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Experimental Study of Parameters Influencing the Purity of Potassium Sulfate Fertilizer Produced from Jordanian Raw Materials

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Abstract: The general objective of the present investigation was to make a contribution towards improving the purity of the produced potassium sulfate from (KCl, Arab Potash Company-Dead Sea) and (H_2SO_4, Jordanian Phosphate Company). The process parameters influencing the contamination of the poisoning chlorine within the product were experimentally investigated. The experiments were performed in a small-scale batch reactor equipped with a high temperature control system. The role of temperature was studied. Higher purity of potassium sulfate was achieved at higher temperatures. The effect of the quality of KCl used was investigated. It was found that implementing fine KCl as reagent is a dvantageous over standard KCl. A completely pure potassium sulfate fertilizer was produced after 110 minutes residence time in the case of using fine KCl.

Key words: K_2SO_4, purity, chlorine content, KCl reagent, particle size distribution

INTRODUCTION

The Dead Sea is the terminal lake of the Jordan River System. Over the millennia, salts carried by the river system - as well as discharges from many saline ground water sources - have accumulated in the lake, transforming it into one of the greatest mineral reservoirs on earth[1]. The Dead Sea measures 750 km^2 in area with an average of 370g of salt per kilogram of water. It is the saltiest body of water on the planet. Its surface is the lowest point on earth with a depth of 412 m.

Extensive amounts of salt minerals are present in the Dead Sea, there are three major industrial minerals - Carnallite ($KCl.MgCl_2.\ 6H_2O$), Sylvite (KCl) and Langbeinite ($K_2SO_4.2MgSO_4$). These economically valuable minerals have been extensively utilized for industrial applications, especially fertilizers.

Over 43 billion tons of the salts are believed to be available in the Dead Sea, of which almost two billion tons are potassium chloride. This makes it one of the world's largest potash deposits. Arab Potash Company (APC) produces the Potash through evaporation from ponds in Al-Safi, at the southern end of the Dead Sea. The Dead Sea brine has a potash content of 1.2 %[2].

In Jordan about 90 % of the potassium chloride (KCl) is produced as fertilizer grade of about 97 % purity, which also used as raw material for the production of potassium sulfate (K_2SO_4) fertilizer. The chemical grade or 99.9 % potassium chloride is the basis for the manufacture of most potassium salts[3].

The present study of the potassium sulfate (K_2SO_4) production was stimulated due to the presence of appreciable and economical amounts of KCl in the Dead Sea. In Jordan the produced potassium sulfate still does not meet the required agricultural specifications due to the existence of some harmful traces. This resulted from the low purity of KCl feed. One of the major problems associated with the potassium sulfate production from Jordanian raw materials is its low purity, which resulted from the inclusion of chlorine within the final solid product. This represents a challenge to meet the market requirements[4-6].

The main objective of the present study is to investigate the process parameters influencing the quality of potassium sulfate produced from Jordanian potash and sulfuric acid and to evaluate its purity. The parameters studied are particle size distribution and temperature.

MATERIALS AND METHODS

The raw materials that implemented are potassium chloride (fertilizer grade, 97% purity, average particle size of 100 µm) and sulfuric acid (93% purity) produced by wet process at Jordanian Phosphate Company (JPC). The potassium chloride was crushed in a jaw crusher, ground in a ball mill and sieved at 160 mesh (100 µm). In all experiments of the present study, standard and fine potassium chlorides (KCl) were used.

Experimental apparatus and procedures: The experimental apparatus consists of a small platinum rounded batch reactor having a volume of 250 ml. The reactor is covered with a led and equipped with a mechanical stirrer and thermocouple. It is placed in a muffle furnace with temperature control unit.

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The experiments were conducted by introducing the reagents to the reactor. The amounts added according to the stoichiometry of the following equation:

$$2KCl + H_2SO_4 \longrightarrow K_2SO_4 + 2HCl$$

The reaction is performed at elevated temperature where all reactants are present as a melt. The temperature was controlled using the computerized program of the furnace in order to achieve the required reaction temperature. Samples of the melt are withdrawn periodically, cooled and then analyzed to determine the chlorine content.

RESULTS AND DISCUSSION

An experimental study is conducted aiming to understand some parameters influencing the purity of potassium sulfate produced by reacting potassium chloride with concentrated sulfuric acid. The most poisoning impurity, which affects the quality of potassium sulfate and its availability as a fertilizer, is the chlorine contents. The incorporated chlorine is resulted from the hydrochloric acid gas, which is generated as a side product during the reaction. Controlling chlorine content can be achieved by a better knowledge of the factors affecting the incorporation process of hydrochloric acid gas within the particles in the reaction mixture.

The role of temperature: Temperature is the mostly important factor influencing the kinetics of the reaction as well as the absorption/desorption rate of hydrochloric acid gas from the liquid melt or the reaction medium. Figure 1 shows the influence of temperature on the presence of chlorine during the course of the reaction between the sulfuric acid and potassium chloride.

