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A New Way to Separate Anions and Cations

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Abstract- Electrolysis is currently widely used for the production of various substances, as well as for the isolation of individual elements from the composition of chemical compounds, which by electrolysis are decomposed into anions and cations. For this purpose, electrolysis of aqueous solutions is used, which makes it possible to carry out such a separation in a simple way. For this, electrolyzers are used, where a current is passed through aqueous solutions, while the anions are grouped near the cathode, and the cations are near the anode, from where they are taken. The article considers a new method for the separation of anions and cations, which is based on the polarization of electrolytes. This method differs from the known ones in that it does not require passing current through the electrolyte, which reduces the cost of the production process.

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I. Introduction

By electrolysis, salts, acids and other substances soluble in water are separated into their elements or individual groups. The processes occurring during electrolysis are shown in Fig. 1.

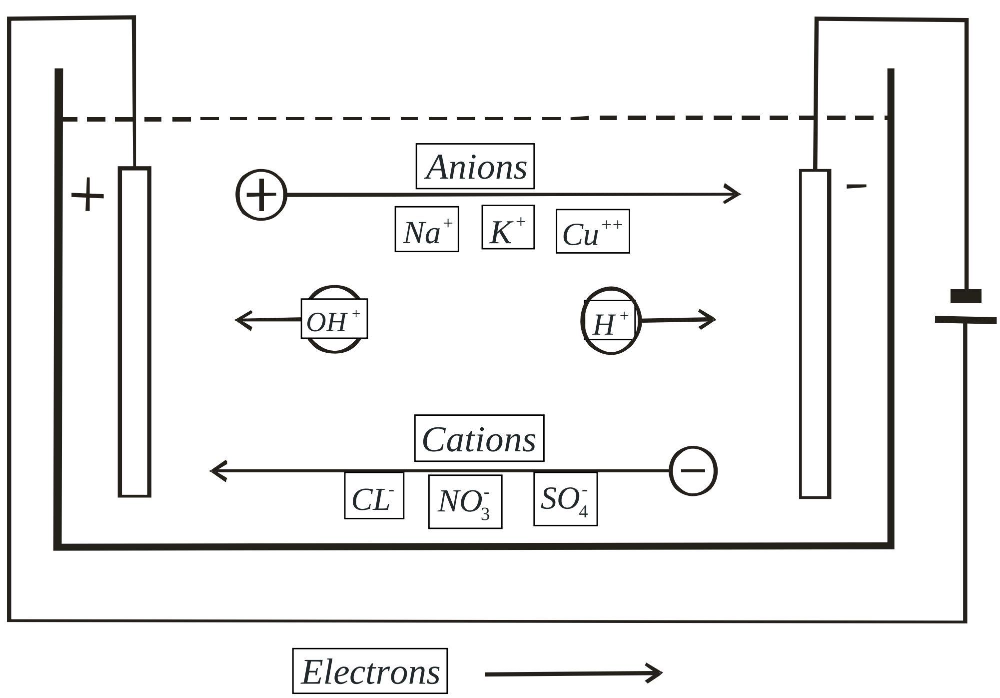

Fig. 1: The processes occurring during electrolysis

In aqueous solutions, salts and acids dissociate into anions and cations [1]. If a current is passed through such a solution, then the anions will move towards the cathode, and the cations will move towards the anode. Anions and cations give their charges to the corresponding electrodes, while neutral atoms accumulate near the cathode, and separate groups of atoms accumulate near the anode, from where they are taken for further use.

Industrial plants using this method are rather cumbersome (Fig. 2) and require significant energy consumption for their operation.

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Fig. 2: Industrial plants for the production of caustic soda and chlorine

II. Methods of Production of Caustic Soda

At the beginning of the 19th century, the production of caustic soda (NaOH) was closely associated with the development of the production of soda ash. This relationship was due to the fact that the raw material for the chemical method of producing NaOH was calcined soda, which was caustified with milk of lime in the form of a soda solution. At the end of the 19th century, electrochemical methods began to rapidly develop for the preparation of NaOH by electrolysis of aqueous NaCl solutions. In the electrochemical production method, chlorine is obtained simultaneously with NaOH, which is widely used in the industry of heavy organic synthesis and in other industries, which explains the rapid development of the electrochemical production of NaOH.

Today, caustic soda is produced either by electrolysis of a solution of sodium chloride (NaCl) to form sodium hydroxide and chlorine [2-4], or, less commonly, using an older method based on the interaction of a solution of soda ash with hydrated lime. A large amount of soda ash produced in the world is used to produce caustic soda.

Consider the process of interaction of a solution of soda ash with hydrated lime. Caustic soda is obtained from calcined at a batch or continuous plant. The process is usually carried out at moderate temperatures in reactors equipped with agitators. The caustic soda formation reaction is an exchange reaction between sodium carbonate and calcium hydroxide:

$$Na2CO3 + Ca\ (OH)\ 2 = CaCO3 + 2NaOH$$

Calcium carbonate precipitates, and sodium hydroxide solution is discharged into the collector.

On an industrial scale, sodium hydroxide is obtained by electrolysis of halite solutions (rock salt NaCl) with the simultaneous production of hydrogen and chlorine according to the scheme

$$2NaCl + 2H2O = H2 + Cl2 + 2NaOH$$

When a concentrated sodium chloride solution is electrolyzed, chlorine and sodium hydroxide are formed, but they react with each other to form sodium hypochlorite, which is used as a bleaching agent. This product, in turn, especially in acidic solutions at elevated temperatures, is oxidized in the electrolysis chamber to sodium perchlorate. To avoid these adverse reactions, electrolysis chlorine should be spatially separated from sodium hydroxide.

