₂S nanocrystals, for instance, can be used as high-capacity cathodes for inexpensive, high-energy-density Na-S batteries. Additionally, Na₂S is a necessary precursor for solid-state electrolytes, which might make using a sodium-metal anode safe. Na₂S is also a handy reagent for making a variety of specialized chemicals, such as metal-sulfide compounds and polymers incorporating sulfides [12]. Finally, Na₂S has drawn interest as a "rapid-release" donor of H₂S in aqueous solutions, a vital gasotransmitter that may be used to treat a variety of illnesses, including neurological and cardiovascular conditions. Issues of cleaning, neutralization, disposal or use of hydrogen sulfide as a raw material by industrial enterprises are an integral part of the problem of environmental protection. One of the pressing problems of our time is environmental protection. Therefore it is important to identify the possibilities to utilize H₂S to produce Na₂S to maximize the profit. In this study, we show that Na₂S may be formed either by direct synthesis utilizing H₂S or by purifying technical grade Na₂S hydrate.

2 Methods

Environmental contamination and equipment corrosion are caused by hydrogen sulfide, which is found in gas emissions from the oil, gas, and petrochemical sectors. Because these gas streams, also known as off-gases, have a high concentration of H₂S, it is possible to employ them to reactively absorb H₂S and generate sodium sulfide. Absorption processes involve two phases - liquid and gas, resulting in a transition of the substance from the gas phase to the liquid. Thus, absorption processes are one of the types of mass transfer processes. From published sources, it is known that Na₂S obtained in the absorption process is widely used in the chemical industry, but there is a need to concentrate the sodium sulfide required for the absorption process, and its parallel purification from the accompanying carbon dioxide.

Therefore, a new method and technology for the production of sodium sulfide has been developed, while the cost of the resulting product has been reduced due to the available local cheap raw materials, widely used in the chemical and mining industries and the simplification of the technological scheme and equipment used. Due to the developed method for the production of Na₂S, it is possible to utilize a large number of waste gases from hydrocarbon production, as a result of which both environmental problems of the regions are solved, and it is also possible to obtain a product with great economic profitability.
For the possibility of extraction (H₂S) and the choice of equipment, in particular the type of absorber, we proceeded from the physicochemical conditions of the process, taking into account technical and economic factors.

There are various types of devices; the most common at present are packed and bubbling plate absorbers. The main dimensions of the bubbling plate absorber and evaporation unit for the designed technological scheme (diameter and height) were calculated based on the specified operating conditions (productivity, required degree of component extraction, etc.). For the calculation, information on the statics and kinetics of the process was used (Figure 1).

![Technological scheme for the production of sodium sulphide.](image)


Fig. 1. Technological scheme for the production of sodium sulphide.

The kinetics of the absorption process largely depends on the type of apparatus and its operating mode. In our case, the most reliable were the results of experiments conducted under similar conditions.

Experiments carried out to develop technology for producing sodium sulfide from natural gas processing waste, which contains hydrogen sulfide, showed the possibility of carrying out the absorption process. In laboratory experiments, the reactive absorption process by bubbling was carried out using a NaOH solution as a reagent. The methodology of the research was to be used in the experiment for the synthesis of sodium sulfide, a waste product of natural gas production - hydrogen sulfide, which was synthesized in laboratory experiments and two independent operating conditions: a given mass percentage of NaOH concentration, and a certain solution temperature.

The synthesis of sodium sulfide from hydrogen sulfide in the experiments was carried out with varying concentrations of zinc sulfide, caustic soda, water and hydrochloric acid solution. In the Kipp apparatus, zinc sulfide was mixed using a burette with a solution of hydrochloric acid. As a result of the reaction that took place, pure hydrogen sulfide was
released, which, using a hose and a glass tube, was absorbed in a 30-45% sodium hydroxide solution during a varying reaction time of 30-90 minutes. Physical and chemical analyses were carried out [11], such as X-ray diffraction and infrared spectroscopic studies showed that the content of crystalline sodium sulfide in the obtained samples varied from 40 to 70%.

3 Results and Discussion

The development of a new cheap method for producing sodium sulfide and the selection of the most accessible cheap feedstock, widely used in the chemical and mining industries, were the main tasks that needed to be solved.

Therefore, along with laboratory experiments, experiments were carried out using a new technological scheme, on a developed pilot plant, for the absorption of hydrogen sulfide with a solution of sodium hydroxide.

As a result of the interaction of a saturated solution of sodium hydroxide with hydrogen sulfide using the developed simplified technology, the main product was obtained, based on the waste obtained after purification of natural gas in the conditions of gas processing enterprises, such as the Mubarek gas processing station, where tests of the proposed installation were carried out.

This made it possible to reduce the cost of production through the use of local, inexpensive and accessible raw materials and also does not require special bulky equipment during its production.

![Yield of Exodus Na₂S at 20°C](image)

**Fig. 2.** Effect of NaOH concentration on product yield at 20°C.

Figure 1 shows that there is a positive correlation between the NaOH concentration and the Na₂S yield, which is consistent with the previous work [13] that described the exceptional effects of combining NaOH and Na₂S/Na₂SO₃ pretreatment at low concentrations and yields.

In addition, The findings of a previous study [14] demonstrated that producing Na₂S from H₂S-rich off-gas is a feasible and appropriate method of producing Na₂S in addition to
extracting the majority of the H$_2$S from off-gas. The yield of Na$_2$S was affected by the starting concentration of NaOH, the temperature of the cleaning solution, and the volumetric ratio of liquid to gas. Table 1 clearly shows that the yield is significantly influenced by the linear and quadratic components of the initial NaOH concentration.

Table 1. The effect of solution evaporation time on the amount of product obtained.

<table>
<thead>
<tr>
<th>Experience No.</th>
<th>Saturation of the resulting solution Na$_2$S, v %</th>
<th>Residue time solution, (min)</th>
<th>Yield of Na$_2$S (kg)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>35</td>
<td>40</td>
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It has been established that the saturation and evaporation time of the sodium sulfide solution leads to an increase in the concentration and yield of the product (Table 1). It is identified that the Na$_2$S yield is increasing with the saturation of the resulting solution and the residual time. The Research conducted in semi-industrial conditions confirms the possibility of obtaining the sought-after sodium sulfide using a new method of production.

4 Conclusions

As a result, the possibility of using waste gases from the purification of natural gases as the raw material for the production of sodium sulfide, which is necessary for several industries in the Republic of Uzbekistan, has been confirmed. A new method and technology for the production of sodium sulfide has been developed, while the cost of the resulting product has been reduced due to the available local cheap raw materials, widely used in the chemical and mining industries and the simplification of the technological scheme and equipment used.

Due to the developed method for the production of Na$_2$S, it is possible to utilize a large number of waste gases from hydrocarbon production, as a result of which both environmental problems of the regions are solved, and it is also possible to obtain a product with great economic profitability.

References

metal-driven biogeochemistry of gaseous compounds in the environment, \textbf{237-277} (2014)


10. D.A. Voevodkin, V.A.Skripnichenko, Rational use of secondary resources in the economics of the oil and gas industry, Bulletin of the Northern (Arctic) Federal University, \textbf{83-89} (2013)