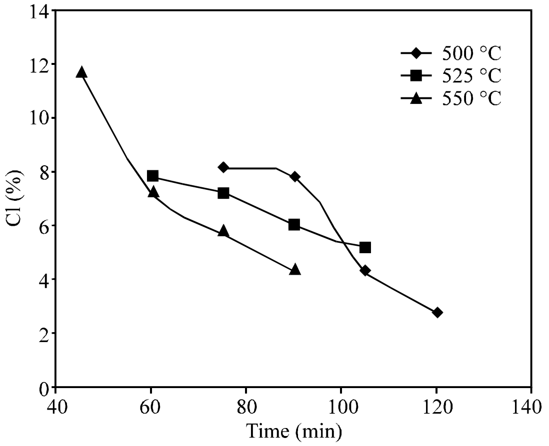

Fig.1: The measured chlorine content incorporated in the produced potassium sulfate during the course of reaction at different temperatures

As presented in Fig. 1, at the initial stages of the reaction after 60 min, the amount of chlorine content is very high due to the larger amounts of hydrochloric gas absorbed by the liquid melt. The amount of chlorine then starts to decrease with time due to desorption of the generated hydrochloric gas from the melt. As depicted in Fig. 1, it was experimentally found that when the reaction proceeds at higher temperature, the inclusion of chlorine within the melt (reaction mixture) is reduced remarkably. Higher temperatures can lead to decrease in the viscosity of the melt as well as an increase of the kinetic energy of the produced gas. This will contribute in facilitating the collapsing of the gas bubbles and liberation (desorption) of the by-product hydrochloric acid gas from the liquid melt. The results obtained in Fig. 1 indicate that the fluid dynamics plays an important role on the rate of liberation of the gas within the melt. The time elapsed to liberate the produced gas can be reduced significantly by increasing the mixing intensity i.e. fluidity of the melt. An important parameter beside temperature and the fluid dynamic is the pressure above the melt. Increasing the vacuum pressure accelerates the rate of desorption from the melt and higher purity can be achieved at lower temperatures.

Effect of the particle size distribution of the feed KCl: The influence of the particle size distribution of the fed KCl on the purity of produced potassium sulfate was investigated by carrying out experiments with different size distribution qualities (standard and fine). The grain size analysis of both qualities is shown in Fig. 2.

The amount of chlorine content in the melt during the course of the reaction at a constant temperature of 500 ºC was analyzed in both cases where standard and fine KCl are fed as reactants. Th results are shown in Fig. 3.

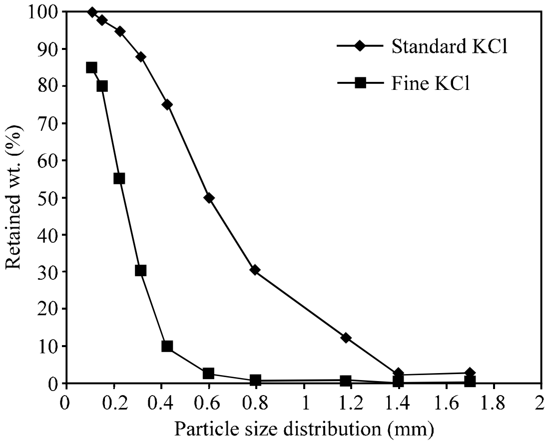

Fig. 2: The particle size distribution of the standard ad fine KCl used in the experiments

Obviously, the amount of chlorine remaining in the melt at the first stages (60-min) is much lower in the case of introducing fine crystals of KCl than the standard KCl. Figure 3 shows that the total amount of chlorine can be completely separated after a relatively short time in the case of fine KCl. In the other hand, purification of the product cannot be achieved in the case of standard KCl.

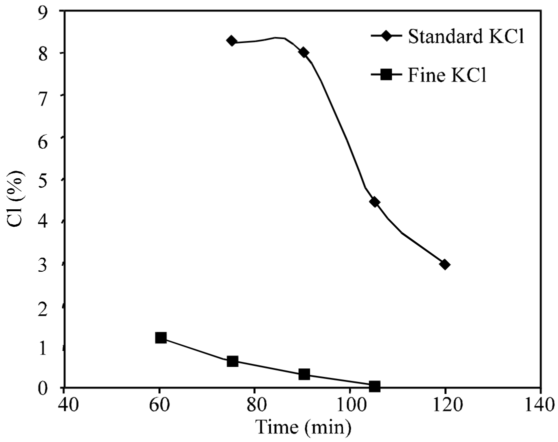

Fig. 3: The measured chlorine content at 500 ºC in the reaction mixture when standard and fine KCl are implemented as reactants

An important result can be extracted from Fig. 3 is that the mean size of the feed KCl is an important parameter influencing the purity of the final product should be considered in the design and operation of the industrial reactor. This interpretation agrees with that discussed by Abu-Eishah et al.[6]. The more fine the feed crystals the easier and the faster the achievement of pure potassium sulfate fertilizer.

CONCLUSION

In the design of the operation of the batch reactor for the production of potassium sulfate fertilizer, one of the mostly important parameters that must be considered is the temperature. The increase in the temperature can lead to more pure product due to the increase in the rate of desorption of HCl gas. The increase in fluidity by agitation and mixing can also reduce the chlorine contents. Also the size of the feed KCl is a parameter must be taken in account when considering the purity of the product. The introduction of finer KCl to the reactor results in the production of completely pure fertilizer.

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