In most industrial plants used to produce electrolytic caustic soda, this is done using a diaphragm (diaphragm method) placed near the anode on which chlorine is formed. There are two types of installations: with a submerged or non-submerged diaphragm. The installation chamber with a submerged diaphragm is completely filled with electrolyte. A saline solution flows into the anode compartment, where chlorine is released from it, and a solution of caustic soda fills the cathode compartment. In an installation with an unloaded sub-diaphragm, a solution of caustic soda is discharged from the cathode compartment as it is formed, so that the chamber is empty. In some installations with an unloaded diaphragm, steam is introduced into the empty cathode compartment to facilitate removal of caustic soda and raise the temperature.

In diaphragm plants, a solution is obtained containing both caustic soda and salt. Most of the salt crystallizes when the concentration of caustic soda in the solution is brought to a standard value of 50%. Such a "standard" electrolysis solution contains 1% sodium chloride. The electrolysis product is suitable for many applications, for example, for the production of soap and cleaning products. However, the production of artificial fiber and film requires highly purified caustic soda containing less than 1% sodium chloride (salt). The "standard" liquid caustic can be properly cleaned by crystallization and precipitation.

The membrane method is similar to the diaphragm method, but the anodic and cathodic spaces are separated by a cation exchange membrane. Membrane electrolysis provides the most pure caustic.

Continuous separation of chlorine and caustic can also be carried out in a mercury cathode installation (mercury electrolysis). Sodium metal forms an amalgam with mercury, which is discharged into the second chamber, where sodium is released and reacts with water, forming caustic and hydrogen. Although the concentration and purity of the brine for the mercury cathode unit are more important than for the diaphragm unit, the former produces caustic soda suitable for the production of artificial fiber. Its concentration in the solution is 50–70%. Higher costs for installing a mercury cathode are justified by the benefits.

III. Polarization Method for the Separation of Anions and Cations

As already mentioned, the separation of anions and cations in an electrolytic bath requires passing currents through the solution, which requires a certain amount of energy. But there is a method that does not require such expenses, but this method has not yet been described in known sources. If, as shown in Fig. 3, an electric field is applied to the electrolyte, then it is polarized, while anions will collect on the left side of the bath, and cations will collect on its right side. The charged anions and cations discharged through the openings in the lower part of the bath fall into separate baths, forming two poles of the battery, which generates current if the load is connected between these poles. Upon completion of the cycle of work and a complete discharge of the lower baths, the components of electrolysis remain in them.

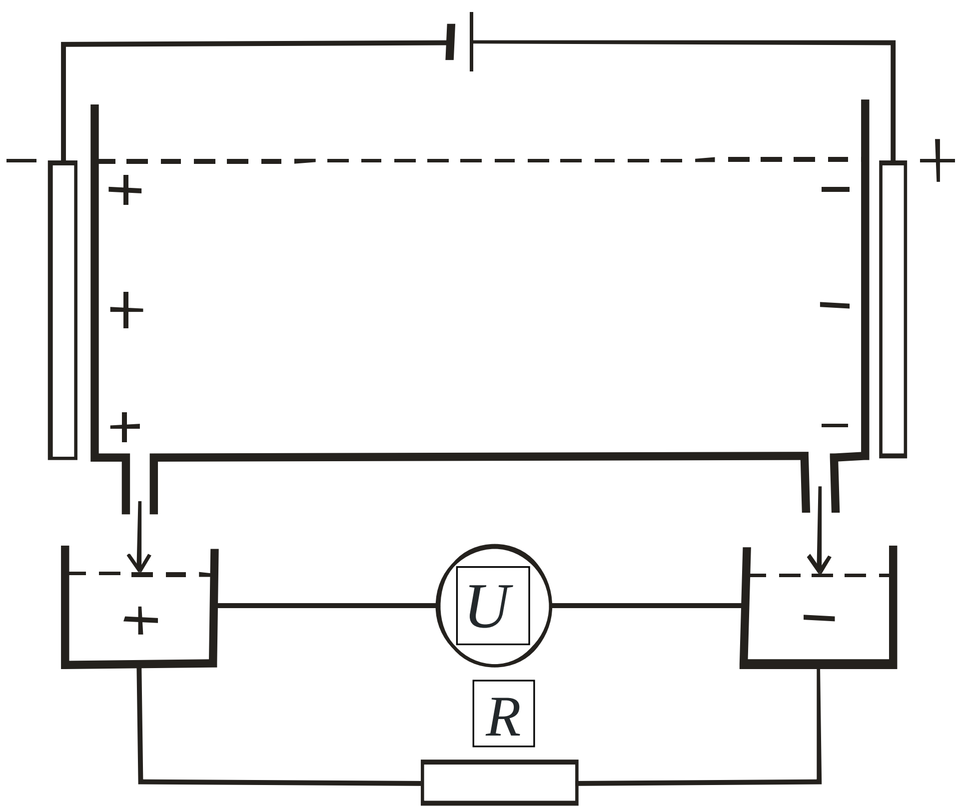

Fig. 3: Installation diagram for the separation of anions and cations by polarization

IV. Conclusion

Electrolysis is currently widely used for the production of various substances, as well as for the isolation of individual elements from the composition of chemical compounds, which by electrolysis are decomposed into anions and cations. For this purpose, electrolysis of aqueous solutions is used, which makes it possible to carry out such a separation in a simple way. For this, electrolyzers are used, where a current is passed through aqueous solutions, while the anions are grouped near the cathode, and the cations are near the anode, from where they are taken. The article considers a new method for the separation of anions and cations, which is based on the polarization of electrolytes. This method differs from the known ones in that it does not require the passage of current through the electrolyte, which simplifies and reduces the cost of the production process.

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